AGENDA

California Avocado Commission
Board of Directors Meeting

Meeting Information

Date: May 21, 2025
Time: 2:00 p.m.

Location: Hilton Pasadena
168 South Los Robles Ave.
Pasadena, CA 91101

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

Board Member and Alternate Attendance

Board members and alternates, please contact Cristina Wede, cwede@avocado.org or 949-341-1955, to confirm attendance no later than Wednesday, May 14, 2025.

Time	Item
2:00 p.m.	**1. Call to Order** a. Roll Call/Quorum b. Introductions
	2. Opportunity for Public Comment Any person may address the Board at this time on any subject within the jurisdiction of the California Avocado Commission.
	3. Industry Strategic Intent 2030 a. What is the Commission's purpose? b. Who does the Commission serve? c. Vision statement d. Mission statement
	4. Operations a. Budgeting for the future
	5. 2025-26 CAC Priorities

Time	Item
	6. Production Research a. Review PRC rankings of research proposals b. Consider approval of funding for research proposals
5:00 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 April Aymami at aaymami@avocado.org or 949-341-1955.

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.

BOARD INFORMATION

ITEM 3: **Industry Strategic Intent 2030**
ITEM 5: **2025-26 CAC Priorities**

SUMMARY:

The attached material has been prepared for the Board to review prior to the planning meeting on May 21-22, 2025. It is meant to provide background and context to facilitate productive discussion on CAC's vision, mission and priorities for the future. **Please be sure to read the attachments and come prepared to engage in discussion with the Board.**

FISCAL ANALYSIS:

- Not applicable

BOARD OPTIONS:

- Not applicable

STAFF RECOMMENDATION:

- Not applicable

EXHIBITS / ATTACHMENTS:

- Industry Strategic Intent 2030 Board pre-read

HISTORICAL CONTEXT
In the early years of the California avocado industry, forward thinking growers and packers recognized the importance of organizational structure and collective financing for industry programs with particular focus on marketing the increasing volume of avocados being produced in California.

They found this opportunity in the California Marketing Act of 1937 which led to industry forming the California Avocado Marketing Order that was authorized to operate under the direction of the Department of Agriculture (later renamed the Department of Food and Agriculture).

In 1976 the Marketing Order board of directors looked into the future and determined that more operational and program flexibility was needed to effectively manage the multitude of challenges on the horizon. This time, however, rather than looking within for assistance, industry drafted the California Avocado Commission legislation and worked with the California State Legislature to secure its passage into law. Following a successful industry vote, the Commission became operational in 1978.

Now, 47 years later, here we are facing obstacles—and opportunities—not necessarily envisioned many decades ago but thankful (as reflected in periodic industry continuation votes) that the avocado industry has both the legal structure and leadership to successfully move us into the future.

AVOCADO CONSUMPTION AND SUPPLY
In 1977, U.S. per capita consumption was about one pound. The good news at the time was that growers, packers and the Commission recognized the upward opportunity and set about building demand to the point that per capita consumption was over 9 pounds in 2024.

In 1977, California packers supplied only home-grown avocados to the U.S. market. Chile gained market access in the early 1980's. Now, 48 years later, California produces less than ten percent of U.S. demand with the remainder coming from offshore suppliers.

COMMISSION PURPOSES
Commission law in part recognizes that avocados "constitute one of the state's principal tree fruit crops" and is "an important source of jobs". The law also authorizes the industry to engage in the "broad fields of advertising; promotion; production, nutrition, and marketing research; quality and maturity standards; the collection and dissemination of crop volume and related statistics; and public education."

WHO DOES THE COMMISSION SERVE?
The Commission law was constructed to be inclusive as indicated by the multiple references to industry while recognizing the unique roles of producers and handlers.

More specifically, "industry" is referenced throughout the General Provisions and elsewhere in Commission law. As the law requires, the definitions of "Producers" and "Handlers" and their responsibilities are also specified throughout Commission law.

QUESTIONS TO CONSIDER
1. Commission's purposes? Are you satisfied that Commission actions are consistent with the law? Should the law be revised to accommodate the industry's future?
2. Who does the Commission serve? Is there a need to reshape Commission law and if so, why and how? NOTE: There is a minimum production threshold in Commission law, but all

producers pay the HAB assessment, 85 percent of which is returned to the Commission for marketing.
3. Ways in which the Commission can increase value to the industry?

VISION AND MISSION STATEMENTS BACKGROUND

The California Avocado Commission has had the same Vision Statement and Mission Statement for more than a decade. CAC's staff recommends 1) updating the organization's Vision Statement to specify that it is a **Vision for the California avocado industry**; and 2) creating a new **Mission Statement for the California Avocado Commission** that states what the organization does, in broad terms, to support the Vision. Staff also recommends that Vision and Mission should be brief for clarity and memorability.

Current Vision
To be recognized as the most desired avocado in the world by fostering a vibrant industry

Proposed Vision
To be a healthy California avocado industry

Current Mission
To maximize grower returns by enhancing premium brand positioning for California avocados and improving grower sustainability

Proposed Mission
To support California avocado growers' ability to compete successfully through strategic marketing, advocacy and research

Current Priorities
Priority #1: Position California avocados to be the most valued and desired avocados among targeted audiences (targeted consumers, retailers, foodservice operators, wholesalers)

Priority #2: Advocate for, and engage with the industry

Priority #3: Support industry strategy through research and outreach

Priority #4: Cultivate organizational excellence / Demonstrate effective use of resources

BOARD INFORMATION

ITEM 6.a: PRODUCTION RESEARCH: REVIEW PRC RANKINGS OF RESEARCH PROPOSALS

SUMMARY:

The Production Research Committee met on Thursday, April 3, 2025, to review full proposals submitted to the Committee in response to their request following their January 29, 2025, meeting. The Committee requested full proposals from 13 researchers and have recommended nine projects for funding.

Following the review of all 13 proposals and an up or down vote on whether to recommend each for funding, each Committee member ranked the recommended proposals from one (highest priority) to nine (lowest priority). A summary of the Committee's rankings is attached.

FISCAL ANALYSIS:

- N/A

BOARD OPTIONS:

- Information item only

STAFF RECOMMENDATION:

- N/A

Average Rank	Proposal Author	Project Title	Individual PRC Member Rankings								
1.6	Cohen	A pesticide resistance monitoring program for avocado thrips	1	1	1	1	2	2	1	4	1
3.0	Montazar	Assessing irrigation management tools and strategies on avocado fruit quality and yield impacts	4	3	2	4	3	1	5	1	4
3.8	Khodadadi	Integrating chemical and cultural practices for bot canker control in avocado	2	6	4	3	4	3	2	5	5
4.7	Manosalva & Adaskaveg	Improve Phytophthora cinnamomi management by monitoring field populations for changes in fungicide sensitivity and conducting efficacy field trials	3	5	3	2	9	5	4	9	2
5.6	Biscaro	Creating a weather station network to guide irrgiation decision of avocados	6	2	6	6	7	9	8	3	3
5.9	Landesman	Addressing the relationship between soil characteristics and soil salinity in California avocado orchards	7	4	8	5	8	6	3	6	6
5.9	Liu	Development and demonstration of a cost-effective electrodialysis reversal (EDR) process ofr chloride removal from avocado irrigation water	5	9	5	8	1	7	7	2	9
7.0	Garner	Continued research at the San Luis Obispo rootstock trial site (2025-2027)	8	8	9	7	5	4	6	9	7
8.0	Loudermelt	Impact of natural vegetation on insect pollinators in agroecosystems	9	7	7	9	6	8	9	9	8

BOARD ACTION

ITEM 6.b: PRODUCTION RESEARCH: CONSIDER APPROVAL OF FUNDING FOR RESEARCH PROPOSALS

SUMMARY:

The Production Research Committee met on Thursday, April 3, 2025, to review full proposals submitted to the Committee in response to their request following their January 29, 2025, meeting. The Committee requested full proposals from 13 researchers and have recommended nine projects for funding. A summary of the Committee's comments on each proposal follows and the full proposals are attached. Proposals are presented in rank order as described in Item 6.a.

A pesticide resistance monitoring program for avocado thrips: Hamutahl Cohen (Rank 1.6)

It is extremely important to have this information so that we know what works and what doesn't. We need to be able to prove that existing tools are ineffective if we expect DPR to approve new tools. The price point is very good and definitely worth it. The project has good extension tools.

Total budget: $33,460 (FY 24-25 $9,411; FY 25-26 $12,149; FY 26-27 $3,300; FY 27-28 $5,300; FY 28-29 $3,300)

Assessing irrigation management tools and strategies on avocado fruit quality and yield: Ali Montazar (Rank 3.0)

Ali's current project to update the avocado crop coefficient has been extremely worthwhile and of great benefit to growers. When Ali showed his report last year it was an eye opener as to when we were missing irrigations. Valuable information that growers will be able to use quickly. Moves us in the direction we need to be going. Irrigation can make or break your operation so anything to help growers better manage irrigation is worth it.

Total budget: $219,110 (FY 24-25 $42,955; FY 25-26 $73,370; FY 26-27 $57,370; FY 27-28 $45,415)

Integrating chemical and cultural practices for bot canker control in avocado: Fatemeh Khodadadi (Rank 3.8)

Fatemeh is a new researcher and it's important to get her on board and working with the industry; it's a problem and I think we need to get data to get materials into the queue with DPR. We need to know what fungicides work so we can go to DPR. There's a lot of new fungicides and we need data on them; people are pruning more to keep tree size down and we need to be treating those pruning wounds to prevent movement of the fungus. Benefits the industry and is exactly the kind of work we need. We need to get good researchers on board with CAC's thinking and this is a good way to get Fatemeh involved. This problem is only going to get worse and drive-up management costs.

Total budget: $148,119 (FY 25-26 $ 73,149; FY 26-27 $74,970)

Improve *Phytophthora cinnamomi* management by monitoring field populations for changes in fungicide sensitivity and conducting efficacy trials: Patricia Manosalva and Jim Adaskaveg (Rank 4.7)

There's three new chemistries on the horizon that we need in our tool box and we need this work because manufacturers aren't going to do it; if we don't have alternatives we're going to lose Orondis. Reminds me of the thrips project and if we can get other chemistries registered it is worth it. A good

proposal, it's good to keep root rot work going and building on previous work; with ever changing resistance it's needed.
Total budget: $324,901 (FY 25-26 $101,266; FY 26-27 $105,696; FY 27-28 $117,939)

Creating a weather station network to guide irrigation decision of avocados: Andre Biscaro (Rank 5.6)

We need a better option than CIMIS, particularly in the south, and the price isn't too bad, the 4-acres of grass is going to be an issue. Is this old tech, should we be looking at something new? But I feel the pain of not having a local station. The 4-acres of grass is an issue and could be seen as a waste of water even though it helps growers irrigate more efficiently. It's prudent for growers to have their own weather station and there's lots of affordable options available; learning your local microclimate with your own weather station really helps make you a better grower. Weather data is important and reliable data is important, so that is a plus, but most of the cost is equipment and stations are cheap for growers to have their own. I really, really like this project; the goal is to figure out how small a weather station can be to get accurate data, the 4-acres of grass is not good and they want to try to determine how small an area will still produce accurate data. Next steps could be to compare smaller, cheaper stations once the grass area is better defined. Brings to light the importance of growers using weather data and ET; the first step toward getting us better data.
Total budget: $92,746 (FY 25-26 $88,375; FY 26-27 $4,371)

Addressing the relationship between soil characteristics and soil salinity in California avocado orchards: Jesse Landesman (Rank 5.9)

It sounds interesting; there are major issues with salinization. I'm leaning more toward treating the water than dealing with soil salinization, but we still need data. It's what we asked for initially; we are supporting the student and it does what we asked for. I like to support a student interested in working with avocados. I think the project will have value, how important it will be is uncertain, but knowing what biochar does before any recommendations for it is good. The real focus is soil physics and biogeography, trying to integrate basic science into a practical project. She has cooperation from the Lambs who have a unique ranch with two distinct soils and one water source.
Total budget: $53,097 (FY 24-25 $47,590; FY 25-26 $5,507)

Development and demonstration of a cost-effective electrodialysis reversal (EDR) process for chloride removal from avocado irrigation water: Haizhou Liu (Rank 5.9)

We've invested in this already and I think we need to keep going, it sounds promising. Five to 10% brine compared to what we currently have could really help growers in the south. The problem is the speed, 1 gal/min, the flow rates will have to be much higher. It's an example of a project that could offer a long-term solution and the opportunity and potential are there but agree that the flow rates will need to increase. I looked closely at both water proposals, and I think this one is very promising. The technology can be tailored to take out a number of ions depending on the water supply. Very science based but lacks practical experience of how to make it work effectively in a grove setting, but we will probably have a pretty good idea after a year. On the fence about funding technology development, should we be paying a company to develop technology they will turn around and profit from? This is a longer-term solution, it's not going to be a commercial product in one year.
Total budget: $300,000 (FY 25-26 $94,977; FY 26-27 $99,892; FY 27-28 $105,131)

Continued research at the San Luis Obispo rootstock trial site (2025-2027): Lauren Garner (Rank 7.0)

A large part of the budget goes toward student tuition and funding and the project will only provide an incremental increase in knowledge. Collecting the data is important, but we shouldn't have to fund the grove maintenance aspect of this; they can use the profit from fruit sales to cover maintenance costs. We need data from mature trees, and this block is reaching that point. I like that it continues to collect the data

we need to support the release of rootstocks, but the student time seems high. I'm open to sharing the maintenance costs, but fruit sales should cover some of it. I like that this is part of the overall rootstock trials, I like student engagement, I don't know that we are getting the most value out of the block, but it's still worth funding to keep that facility.
Total budget: $58,065 (FY 25-26 $29,232; FY 26-27 $28,833)

Impact of natural vegetation on insect pollinators in agroecosystems: Carson Loudermelt (Rank 8.0)

The idea is to try to find how valuable other plants in the orchard are to the insect population in a grove, very inexpensive. EQIP program has been funding planting headlands and natural habitats to stabilize insect populations by providing refuge for predators and parasites, but no one has ever looked at what insects are attracted to what plants. Identifies what vegetation attracts what pollinators. Does not directly address pollination, only what pollinators are in the grove, but not which pollinators are doing the pollination. What if some plants attract endangered species into a grove? Would having data on what plants attract endangered insect species allow us to avoid regulatory issues by knowing not to plant to plants?
Total budget: $9,362 (FY 24-25 $4,831; FY 25-26 $4,531)

<u>FISCAL ANALYSIS:</u>

- If approved, these nine projects would have a total cost of $1,238,860 over the next five CAC fiscal years, including an additional $104,787 in the 2024-25 fiscal year. If approved, this funding would require a budget amendment for the 2024-25 fiscal year.

<u>BOARD OPTIONS:</u>

- Accept the PRC's recommendation
- Modify the PRC's recommendation
- Take no action

<u>STAFF RECOMMENDATION:</u>

- Accept the PRC's recommendation

PRODUCTION RESEARCH BUDGET 2024-25 ACTUAL THROUGH 2028-29 PROPOSED

Acct Code	**Investigator**	**Project**	**2024-25 Budget**	**2025-26 Budget**	**2026-27 Budget**	**2027-28 Budget**	**2028-29 Budget**
Reasearch - Pest and Disease Projects							
65132	Hoddle	Surveys for avocados fruit feeding insect pests in Guatemala	$94,093	$243,700	$172,409		
65133	Hoddle & Kou	Chemical Synthesis and Field Evaluation of an Enantiopure (+)-Grandisol, the Putative Avocado Seed Weevil (Heilipus lauri) Aggregation Pheromone	$116,773	$85,740	$146,699		
651xx	*Cohen*	*A pesticide resistance monitoring program for avocado thrips*	*$9,411*	*$12,149*	*$3,300*	*$5,300*	*$3,300*
651xx	*Khodadadi*	*Integrating Chemical and Cultural Practices for Bot Canker Control in Avocado*		*$73,149*	*$74,970*		
651xx	*Loudermelt*	*Impact of Natural Vegetation on Insect Pollinators in Agroecosystems*	*$4,831*	*$4,531*			
651xx	*Manosalva & Adaskaveg*	*Improve Phytophthora cinnamomi management by monitoring field populations for changes in fungicide sensitivity and conducting efficacy field trials*		*$101,266*	*$105,696*	*$117,939*	
		Current Pest and Disease Sub-total	**$210,866**	**$329,440**	**$319,108**	**$0**	**$0**
		Proposed Pest and Disease Sub-total	***$14,242***	***$191,095***	***$183,966***	***$123,239***	***$3,300***
		Pest and Disease Sub-total	**$225,108**	**$520,535**	**$503,074**	**$123,239**	**$3,300**
Research - Breeding, Varieties, Genetics Projects							
65216	Manosalva	Commercial-scale field testing and potential release of five elite advanced rootstocks	$89,628				
65217	Garner	Cal Poly Project #24-044 Avocado Rootstocks	$16,690				
652xx	*Garner*	*Continued Research at the San Luis Obispo Rootstock Trial Site (2025-2027)*		*$29,232*	*$28,833*		
		Current Breeding and Genetics Sub-total	**$106,318**	**$0**	**$0**	**$0**	**$0**
		Proposed Breeding and Genetics Sub-total	***$0***	***$29,232***	***$28,833***	***$0***	***$0***
		Breeding and Genetics Sub-total	**$106,318**	**$29,232**	**$28,833**	**$0**	**$0**

PRODUCTION RESEARCH BUDGET 2024-25 ACTUAL THROUGH 2028-29 PROPOSED

Acct Code	Investigator	Project	2024-25 Budget	2025-26 Budget	2026-27 Budget	2027-28 Budget	2028-29 Budget
Research - Cultural Management Projects							
65323	Montazar	Developing tools and information on crop water use and effective irrigation management for more profitable and sustainable avocado production	$55,603				
65324	Biscaro	Adapting a user friendly online irrigation calculator for avocados	$4,000				
65325	Arpaia	Does artifical pollination improve yield of Hass and GEM avocado?	$62,719	$62,116	$47,990	$47,991	
653xx	*Biscaro*	*Creating a Weather Station Network to Guide Irrigation Decision of Avocados*		*$88,375*	*$4,371*		
653xx	*Landesman*	*Addressing the relationship between soil characteristics and soil salinity in California avocado orchards*	*$47,590*	*$5,507*			
653xx	*Liu*	*Development and Demonstration of a Cost-effective Electrodialysis Reversal (EDR) Process for Chloride Removal from Avocado Irrigation Water*		*$94,977*	*$99,892*	*$105,131*	
653xx	*Montazar*	*Assessing irrigation management tools and strategies on avocado fruit quality and yield impacts*	*$42,955*	*$73,370*	*$57,370*	*$45,415*	
		Cultural Management Sub-total:	**$122,322**	**$62,116**	**$47,990**	**$47,991**	**$0**
		Proposed Cultural Management Sub-total	***$90,545***	***$262,229***	***$161,633***	***$150,546***	***$0***
		Cultural Management Sub-total:	**$212,867**	**$324,345**	**$209,623**	**$198,537**	**$0**
		Current Annual Total	**$439,506**	**$391,556**	**$367,098**	**$47,991**	**$0**
		Proposed Annual Total	***$104,787***	***$482,556***	***$374,432***	***$273,785***	***$3,300***
		Annual Total	**$544,293**	**$874,112**	**$741,530**	**$321,776**	**$3,300**

Title: A pesticide resistance monitoring program for avocado thrips

PI: Hamutahl Cohen, Assistant Entomology Advisor, Ventura, UC ANR Cooperative Extension
Co-PI: Bodil Cass, Assistant Subtropical Entomology Specialist, UC Riverside
Co-PI: Laura Leger, Postdoctoral Researcher, UC Riverside
Co-PI: Ben Faber, Subtropical Crops Advisor, Ventura, UC ANR Cooperative Extension

Executive Summary

Pesticide resistance is a major global challenge threatening food security and resulting in increased pesticide use. Our aim is to develop a regional resistance monitoring program for avocado thrips (*Scirtothrips persea*), a severe pest of avocado in Ventura County that is vulnerable to pesticide resistance due to its high fecundity, short life cycle, asexual reproduction, and cryptic behavior. Abamectin is the primary chemical control product for avocado thrips because it has strong efficacy and a limited impact on natural enemies – however, resistance with abamectin is likely because it has long a persistence inside leaf tissues which may subject sequential generations of thrips to the same chemical mode of action. Resistance is also likely because it is often applied more than once a year for control of both avocado thrips in the spring and persea mites later in the season. For avocado thrips, resistance monitoring has not been conducted in over 12 years. To obtain new baseline resistance data for avocado thrips, we will establish study sites in Ventura County and annually monitor avocados thrips for resistance at these sites using bioassays. This program will set the groundwork for offering growers resistance diagnostic services in the future wherein we could compare grower-submitted samples to baseline resistance levels at the nearest study site from this project. This program provides a critical contribution to the avocado industry in Ventura because it is unlikely that abamectin will be easily replaced if lost to resistance.

Project Narrative

Avocado thrips (*Scirtothrips persea*) arrived in California in 1996 from Mexico. Without available control mechanisms, heavily infested orchards in Ventura County experienced 50% to 80% crop damage in 1997, and much of the fruit was unmarketable (Hoddle et al. 2002). Today, avocado thrips are thought to infest 80% of the state's ~53,000 avocado acres (Hoddle et al. 2002). Because this pest lacks effective natural predators in California, the use of chemical control is one of the primary control options. Although growers rely on pesticide applications to control avocado thrips, this tool is threatened by the development of pesticide resistance. We are proposing to develop a pesticide resistance monitoring program for avocado thrips and disseminate best practices for the prevention of resistance development.

Avocado thrips are small, slender, straw-yellow insects that are a serious threat to avocado production. Adult females lay eggs on immature leaves and fruit. Thrips larvae and adults can build to high densities on young leaves during the spring, then move to fruits when the leaves harden off. Losses are caused by lesions from feeding. Thrips mouthparts consist of mandibular stylets that pierce plant tissue and result in deformation of the fruit in the form of elongated, ridged scarring that looks like "alligator skin" and can downgrade fruit at harvest and result in loss of value to the grower (Ávila-Quezada et al. 2005, Goldarazerna 2015).

To control avocado thrips, the chemical control option with the greatest IPM value is abamectin (Agri-Mek) because it is considered fairly innocuous to natural enemies and pollinators. This product is a macrocylic lactone, unstable in sunlight, exhibits translaminar activity, and must be used with oil. Thrips exposed to abamectin take 3-5 days to die and, thus, control can be somewhat slower than with faster acting insecticides. This material is quite persistent in leaves (Rugg et al. 2005) and treatments and can hold for 6-10 weeks or more. In 2022, California growers applied approximately 400lbs of the active ingredient abamectin to avocado for the control of avocado thrips and persea mite (California Department of Pesticide Regulation 2022).

The concern is that grower reliance on abamectin will result in pesticide resistance. Resistance is a phenomenon in which insect evolve physiological and chemical mechanisms to overcome pesticide exposure. These mechanisms include toxicodynamic and toxicokinetic changes, such as reduced penetration, activation, detoxification, and excretion. For thrips in particular, resistance is a global issue. There are over 150 worldwide cases of insecticide resistance associated with different thrips species, including products in seven chemical classes (Gao et al. 2012). This is because thrips species have short generation times, high reproductive fecundity, and a haplodiploid breeding system where resistance genes can be passed undiluted from females to their offspring as they do not require mating to reproduce. The likelihood of resistance developing is further exacerbated by reliance on a single active ingredient for control, which creates stronger selection pressure from repeated, successive applications.

The combination of thrips reproductive biology and the lack of other management options makes the California avocado system particularly at risk for developing avocado thrips resistance. If avocado thrips become resistant to available control tools, they will become increasingly difficult to control. Once resistance develops, product efficacy may be lost for years or indefinitely. This has been the case for sabadilla (Humeres & Morse, 2006). Because of environmental, economic, and health concerns, new insecticide chemistries can take many years to become available. It is therefore critical to monitor pesticide resistance to inform growers about thrips susceptibility and resistance. This information about local resistance levels helps growers distinguish control failures due to resistance, from control failures due to other causes including high pest pressure or application failures (timing, coverage, etc.), and inform management decisions moving forward.

Deliverables

They key deliverable of our project is **a resistance monitoring program** resulting in publicly accessible, easy-to-read results for our local avocado community shared online. We will obtain baseline resistance levels for avocado thrips in our county so that UCCE Ventura can offer diagnostic services in the future where thrips resistance can be compared to baseline data. We are focusing on avocado because the industry has specifically requested support for grower decision-making with regards to pesticide resistance and identified this as a project of interest.

Objectives

While growers *can* manage and prevent resistance, they need data on resistance development to inform practices such as reduced spraying or using alternative controls. We aim to deliver resistance data directly to growers. We will address three objectives: 1) pilot field and laboratory protocols, 2) measure baseline pesticide resistance in avocado thrips, and 2) communicate results and strategies to reduce resistance to avocado industry stakeholders.

Work Plan & Methods

Pilot field and lab protocols (July 2025 – Oct 2025)

One of the primary challenges for implementing this project is that thrips are challenging to rear in a lab setting. Because thrips populations are lower in the late summer and Fall, we will utilize Year 1 of the project to trial the a) best methods for field collecting thrips, including how to transport thrips and store them prior to lab bioassays, and b) best methods for lab bioassays, including pesticide preparations, rearing receptacles, and timing and conducting mortality assessments. Protocols will be modified from existing literature (Morse et at. 2006). Cohen, Cass, and Leger will trial both field and lab protocols in Fall 2025 during secondary flush events. Year 1 of the project will also be used to identify 4-6 participating study sites for specimen collections and to train a Cooperative Extension Staff Research Associate (SRA) on field and lab protocols for project support.

Measuring resistance levels (Nov 2025- Oct 2026, Nov 2026- Oct 2027, Nov 2027- Oct 2028, Nov 2028 – Oct 2029)

In Years 2-5 we will implement resistance monitoring at 4-6 sites and collect thrips twice annually at each site for resistance testing. Our initial goal is to monitor resistance for four growing seasons at the same set of sites to characterize base resistance levels across the region. In Years 4 and 5 of the project we will expand field collections to include additional grower sites based on grower interest and demand for diagnostic services – we should be able to assess resistance and compare resistance levels to baseline data. Field collections will occur during avocado flush in the early Spring in the Fall during secondary flushes. Field collection involves sealing young leaves with thrips into plastic bags, then storing in the fridge for a maximum of 24 hours before the lab bioassay. To conduct the lab bioassay, we will collect young avocado leaves with no prior pesticide exposure, treat them with different pesticide concentrations using a hand-held stainless steel sprayer, and place them inside plastic modified Munger cells with 10-15 females second instar thrips in each cell. We will include a control with no exposure to pesticide. Munger cells will be kept at 25C ±1 °C with a 14:10 h light: dark photoperiod. We will assess thrips mortality after 48hr. under the microscope by counting thrips not exhibiting movement.

Analysis

We will calculate mortality of thrips as the number of thrips surviving after treatment, adjusted by the number of thrips in the control (Immaraju et al. 1990) as follows:

$$\text{Adjusted \% mortality} = \frac{(PR \times C) - PS}{(PR \times C)} \times 100$$

Where PR is the number of thrips before treatment, PS is the number of thrips after treatment, and C is the number of thrips in the control after treatment. Probit analysis will be used to quantify the lethal concentration of abamectin that generates 50% mortality (LC50) in the population. Bioassays with control mortality >20% will be omitted from analysis. We will calculate resistance ratios for each avocado field site using the most susceptible LC50 value for abamectin.

Project Outreach

Starting in the second year of the project, we will work closely with the California Avocado Commission to share research progress and results to growers 1) annually through an oral presentation (e.g. at a field day or workshop) and 2) through an online, interactive web-based resource of resistance data (Figure 1). We will use ArcGIS Story Maps to share with growers the number of specimens tested for resistance in each year and categorical and numerical levels of resistance. The identity and location of participating growers will be anonymized by jittering data points, i.e. using an algorithm to provide random noise and displace locations while still preserving the pattern of the dataset. The UC ANR website hosting this map will include information on management practices that can prevent pesticide resistance, such as preventing product degradation, adjusting the pH of spray solutions, and timing applications. We will evaluate grower utilization and understanding of this data with a survey that will inform the continuation of this project. The baseline resistance data from this project can serve as a reference point for diagnostic assays provided to the grower community in the future.

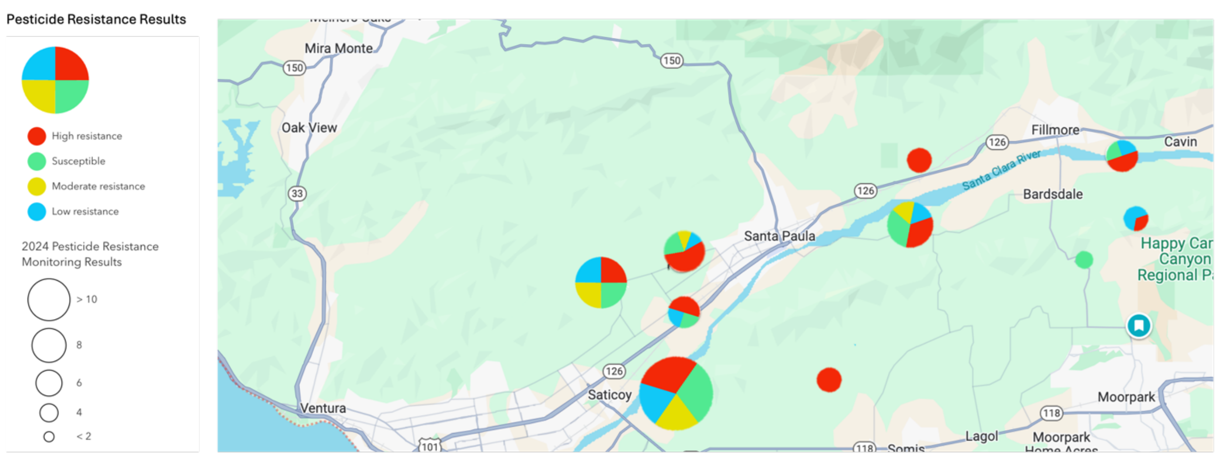

Figure 1. An example of the type of map that we can generate with ArcGIS Story Map for Ventura County resistance monitoring of avocado thrips. Each point on the map reflects categorical resistance levels and the number of thrips collected. Farm location will be anonymized by an algorithm that randomly moves the center of each sampling point to another. Each point on the map can be clicked on to obtain detailed, non-categorical number data about resistance levels.

Milestone Table

Outcome	**Year 1** (July 25-Oct 25)	**Year 2** (Nov 25-Oct 26)	**Year 3** (Nov 25-Oct 26)	**Year 4** (Nov 25-Oct 26)	**Year 5** (Nov 25-Oct 26)	**Budget**
Identify field sites, develop methods, obtain equipment	X					$9,411
Sample insects for establish baseline resistance levels		X	X			$13,139
Expand field collection sites and provide diagnostic services				X	X	$5100
Share results to growers at a field day or seminar		X	X	X	X	$1,200
ArcGIS Story Map		X	X	X	X	$2,610
Publication				X		$2,000

Budget & Budget Justification:

UC ANR (Cohen & Faber)	Year 1 (July 25-Oct 25)	Year 2 (Nov 25-Oct 26)	Year 3 (Nov 25-Oct 26)	Year 4 (Nov 25-Oct 26)	Year 5 (Nov 25-Oct 26)
Hand-held pesticide sprayer (B&G)	$450				
Munger Cells for bioassay	$150				
Misc. field & lab supplies (e.g. nitrile gloves, distilled water, pesticide product, beakers, fine sable brush, forceps, aspirator, paraffin)	$500				
Staff Research Associate (SRA, 10hr in Year 1, 50hr Year 2-5 at $51/hr for salary + fringe)	$510	$2,550	$2,550	$2,550	$2,550
Extension materials (printing, food for grower events)		$300	$300	$300	$300
ArcGIS Story Mapping and website support from UC IGIS Center		$1,260	$450	$450	$450
Total	$1,610	$4,110	$3,300	$3,300	$3,300
				TOTAL	**$15,620**

UC Riverside (Cass & Leger)	Year 1 (July 25-Oct 25)	Year 2 (Nov 25-Oct 26)	Year 3 (Nov 25-Oct 26)	Year 4 (Nov 25-Oct 26)	Year 5 (Nov 25-Oct 26)
Travel from UC Riverside to Ventura with vehicle ($400) and 3 nights overnight stay each year ($200 x 3=$600)	$1,000	$1,000			
Postdoctoral Salary + Fringe (1 month/annually)	$6,801	$7,039			
Publication costs				$2,000	
Total	$7,801	8,039$		$2,000	
				TOTAL	**$17,840**

Support from CAC is critical for the success of this project, which is currently unfunded. The research team includes early-career UCCE researchers proposing to advance integrated pest management of a key pest of avocado. Our budget includes requests for materials, labor, and travel.

Materials: In Year 1 of the project, we are requesting support for materials which can be used throughout the project duration, including materials to create munger cells, a small hand-held sprayer, and safety equipment such as gloves.

Labor: Because Year 1 only includes a few months, we are requesting only 10 hours of field work support for our staff research associate (SRA) at UC ANR to collect specimens. In Years 2-5, we are asking for 50 hours of field work support each year. The SRA will also assist in setting up the bioassay and monitoring for mortality. We are requesting funds for our UCR postdoctoral researcher, Laura Leger, to travel to Ventura help us refine our bioassay in Year 1. In Year 2, Dr. Leger will work on designing and maintain the data management infrastructure for this project, analyzing preliminary data, writing reports, and disseminating results.

Mapping: In Year 2 of the project, Dr. Leger will work with the UC Informatics and GIS Center (IGIS) to develop the ArcGIS Story Map for this project. IGIS have provided a project estimate of 14 contracted hours for this project at $90/hr. In Years 3-5, we are requesting 5 hours of each year for IGIS support in managing our map and providing refinement the map design.

Dissemination: In Years 2-5 we will host an annual presentation to update growers on our progress. We will use funds to provide lunch. In Year 4 we are requesting funding support to publish results in a peer-reviewed journal as we this data will additionally be of interest to the scientific community.

D. Curriculum Vitae or Resume:

Roles and Contribution:
Principal Investigator Cohen will serve as project leader and manager, overseeing day-to-day operations of the experiments, including communication with the participating growers, adhering to the project timeline, reporting deliverables, and organizing outreach activities. Co-PIs Cass, and Leger will be responsible for conducting laboratory work, participating in data analysis/interpretation, writing reports, and speaking at extension events. All team members will contribute to experimental design, project implementation in the field, data management, and report writing.

Project Narrative

Project Title: Assessing irrigation management tools and strategies on avocado fruit quality and yield impacts

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

Project Cooperator: Ben Faber, Subtropical Crops Advisor, UCCE Ventura and Santa Barbara Counties; email: bafaber@ucdavis.edu.

Executive Summary: Careful water management is critical to ensure optimal yield and high-quality avocado fruits. This is even more important under avocado crop production systems in California due to uncertain water supplies, mandatory reductions of water use, the rising cost of water, and increasing salinity in water sources. We have conducted extensive data collection and analysis over the last three years on 12 avocado commercial sites. Through this past study, seasonal crop coefficient (Kc) curves have been updated for California avocados, as well as an evaluation of avocado crop water consumption conducted under different environments and orchard features. While we developed more accurate seasonal Kc values and a better understanding of the efficacy of irrigation tools in CA avocados, a second phase of this study needs to be carried out assessing the developed Kc values in regards with avocado fruit quality and yield impacts. This is a necessary phase that may provide growers with a high level of confidence to adopt the information and enhance the efficiency of water use in avocados. This new study intends to evaluate the impact of irrigation management using the developed seasonal Kc curve and other cost effective and user-friendly tools in California avocados. It is expected that the tools and information under development by this study will enable more efficient resource- use irrigation management and long-term sustainability in avocado production.

List of specific project objectives: This project aims to assess the impact of irrigation tools and management strategies to optimize water-use efficiency and economic productivity in avocado production systems. Enhancing water-fertilizer, and energy-use efficiency, water conservation, water quality, and economic gains of avocado growers are the primary goals that this study will address. The project specifically aims to:

- verify the developed Kc seasonal curves for California Hass avocados in regards with avocado fruit quality and yield impacts.
- assess the impact of irrigation tools (ET-based irrigation, OpenET satellite data, soil moisture sensing, Implexx Sap Flow sensor) and irrigation management strategies (various water application rates) on yield and fruit quality of avocados.
- quantify water use efficiency enhancement following improved irrigation management practices.
- disseminate project findings to growers and stakeholders.

List of specific project deliverables:

- evaluation of ET-based irrigation scheduling using the developed Kc values on avocado fruit quality and yield impacts.

- evaluation of irrigation management using OpenET satellite data on avocado fruit quality and yield impacts.
- the effectiveness of soil moisture sensing and Implexx Sap Flow sensor on improving avocado irrigation management.
- evaluation of various irrigation regimes on avocado fruit quality and yield impacts.
- assessing the impact of irrigation tools on water use efficiency and water conservation.
- assessing leaching requirements of avocado orchards over season/s.

Background: The PI of this project has recently completed an irrigation study to better understand the impacts of environmental and plant factors on crop water use and to develop more precise crop coefficient values for California Hass avocado production systems. The study was conducted in 12 avocado sites in southern California (Fig. 1).

Fig. 1. A demonstration of flux tower monitoring station and some of the instrumentation set up.

While a similar crop water use pattern was found over the course of the measurement seasons in avocado experimental sites, considerable differences were found in the seasonal ET (actual evapotranspiration) amounts determined across avocado sites and seasons. For instance, an 11.4-in difference in the seasonal consumptive water use was determined amongst the four avocado sites in 2024 (Fig. 2).

The results of this study clearly show that avocado crop water use varies spatially and temporally. The greatest seasonal crop water consumption was determined at an avocado site (site A) with the features of coarse sandy loam soil texture, 44% south facing slope, average elevation of 758 ft. above mean sea level, plant density of 120 trees per acre, mean canopy coverage of 88.7% and tree height of 23.2 ft. In contrast, the least seasonal crop water use was observed at an avocado site (site D) affected by coastal climate with the features of loamy soil texture, 3% southwest facing slope, average elevation of 164 ft. above mean sea level, plant density of 254 trees per acre, mean canopy coverage of 75.9% and tree height of 12.5 ft.

The results illustrate that avocado has the lowest crop coefficient values during the summer months, increasing gradually from late September to a maximum in mid-winter, again gradually reducing during spring to a minimum in mid-summer (Fig. 3). To be more precise, the findings revealed greater crop coefficient values of avocados during flower bud development, and flowering through fruit set growth phases than the fruit development phase.

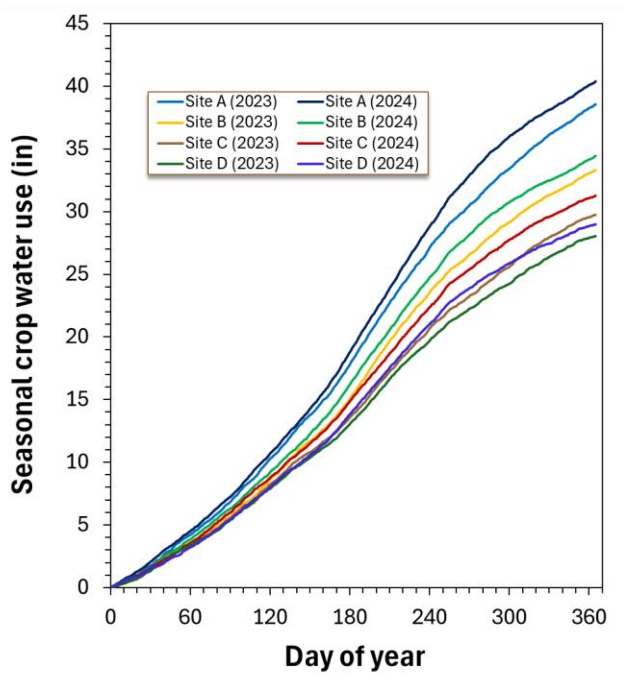

Fig. 2. Seasonal crop water use measured at the avocado sites in 2023 and 2024. The comparison demonstrates that the seasonal consumptive water use at avocado sites varied from 28.1 in. (affected by coastal climate) to 40.4 in. (an inland valley) over the two growing seasons of 2023 and 2024. Considering the tree spacings at the avocado sites, the seasonal crop water requirements may vary from about 3,000 gallons per tree (high density orchard affected by coastal climate) to about 9,000 gallons per tree (low density orchard under growing conditions of inland valley).

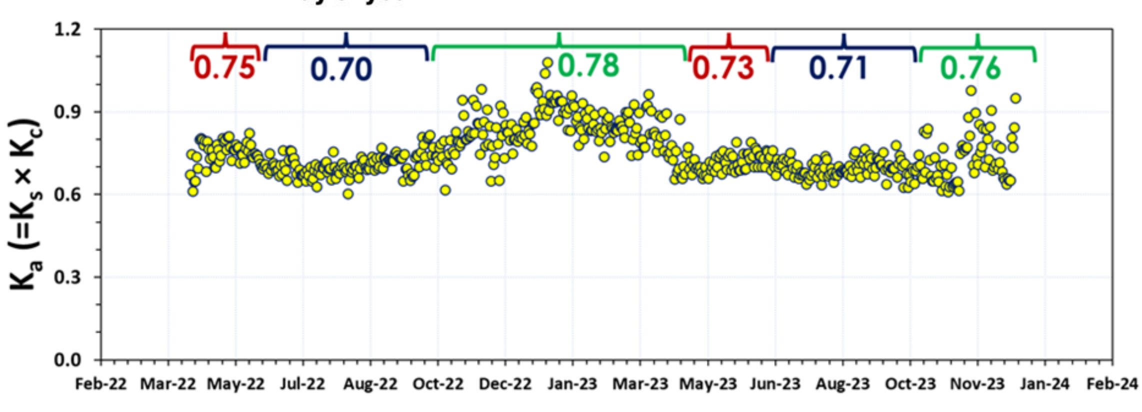

Fig. 3. Avocado crop coefficient curves over two growing seasons in a high water-use avocado site.

Work Plan and Methods: The field experiment will be conducted in two avocado research sites equipped with the flux tower over a three-year period, one in Temecula and one in Escondido. The seasonal Kc curve had been already developed for these sites. Four irrigation strategies will be arranged in a Randomized Complete Block Design with six replications (six trees per irrigation strategy: for the analysis, we will consider three tree sets consisting of two trees per set per each irrigation treatment to consider soil variability and the impact of top-bottom of slope)

(Fig. 4). The irrigation strategies will consist of (1) grower practice the entire growing season as control treatment, (2) 100% ETc, (3) 80% ETc, and (4) irrigation based on the best OpenET model identified for avocados (an assessment of OpenET models will be undertaken for avocados using the flux tower data and the results will be used for the irrigation strategy 4). ETc will be determined using the Kc values developed for the sites and spatial CIMIS ETo data (ETc=Kc × ETo). It needs to be noted that the leaching requirements will be added to ETc in irrigation treatments 2-4. The assumption is that grower irrigation practice provides an over irrigation strategy in this study. Our earlier date collected from several avocado sites verifies this assumption.

The soil water status will be monitored within the soil profile, depths of 6 through 36 in., in each treatment using two different types of soil moisture sensors measuring soil water potential and volumetric water content. A precision irrigation system will be set up to accurately monitor water applied (using digital flowmeter) and deliver irrigation water in each treatment. EM-38MK2 will be run to develop salinity maps in the experimental areas of each site. Soil salinity will be evaluated twice per year, mid-August and early May and the required leaching will be performed as needed. In addition, soil solution access tubes will be installed at the depths of 1 to 3 ft to monitor ECe, chloride, and nitrate-N of soil solution on a regular basis.

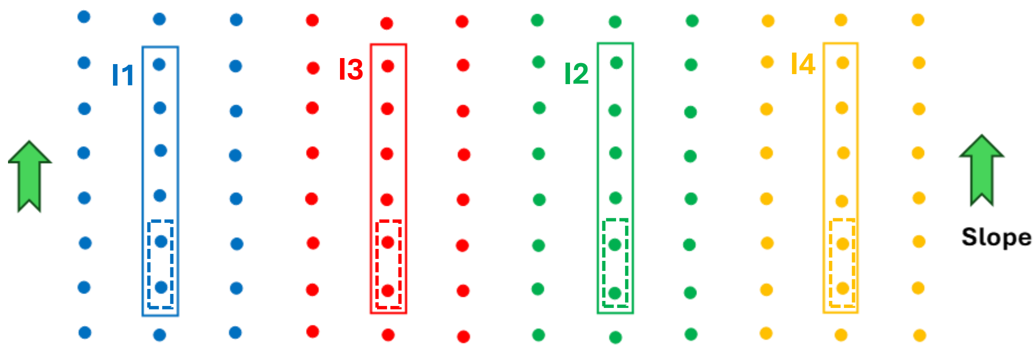

Fig. 4. Layout of experimental sites. Dots with similar colors demonstrate avocado trees under a similar irrigation strategy. Six central trees in each irrigation strategy (I1 – I4) will be considered for monitoring and yield assessment (three sets of trees consisting of two trees per set per each irrigation treatment to consider soil variability and the impact of top-bottom of slope). The experiment will be conducted in about 0.6 acres in two different mature avocado sites. All experimental tress in each site will be on the same row (predominant slope) orientation.

Implexx Sap Flow sensor will be utilized to measure trees transpiration as well as Leaf Porometer to monitor stomatal conductance. Monitoring plant water status will be conducted using dendrometers on a continuous basis along with pressure chamber readings (three times per month between May and September). In addition, the difference of canopy temperature versus air temperature recorded by fixed view-angle infrared thermometers along with aerial imagery and analysis will be used to evaluate crop water stress indices. Continuous normalized difference vegetation index (NDVI) values will be measured by Spectral Reflectance sensors. All data will be measured and transferred using telemetry devices on a continuous basis. 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 on three different days per season. Water distribution uniformity will be evaluated using the standard evaluation methods for micro irrigation systems.

The agronomical performance of irrigation strategies will be also assessed during the seasons by monitoring fertilizations, foliar nutrient content and fruit yield. Avocado fruits are gradually harvested from February to April to assess yield and water productivity. To evaluate the fruit size (i.e. indicative of commercial quality), fruits are analyzed and classified into different size-classes according to their weights. The percentage of dry matter is also analyzed in 10 randomly selected fruits per irrigation treatment with a Near Infrared Analyzer (NIR).

Project Outreach: A robust outreach program will be developed to disseminate project findings to growers and stakeholders. We will hold three avocado irrigation workshops. The findings will also be presented at the grower meetings of the CAC and at the Avocado Café. Results will be published as extension publications in *Topics in Subtropics* and *Extension Connection* newsletters, CAC- *from the Grove Magazine*, and UC blogs and as scientific articles in peer-reviewed journals. The PI will participate and present the project findings at the 11th World Avocado Congress and the American Society for Horticulture Science (ASHS) annual conference.

Milestone Table: The project milestones of Year 1 - Year 3 are given in Table 1. Starting this project from July 2025 provides the research team with better time management to gather a three-year yield data and ensure a more comprehensive assessment of irrigation strategies. It might be a little bit weird, but to stay with the CAC fiscal years, we need to consider Year 1 – Year 3 as follows; Year 1: July 1, 2025 – October 31, 2026 (15 months), Year 2: November 1, 2026 – October 31 (12 months), 2027, and Year 3: November 1, 2027 – June 30, 2028 (9 months).

Table 1. Project milestones of Year 1 – Year 3. Each year consists of two milestones (M1 and M2).

Milestone	Activities	Time completion	Estimated budget amount ($)
M1 – Year 1	Purchase the special purpose equipment.	Jul 2025	29,500
	Field visits to finalize the exact locations of experimental sites.	Jul 2025	5,000
	Set up field experiments in two avocados sites including irrigation treatments and sensor installation.	Aug 2025	
	Run irrigation treatments.	Mar 2026	40,913
	Regular data collection (soil, plant, water, yield, aerial imagery), sensor and equipment maintenance, and data analysis. Conduct salinity survey.	Mar 2026	
M2 – Year 1	Run irrigation treatments	Oct 2026	40,912
	Regular data collection (soil, plant, water, aerial imagery), sensor and equipment maintenance, and data analysis.	Oct 2026	
	Hold Avocado Irrigation Workshop.	Jul 2026	
	Publish extension article.	Sep 2026	
M1 – Year 2	Run irrigation treatments.	Mar 2027	28,000

	Regular data collection (soil, plant, water, yield), sensor and equipment maintenance, and data analysis.	Mar 2027	
	Develop University of California blogs and various web-based platforms to share science-based information.	Feb 2027	
M2 – Year 2	Run irrigation treatments.	Oct 2027	29,370
	Publish extension article.	Sep 2027	
	Regular data collection (soil, plant, water, aerial imagery), sensor and equipment maintenance, and data analysis. Conduct salinity survey.	Oct 2027	
	Hold Avocado Irrigation Workshop.	Jul 2027	
	Publish extension article.	Sep 2027	
	Participate in and present the project findings in national/international conference.	Sep 2027	
M1 – Year 3	Run irrigation treatments.	Mar 2028	32,000
	Regular data collection (soil, plant, water, yield), sensor and equipment maintenance, and data analysis.	Mar 2028	
	Publish extension articles.	Mar 2028	
	Develop University of California blogs and various web-based platforms to share science-based information.	Mar 2028	
M2 – Year 3	Run irrigation treatments.	Apr 2028	13,415
	Regular data collection (soil, plant, water, aerial imagery), sensor and equipment maintenance, and data analysis. Conduct salinity survey.	Apr 2028	
	Hold Avocado Irrigation Workshop.	May 2028	
	Participate in and present the project findings in national/international conference.	May 2028	
	Publish extension articles.	Jun 2028	
	Publish peer-reviewed journal article.	Jun 2028	

Project Budget

Budget Detail: A total budget of $219,110 is requested for conducting this project (July 1, 2025 – June 31, 2028). The details of the budget can be found in Table 2.

Table 2. Detailed budget of the project.

Item	**Budget ($)**				**Total budget ($)**
	Year 1		**Year 2**	**Year 3**	
	FY 24-25	**FY 25-26**	**FY 26-27**	**FY 27-28**	
Personnel					
Staff research associate salary	7,250	29,000	29,000	21,750	87,000
Staff research associate fringe benefits	4,205	16,820	16,820	12,615	50,460
Graduate student salary and fringe benefits (to be determined)	-	6,250	6,250	6,250	18,750
Personnel subtotal	11,455	52,070	52,070	40,615	156,210
Supplies					
3-D sonic anemometer (no=2)	7,500	-	-	-	7,500
CR3000 datalogger (no=6)	3,000	-	-	-	3,000
digital flowmeter (no=6)	2,000	-	-	-	2,000
soil moisture sensor (no=9)	9,000	-	-	-	9,000
Implexx Sap Flow Sensor (no=12)	8,000	-	-	-	8,000
Supplies subtotal	29,500	-	-	-	29,500
Travel					
Travel to the experimental sites	2,000	3,000	3,00	2,500	10,500
Other costs					
Scaffolding structures to set up sensors above canopy (no=2)	-	16,000	-	-	16,000
Soil/water/plant lab analysis	-	1,500	1,500	1,500	4,500
Cell phone modem services	-	800	800	800	2,400
Total	42,955	73,370	57,370	45,415	219,110

Budget Narrative:

1- Personnel: A Staff research associate (SRA) will be recruited for the project who will help the research team with setting up and performing the irrigation treatments, monitoring stations and sensors in the experimental orchards, tuning up the instruments, collecting field data and conduct analysis, performing other field activities and sensors maintenance, and participating in the outreach program. For a three-year period, the average annual salary of the SRA is estimated to be $58,000 and the fringe benefits are assumed at 58% of salary. We expect this project to support 50% FTE of the SRA salary and fringe benefits in each year over a three-year period.

A graduate student will be hired to work 750 hours at a projected average rate of $25 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 for this study, there are still some supplies that need to be purchased by this project including 3-D sonic anemometer (81000 RE), CR3000 datalogger, digital flowmeter, soil moisture sensor, and Implexx Sap Flow Sensor.

3- Travel: The PI, SRA, and graduate students have several multiple-day (an average of two days per trip) trips for 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 32 trips is estimated with an average of 310 miles per trip. The project estimate for travel expenses is 9,920 miles ($0.67 per mile), 18 nights lodging ($170 per night), 16 days per diem ($60 per day).

4- Scaffolding structures for monitoring towers are required. Renting materials, dismantling scaffolding and demobilizing assembling is at an average flat rate of $8,000 per site.

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 requires four cell modems over a three-year period.

Integrating Chemical and Cultural Practices for Bot Canker Control in Avocado

Project start date: 1 November 2025
Project end date: 31 October 2027
Project Leader: Fatemeh Khodadadi
Position Title: Assistant Professor of Extension and Assistant Plant Pathologist
Address: University of California, Riverside, 900 University Avenue, Riverside, CA 92521
Primary Telephone Contact Number: 951-827-4764 (mobile 845-901-3046)
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Major Collaborator: Dr. Ben Faber
Department: UCCE
School or College: Ventura
Phone: 805-901-0784
E-mail: bafaber@ucanr.edu
Present Title: Farm Advisor

Executive Summary: Avocado branch canker, a fungal disease caused by various species in Botryosphaeriaceae family, significantly threatens global avocado production. These fungal pathogens have been associated with branch canker and dieback in avocado trees worldwide, including Brazil, Chile, Greece, Italy, Mexico, New Zealand, and Spain[1-6]. Recent surveys indicate a dramatic increase in avocado branch canker prevalence across Southern California orchards. Botryosphaeriaceae incidence has surged in Ventura (48% to 73%), San Diego (20% to 65%), and San Luis Obispo (39% to 83.3%) counties, posing a serious threat to the avocado industry's sustainability[7,8]. Pre-harvest avocado branch canker is characterized by distinct cankers with necrotic bark, reddish-brown wood discoloration, and potential whitish exudate. Once established, the pathogen disrupts xylem and cambium, leading to reduced tree vigor, leaf scorch, and branch dieback. Severe infections result in yield loss and tree mortality[7-10]. These fungi, acting as latent endophytes or saprobes, exploit environmental stressors like drought, nutrient deficiency, or mechanical damage to become pathogenic. Wounds from pruning, mechanical damage, sunburn or insect infestations serve as entry points, facilitating spore production and spread.

Avocado branch canker management is challenging due to limited registered fungicides. While some fungicides show potential[11], research is sparse compared to other crops. Current control relies on cultural practices, which are insufficient, highlighting the need for fungicide efficacy studies tailored to California's avocado industry. Water stress, both in terms of amount and timing of irrigation, is suspected to significantly influence tree susceptibility. Drought or inconsistent irrigation can weaken defenses, while over-irrigation or waterlogged conditions compromise root health, both potentially exacerbating canker development. Similarly, salinity stress weakens trees by disrupting nutrient and water uptake, creating entry points for the pathogen. Understanding the precise relationships between irrigation, salinity, and branch canker is crucial for developing effective management strategies.

Having identified and characterized the primary *Botryosphaeria* species causing branch canker in Southern California[12], this project will develop and implement an IDM strategy to minimize disease impact and enhance long-term orchard health and productivity.

Project Objectives

1. Evaluate the efficacy of various fungicides against *Botryosphaeria* species through ***in vitro* and field** trials, assessing both **curative and preventative** applications, and determine optimal application timing and frequency.
2. Investigate the impact of different irrigation levels on branch canker development in avocado trees, both in greenhouse and field settings.
3. Determine the salinity tolerance of *Botryosphaeria* species *in vitro* and to determine how salinity stress influences disease development and avocado tree health under controlled greenhouse conditions.
4. Integrate research findings into a practical IDM guide for avocado growers, disseminated through extension activities.

Project Deliverables:

This project will deliver several key outcomes to combat Avocado Branch Canker in avocados. Firstly, a comprehensive report will detail the efficacy of various fungicides, determined through *in vitro* and field trials, including optimal application timing and frequency for both curative and preventative treatments. This report will be supported by detailed data tables and statistical analyses. Secondly, a research report will document the impact of varying irrigation regimes on canker development, presenting data on disease severity, soil moisture, and tree health, alongside corresponding analyses. Thirdly, the salinity experiment will deliver comprehensive data on Botryosphaeria spp. responses to salt stress. In vitro studies will yield EC_{50} values for mycelial growth and spore germination across various salt concentrations, documented through tables, graphs, and microscopic assessments. Greenhouse experiments will provide detailed records of canker symptom development, disease incidence, and fungal growth in avocado trees subjected to varying salinity regimes, alongside tree health parameters and soil EC. Both phases will culminate in detailed reports with statistical analyses, elucidating the impact of salinity on fungal biology and avocado disease development. Finally, the project will culminate in the development of a practical IDM strategy, integrating fungicide and cultural practice optimizations. This strategy will be accompanied by a user-friendly guide for avocado growers, providing clear instructions, visual aids, and decision-making tools. Workshops will be conducted to disseminate the information, and both digital and physical copies of the guide will be made available to ensure effective implementation.

• **Work Plan and Methods:**

1. Efficacy of various fungicides against Botryosphaeria species through in vitro and field trials, assessing both curative and preventative applications, and determine optimal application timing and frequency.

***In Vitro* Screening:** Isolates of the predominant *Botryosphaeria* species have been collected from symptomatic avocado trees in various California growing regions and identified using morphological and molecular methods[12]. To identify effective fungicides, we will conduct standard laboratory assays, including mycelial growth inhibition and spore germination inhibition, using fungicides representing diverse modes of action. Specifically, we will measure mycelial growth (colony diameter), spore germination rates, and calculate EC_{50} values for each fungicide. In vitro experiments will be conducted in our UC Riverside laboratory. Comprehensive fungicide screening will occur in Year 1.

In Field Screening: To assess the curative effect of fungicides on avocado branch canker in avocado pruning wounds, a field trial will be conducted using a randomized complete block design. Mature avocado trees will have three green shoots of similar thickness tip-pruned at approximately 12-15 cm from the basal ends and immediately inoculated with 20 μL of a *Botryosphaeria* isolate conidium suspension at a specific concentration. Following inoculation, each treated shoot will be covered with a transparent plastic bag for 24 hours to maintain humidity. To assess curative efficacy, designated pruning wounds will be sprayed with selected fungicides at label rates either 24 hours (day 1), 3 days, or 7 days post-pruning and inoculation, while positive and negative control wounds received no fungicide treatment. For each experiment we will use the most effective fungicides from *in vitro* tests, fungicide application combined with 1.15% NAA (Tre-Hold A-112), and NAA application alone. The trees will be maintained under standard field conditions, and lesion development will be assessed eight months post-inoculation by measuring lesion lengths and attempting fungal re-isolations from lesion margins to confirm Koch's postulates.

For preventative treatments in our avocado field trials, we will utilize the most effective fungicides identified from in vitro tests, alongside applications of 1.15% NAA (Tre-Hold A-112) alone, and a combination of fungicides with NAA. Selected branches will be pruned, and treatments will be immediately applied to the pruning wounds using a paintbrush. Subsequently, a 20 μL mixed Botryosphaeria isolate conidium suspension will be applied to each wound with a micropipette at days 1, 7, or 14 post 'pruning and treatment'. For the untreated control, branches will be treated with sterile distilled water immediately after pruning and then inoculated with the *Botryosphaeria* conidium suspension following the same procedure used for the other preventative treatments. After eight months disease incidence (number of cankers per tree), disease severity (canker size, branch dieback), and yield (fruit weight, number) data will be collected. Field trials will be conducted in cooperating commercial avocado orchards with a history of branch canker or will be done in research orchards in Pine Tree Ranch in Santa Paula (Ventura County). Field trial preparation will commence in Year 1, along with fungicide applications, Year 2 will be dedicated to data collection, and initial data analysis and repeat field trials (contingent on Year 1 results), final data analysis, and report completion. We foresee minimal challenges for the *in vitro* fungicide assay. However, potential obstacles for the field trials include weather variability impacting results, the possible development of fungicide resistance, and difficulties in securing cooperating orchards.

2. Impact of different irrigation levels on Botryosphaeria canker development in avocado trees, both in greenhouse and field settings.

To comprehensively investigate the impact of water stress on branch canker development in avocado, a two-pronged approach will be employed. A controlled field experiment will begin by subjecting mature avocado trees to different irrigation regimes: optimal, water deficit, and over-irrigation. Soil moisture sensors will continuously monitor water content. Trees will be inoculated with the pathogen and simultaneously treated with selected fungicides during varying irrigation regimes to assess the independent impact of water stress and the combined effect of irrigation and fungicide application. Second, a complementary pot experiment will be established, allowing for greater control over environmental variables. Young avocado trees will be grown in containers and subjected to the same irrigation treatments as the field experiment. Critically, in the pot experiment, trees will be inoculated with the dominant *Botryosphaeria* species. The pot experiment will also include fungicide treatment groups to isolate the effects of water stress and evaluate the combined impact of water stress and fungicide application on disease control/development. Both experiments will monitor canker lesion development, disease incidence, and tree health parameters. Statistical analysis will be used to determine the impact of irrigation treatments, and fungicide applications on disease development, providing insights into optimal management strategies. Selected branches on each tree will be inoculated with a standardized *Botryosphaeria* strain. Disease severity will be assessed by measuring canker lesion size and recording disease incidence at regular intervals. The greenhouse experiment will be performed during the first year of the project at the UCR campus greenhouse. The field experiment will be executed in the second year, utilizing the same orchard as the fungicide assay. This objective faces potential challenges, notably unpredictable rainfall that can disrupt irrigation regimes and extreme temperatures that may adversely impact tree health and pathogen development.

3. **Determine the salinity tolerance of Botryosphaeria species in vitro and to determine how salinity stress influences disease development under controlled greenhouse conditions.**

To investigate the effects of salinity on *Botryosphaeria* spp. *in vitro*, we will evaluate the impact of various salt concentrations on colony growth and spore germination of ten isolates from each identified *Botryosphaeria* species. Spore suspensions and mycelial plugs will be obtained from 7-day-old colonies grown on Potato Dextrose Agar (PDA) at 25°C. Mycelial plugs and standardized spore suspensions (quantified using a hemocytometer) will be inoculated into PDA and Potato Dextrose Broth (PDB) media amended with varying concentrations of NaCl, KCl, MgSO4, MgCl2, or CaCl2. Cultures will be incubated at 25°C in the dark, with liquid cultures agitated in a shaker incubator. Colony growth (measured as colony diameter) and spore germination rates will be assessed microscopically at multiple time points (e.g., 24, 48, 72, 96 hours). Liquid cultures will be assessed for visible growth (mycelial development or turbidity) after 4 weeks. Sterile, salt-free media will serve as negative controls. All treatments will be performed in triplicate.

To examine the effects of salinity on *Botryosphaeria* species in a controlled environment, we will conduct greenhouse experiments using potted Hass avocado trees grafted onto Duke 7 or Toro Canyon rootstock. Prior to initiating salt treatments, trees will be acclimated to greenhouse conditions. Plants will be randomly assigned to one of three treatment groups: a non-saline control (NS) receiving irrigation at optimal electrical conductivity (EC) for avocado growth, a leached salt treatment (LS), and a continuous salt treatment (CS). For the LS and CS groups, irrigation solutions will be amended with a 1:1 equivalent ratio of NaCl and CaCl2. The EC of these solutions will be incrementally increased over eight days in four equal steps, reaching a maximum of 7 dS·m-1. On day nine, the LS group will undergo leaching with non-saline irrigation solution, while the CS group will continue to receive the 7 dS·m-1 solution. One week after the maximum salt levels are reached (day 15), select branches on each tree will be inoculated with a standardized *Botryosphaeria* conidial suspension. Throughout the experiment, we will monitor symptom development, disease incidence, and fungal growth in tree tissues across all three treatment groups. In vitro experiments will be conducted at the UC Riverside laboratory, while greenhouse experiments will be performed at the UCR campus greenhouse facility. The *in vitro* salinity data will be collected in year one, while the greenhouse experiment will be conducted in year one and two of the project. Challenges include maintaining precise salinity levels in irrigation, ensuring uniform salt distribution in potting media, and effectively leaching salts from the LS treatment, requiring determination of optimal leaching time and volume.

4. Integrate research findings into a practical IDM guide for avocado growers, disseminated through extension activities.

We will create a comprehensive IDM strategy for branch canker by analyzing fungicide and cultural practice data, including pot studies, using statistical methods. A risk assessment framework will guide the development of integrated protocols, combining optimized irrigation, salinity management, and fungicides. On-farm trials will validate the strategy, which will be translated into a user-friendly grower guide with practical tools and disseminated through workshops and ongoing support. To effectively reach California avocado growers, we will use a multi-pronged approach: creating accessible extension publications, conducting in-person and virtual grower meetings, and engaging industry partners like PCAs and Farm Advisors. We will develop clear, visual-based publications available in print and digital formats, hold interactive meetings with Q&A sessions, and provide training workshops and materials to industry professionals. Collaboration with partners will maximize outreach and resource development.

Milestone

The following Milestone Table outlines the activities associated with the project and scheduled completion dates.

Year 1	11/1/2025-10/31/2026		
Milestone	**Activities**	**Scheduled Completion**	**Budget**
1	PhD student Salary (Valentina Valencia Bernal)	October, 2026	$61,149
2	In vitro fungicide sensitivity testing	February, 2026	$2,000
3	In vitro salt sensitivity testing	March, 2026	$2,000
4	Irrigation impact greenhouse trial	October, 2026	$4,000
5	Greenhouse salinity effects experiment	October, 2026	$4,000
		Year 1 Total	**$73,149**
Year 2	**11/1/2026-10/31/2027**		
1	PhD student Salary (Valentina Valencia Bernal)	October, 2027	$63,970
2	Continuation of greenhouse assay	March, 2027	$2000
3	Setting up the trials for the efficacy of fungicides in the field and collecting data	October 2027	$4,500
4	Field trial for irrigation impact test	October, 2027	$4,500
		Year 2 Total	**$74,970**
		Total Project Budget excluding travel	**$148,119**

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Budget

Year 1	**Budget**
Personnel (includes salary, benefits, fees etc.) (Salary: $40,130+ Benefits: $843 + Tuition and Fees: $20,176)	$61,149
Supplies	$12,000
Travel	$4,000
Year 1 Total	**$77,149**
Year 2	
Personnel (includes salary, benefits, fees etc.) (Salary: $42,574+ Benefits: $894 + Tuition and Fees: $20,502)	$63,970
Supplies	$11,000
Travel (weekly trips to field sites [car rental, gas], meetings etc.)	$5,000
Year 2 Total	**$79,970**
Total Budget	**$157,119**

Budget Justification:

A. Senior Personnel – $0 Fatemeh Khodadadi, Lead Principal Investigator ($0) Dr. Khodadadi will be overseeing the project.

B. Other Personnel - $82,704
Graduate Student Researcher, Valentina Valencia Bernal/Dr. Khodadadi Lab ($82,704): Dr. Khodadadi will supervise one graduate student researcher at 50% FTE for 12 months during years 1 and 2 of the project. Costs for wages in Year 1 are $40,130 and $42,574 in Year 2.

UC Riverside defines a year as the Fiscal Year from July 1st through June 30th. All salaries and wages are estimated using UC Riverside's academic and staff salary scales. Anticipated cost of living increases of 3% per year are included for the PI and Graduate Student Researcher . Where appropriate, merit increases are included in the calculations. Merit increases for academic personnel are estimated at 5%.

Fringe Benefits - $1,737

Employee benefits are estimates, using the composite rates agreed upon by the University of California. Graduate Student Researcher fringe benefit rates are estimated at 2.1%.

C. Travel - $9,000
Dr. Khodadadi's lab - $9,000. PI Dr. Khodadadi requests a travel budget to cover travel expenses for grower meetings, workshops, and field trials in Ventura. This will include car rental from Enterprise at $40 per day plus fuel, and overnight lodging and meals at per diem rates or actual expenses for survey location trips. Year 1: $4000; Year 2: $5000.

The travel destinations are tentative and are subject to change. Costs are based upon historical usage and include coach airfare on domestic U.S. flag carriers, ground transportation, lodging, registration fees, meals, and incidental expenses.

D. Other Direct Costs - $63,678
1. Materials & Supplies - $23,000
Dr. Khodadadi Lab - $23,000. Dr. Khodadadi is requesting $23,000 to support the following project needs: rental of greenhouse space in Riverside, purchase of necessary chemicals and slats, acquisition of supplies for in vitro fungicide and salt assays, and the purchase of avocado trees for use in greenhouse experiments. Year 1: $12,000; Year 2: $11,000

2. Tuition & Fees - $40,678
University policy requires inclusion of partial fees and tuition remission and Graduate Student Health Insurance (GSHIP) for GSRs employed during each academic year with an appointment of 25% effort or more. GSR Valentina Bernal will be employed at 50% FTE which will result in tuition and fees costs of $20,176 in Year 1 and $20,502 in Year 2 for a total of $40,678.

E. Total Direct Costs - $157,119

F. Indirect Costs - $0
No Indirect Costs are requested.

K. Total Cost - $157,119

Improve *Phytophthora cinnamomi* management by monitoring field populations for changes in fungicide sensitivity and conducting efficacy field trials

Project Lead: Dr. Patricia Manosalva, Microbiology and Plant Pathology Department, The Regents of The University of California, 245 University Office Building, Riverside, CA 92521, patricia.manosalva@ucr.edu, (951)827-3773.

Project Co-PI: Dr. James Adaskaveg, Microbiology and Plant Pathology Department, The Regents of The University of California, 245 University Office Building, Riverside, CA 92521, jim.adaskaveg@ucr.edu, (951)827-7577.

EXECUTIVE SUMMARY

Phytophthora root rot (PRR), caused by *Phytophthora cinnamomi (Pc)*, is one of the most devastating avocado diseases worldwide. PRR severity and incidence are exacerbated under flooding and hypoxic conditions caused by inappropriate irrigation practices and soil waterlogging conditions, which are common conditions in California (CA). This oomycete root pathogen causes trunk cankers, leaf chlorosis, leaf defoliation, and kills feeder roots reducing fruit yield. This invasive pathogen spreads rapidly and is prevalent in many agricultural systems, attributable to its adaptability to new environments, broad host range, saprophytic capabilities, host resistance, and production of resilient structures for survival and dispersal[1,2,3]. PRR control methods include cultural practices including the use of resistant rootstocks like 'Dusa' and fungicidal treatments such as potassium phosphite (PP), mefenoxam (Ridomil Gold), and oxathiapiprolin (Orondis). Orondis was recently registered to manage avocado PRR based on greenhouse and field efficacy trial results conducted by the Manosalva and Adaskaveg teams[2,4]. Growers have been relying on the combination of using 'Dusa' and field treatments of PP for managing PRR, however, *Pc* isolates, are overcoming these practices by becoming more virulent and developing PP resistance in CA[1-4].

Phytophthora cinnamomi populations in California exhibit large variability in fungicide sensitivity. Manosalva and Adaskaveg's teams have been reporting a shift towards PP insensitivity in *Pc* populations collected from CA avocado orchards. We reported that isolates obtained between 2004 and 2017 from Riverside and San Diego counties exhibiting EC_{50} values (the concentration to inhibit *Pc* mycelial growth by 50%) of as high as 382.5 µg/ml as compared to <25 µg/ml for sensitive isolates[1,2] **(Fig. 1)**. We also reported that the more PP insensitive *Pc* isolates (Riverside and San Diego counties) were also more virulent on avocado rootstocks. We have detected *Pc* isolates with high EC_{50} values for PP (up to 763 µg/ml) also in Santa Barbara and Ventura counties in 2020 and 2022 **(Fig. 1)**. This insensitivity likely reflects the continued overuse of PP applications in orchards and subsequent spread of PP insensitive isolates from southern CA areas to Ventura and Santa Barbara Co. Thus, it is critical that we continue surveying and monitoring the pathogen population to develop more effective protocols for disease chemical control based on fungicide rotations (i.e., PP + Ridomil Gold/ Ridomil Gold + Orondis/ PP + Orondis). Manosalva and Adaskaveg evaluated the *in vitro Pc* sensitivity to additional chemistries including ethaboxam (Elumin), fluopicolide (Presidio), mandipropamid (Revus), oxathiapiprolin (Orondis), and mefenoxam (Ridomil Gold) and found that all these Oomycota-targeting fungicides exhibited high *in vitro* toxicity with relatively low effective concentrations to inhibit *Pc* mycelial growth and found significant variability among isolates[1,2]. This range in sensitivities probably reflects natural variation within the pathogen populations since with the exception of oxathiapiprolin and mefenoxam, these fungicides have not been registered or approved for use on avocado but are registered on other crops. Our recent studies with isolates obtained from 2019 to 2022 also indicated that the sensitivities to these fungicides with the exception

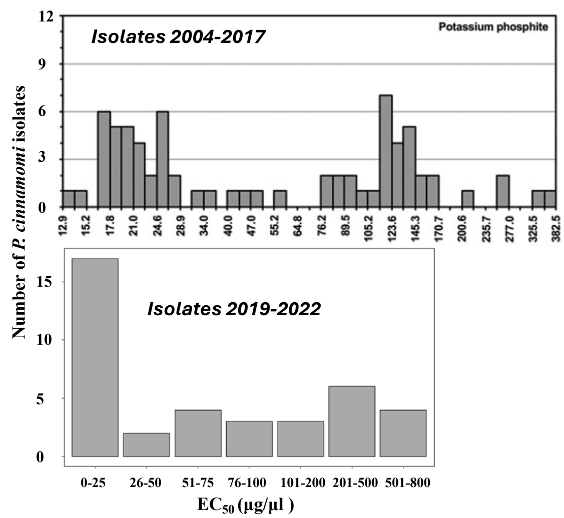

Figure 1. Frequency histograms of effective concentrations to inhibit *P. cinnamomi* mycelial growth by 50% (EC_{50}) for potassium phosphite. Bar height = number of isolates within each bin. Bin widths were calculated using Scott method.

on PP have not changed. Orondis was registered on avocado in 2022 and since then, more growers are applying Orondis to control PRR in their orchards. The majority of these Oomycota fungicides have a single target gene which increases the risk for resistance development. Moreover, resistance to these chemistries has been found in Oomycota pathogens including *Phytophthora* spp.[4-8]. Thus, it is critical to continue the survey of CA orchards and gather information regarding frequency of Orondis applications and if rotations were used of Orondis with PP/Ridomil Gold. More importantly, isolates from these orchards needs to be collected to determine their EC_{50} to Orondis and to the other chemistries to monitor for any shift in the current CA pathogen populations. *Note that these chemistries have been registered on other crops including citrus so there is still a risk for exposure in orchards applying these on citrus in the proximity of avocado orchards.*

A combination of fungicides and new Pc UCR resistant rootstocks results in a better PRR protection under greenhouse and field conditions.

The University of California Riverside (UCR) rootstock breeding program has developed and evaluated under greenhouse (GH) & field conditions, five UCR advanced *Pc* resistant rootstocks (PP40, PP35, PP42, PP45, and PP80) which also exhibit salinity tolerance (PP40, PP35, and PP80), another major production challenge. These UCR rootstocks grafted to 'Hass' in combination with these new fungicides were tested for their efficacy in controlling PRR under GH conditions. All fungicides reduced the PRR incidence caused by a mixture of the most virulent isolates when compared to untreated inoculated control plants. Oxathiapiprolin, mefenoxam, and fluopicolide outperformed ethaboxam, mandipropamid, and PP. Some fungicides paired with the most resistant rootstocks had a synergistic effect, enhancing PRR control **(Fig. 2)**. These new UCR rootstocks will be released in 2025-2027, and the new Oomycota fungicides described above will be registered by 2026. This integrated PRR management strategy holds promise for growers by adopting new resistant rootstocks in combination with appropriate fungicide treatments, however, the effectiveness and durability of these new control methods still deserves extensive evaluation due to the great genome plasticity and adaptative capacity of *Pc* populations[3]. The combination of resistant rootstocks and fungicide rotations or mixture rotations will be desirable to reduce the pathogen selection pressure for breaking the rootstock resistance and developing chemical insensitivity.

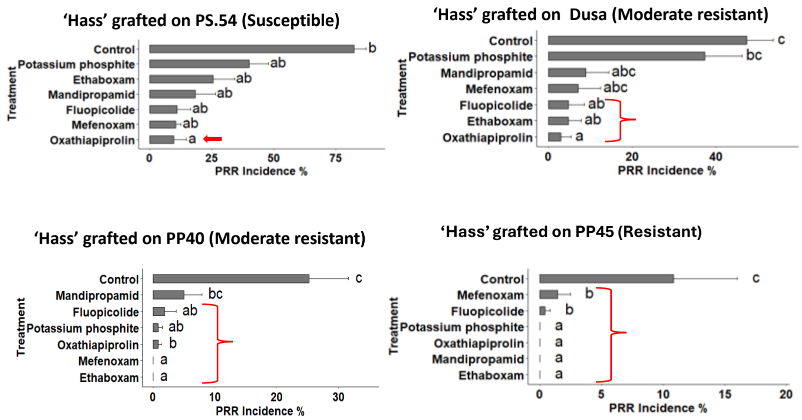

Figure 2. Efficacy of fungicide treatments to reduce avocado PRR incidence in susceptible (PS.54), moderate resistance (Dusa), and the UCR PRR resistant rootstocks (PP40 & PP45) grafted to 'Hass' under greenhouse conditions. Statistics were done using generalized linear mixed models (GLMMs) and LSMeans tests at P<0.05 using R. Different letters above the bars indicate significant differences

In 2018, Adaskaveg, established two fungicide field trials with Duke 7 and Dusa® rootstocks under heavy PRR disease pressure (natural infection). Soil applications of oxathiapiprolin, ethaboxam, fluopicolide, and mefenoxam alone and in combinations were compared to untreated controls and to tree injection with PP (standard grower treatment). Oxathiapiprolin and fluopicolide alone and in combinations with other fungicides were the best treatments for reducing PRR incidence[4] **(Fig. 3).** These studies are important to determine the best rotation protocols and the different combinations that growers can use for PRR control in their orchards and reduce the risk of *Pc* resistance to recently registered fungicides or in the pipeline for federal registration through IR-4.

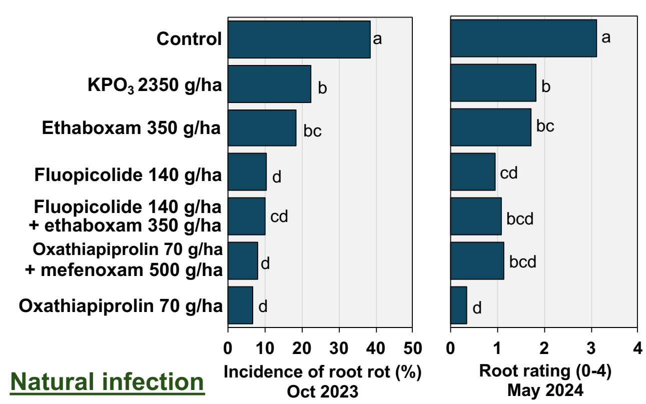

Figure 3. Efficacy of fungicides for managing avocado PRR of 'Hass' trees grafted on Dusa rootstocks in a commercial field trial in Riverside Co., CA established in 2022.

Our overall goal is to ensure the long-term sustainability and competitiveness of the CA avocado industry by reducing production inputs and yield losses due to avocado PRR and by decreasing the risk for the emergence of fungicide resistant pathogen populations threatening the durability and efficacy of current and future chemical PRR control. Thus, in this project, we will continue monitoring *Pc* populations in CA by conducting extensive surveys in orchards throughout CA especially where Orondis, Ridomil Gold, and PP are used to: i) determine their current fungicide sensitivity; ii) assess if the sensitivities to mefenoxam and oxathiapiprolin have been changing; and iii) determine if more isolates are acquiring PP insensitivity and if they continue to spread through CA growing regions. Resistance assessments for fungicides (except for PP) will be conducted alone and in mixtures to: i) determine the risk for shifting baseline sensitivities and acquiring resistance from over usage (i.e., multiple & sequential applications); ii) assess how fungicide mixtures will affect the risk for emergence of resistance; and iii) determine if the use of resistant rootstocks can further reduce the emergence of *Pc* fungicide resistance. Finally, we will continue collecting data including yield from our current fungicide efficacy field trial and will establish a replicated trial in Ventura. These efficacy trials will allow us to: i) test different timings of application to reduce the negative effects of PRR in tree health and productivity, ii) determine the anti-resistance rotation and mixture programs to set sustainable and durable protocols for PRR control in CA, and iii) compare results between two environmental distinct growing areas in terms of pathogen population, climate, irrigation water quality, and soil conditions.

PROJECT OBJECTIVES.

Objective 1. Survey *Pc* populations across major CA avocado growing regions and assess their *in vitro* sensitivities to registered and new Oomycota fungicides to compare those with established baseline sensitivities. Information regarding cultural practices and fungicide history applications at each orchard surveyed will be recorded. Resistance assessments of fungicides alone and in mixtures will be conducted using a genetically and phenotypically representative *Pc* populations under laboratory and greenhouse conditions.

Deliverables

- Collection of current *Pc* populations (2025-2028) for which their *in vitro* sensitivities for potassium phosphite (PP), oxathiapiprolin (Orondis), mefenoxam (Ridomil Gold), ethaboxam (Elumin), fluopicolide (Presidio), and mandipropamid (Revus) will be determined.
- Information regarding the continue increase of *Pc* EC_{50} values for PP (> 763 µg/ml) in the same orchards surveyed before or new orchards. We will continue getting insights for emergence of PP insensitive isolates by gathering information regarding PP application rates and frequency, rootstocks, raining events, production data, etc. We will provide recommendations to reduce the emergence and spread of this PP insensitivity *Pc* populations.
- Ridomil Gold and Orondis baseline sensitivities for the current *Pc* populations especially for isolates collected from orchards where these products have been used. The presence/risk of isolates exhibiting a shift towards fungicide insensitivity will be determined and correlated with cultural practices. Thus, we can provide recommendations on how to delay/avoid the emergence of Orondis and Ridomil Gold resistant isolates early in the process.
- Expanded baseline sensitivities for ethaboxam, fluopicolide, and mandipropamid that are currently not registered on avocado to confirm the previously published baselines.
- Fungicide resistance assessment experiments will provide critical information to assess: i) how many single applications of fungicides will be required to gain insensitivity/resistance, ii) how to best rotate registered products to avoid/delay the emergence of fungicide resistance, and iii) provide an integrated management for PRR control and *Pc* fungicide resistance management by combining the more effective fungicide rotation protocols with host resistance to increase the durability of current controls methods.

Objective 2. Conduct fungicide efficacy trials under commercial conditions to determine the best protocol to maximize chemical protection and reduce the emergence of *Pc* resistant isolates. We will continue the evaluation of several fungicides alone (potassium phosphite, oxathiapiprolin, mefenoxam, ethaboxam, and fluopicolide), in combination, and in mixture rotations of different modes of action (e.g., FC49+FC4, i.e., Orondis Gold sold by Syngenta Crop Protection, rotated with FC22+FC43 [both sold by Valent USA]). In the absence of PP resistance, PP can be mixed with any of the other modes of action to reduce PRR incidence and damage in plant health and productivity in our current trial of 'Hass' trees grafted to Dusa rootstocks in Riverside Co. We will also establish a similar fungicide efficacy trial in a commercial orchard in Ventura Co.

Deliverables

- Provide different alternatives of effective fungicide mixtures and rotation protocols that growers can use in their orchards to manage PRR and reduce the risk of emergence of fungicide resistant isolates.
- Share the data and results with extension agents and farm advisors so these protocols and recommendations can be disseminated to all CA growers.

WORK PLAN AND METHODS

Objective 1. To accomplish this, we have divided this Obj. 1 in several activities:

1.1. Survey avocado orchards and isolate Pc (April-May 2026, 2027, and 2028). We will select avocado orchards to survey and visit them to collect samples by several approaches. We will visit orchards based on previous collections conducted by the Manosalva and Adaskaveg labs and through advertisements of the objectives of this project requesting information and participation of avocado stakeholders willing to have their orchards surveyed and tested. Surveys will also be conducted in collaboration with farm advisors, the California Avocado Society (CAS), California Avocado Commission (CAS), and Avocado Growers of California (AGC) members which always support the UCR avocado rootstock breeding program and the Manosalva Lab research activities. At each visit we will gather as much information from the growers regarding their grove establishment (i.e., year, rootstocks and scions, size of grove, etc.), and management practices (i.e., fertilization, chemical applications, etc.). Root & soil plating and baiting will be performed as described previously[1,2]. Suspected colonies matching the *Pc* morphological characteristics will be subjected to molecular identification using Internal Transcribed Spacer Region (ITS) sequence analyses and using a TaqMan qPCR assay *Pc*-specific test[1,2]. Single zoospore cultures will be obtained for each confirmed isolate and used in fungicide sensitivity assays.

1.2. Fungicide in vitro sensitivity (June-July 2026, 2027, and 2028). The *in vitro* toxicities of oxathiapiprolin (Syngenta Crop Protection), mefenoxam (Syngenta Crop Protection), mandipropamid (Syngenta Crop Protection), ethaboxam (Valent USA), and fluopicolide (Valent USA) to *Pc* mycelial growth will be determined using the spiral gradient dilution method as described in Förster *et al*. (2004)[9]. For PP sensitivity assays, we will use the traditional agar dilution method[1,2]. Pathogen reference isolates with known EC_{50} values will be used as controls in every experiment conducted. Each isolate will be assayed in duplicate, and the experiment will be conducted twice for publication purposes. Data analyses will be conducted as described in Belisle *et al*. (2019b)[2].

1.3. Assessment of the resistance potential of Pc to fungicides under laboratory and greenhouse conditions (Dec 2026 – Aug 2028). To estimate the *in vitro* potential of resistance development of *Pc* populations to oxathiapiprolin, fluocopilide, ethaboxam, mandipropamid, and mefenoxam, we will select 20 *Pc* isolates that are genetically and phenotypically diverse and represent the current CA pathogen population[1-4]. We will select isolates based on geographical location, population structure, sensitivity to PP fungicide (low, mid, and highly resistant), sensitivity based on EC_{50} for all other fungicides, virulence phenotypes, etc. We will conduct this experiment as described in Chen *et al*. (2021)[10]. Briefly, we will calculate the EC_{95} (effective concentration to inhibit mycelial growth by 95%) for each selected isolate and use this value in spiral gradient dilution assays where the EC_{95} concentrations will be positioned 20 mm from the edge of the Petri dish with exponential dilutions of the fungicides towards the center of the plate **(Fig. 4)**. A zoospore suspension with equal parts of the 20 selected isolates described above will be prepared and applied uniformly to each of 10 spiral plates and will be incubated at 25°C in the dark for 3-4 days. Plates will be evaluated for the presence of colonies growing at concentrations above EC_{95} values **(Fig. 4)**. Data analyses and resistance frequency will be calculated as described in Chen *et al.* (2021)[10]. This experiment will be conducted with batches of isolates depending on our results and will be repeated twice. If resistant colonies develop for these fungicides, we will recover them and determine their corresponding EC_{50} values. We will conduct similar experiments with the original parental sensitive populations used above and

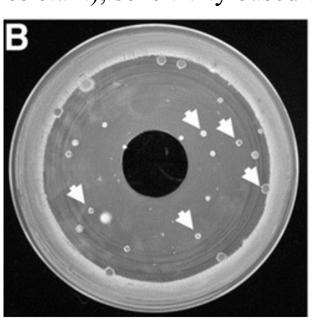

Figure 4. Spiral gradient dilution plates with exponential concentration gradients of fludioxonil (EC_{95} concentrations were positioned at the edge of the plate). Several putative fludioxonil-resistant colonies (arrows) of *P. digitatum* are found in the clear area of the agar plate treated with fludioxonil.

repeat the experiment but using another fungicide. For example, if we detected resistant colonies to oxathiapiprolin in one batch of 20 parental sensitive isolates, then we will repeat the experiment with oxathiapiprolin and in combination with another fungicide like mefenoxam/PP to determine if the mixture avoids the risk for resistance development.

To estimate the *in vivo* potential for fungicide resistance, we will replicate results from the laboratory assays described above for those fungicides and parental *Pc* populations where resistant populations were obtained. We will inoculate avocado seedlings of the susceptible rootstock Zutano and the soon to be released moderate (PP40), and highly resistant (PP45) UCR advanced rootstocks with the parental sensitive populations and expose the inoculated seedlings to repeated applications with increasing concentrations of the fungicides alone and in mixtures. Fungicide applications and recovery of isolates after each application will be conducted as described in Belisle *et al.* (2019a)[1,2]. We will re-isolate and re-assess the *in vitro* sensitivity of the pathogen populations each cycle of fungicide exposure to detect changes in EC_{50} as described above by comparing them with the EC_{50} baseline values of the parental sensitive populations. In addition, the emergence of resistant populations will be detected based on the evaluation of virulence that will be calculated as PRR incidence, pathogen propagules per gram of soil (ppg), and root health scorings and comparing them with the untreated inoculated controls and one-time single application treatments.

Caveats and pitfalls. We do not foresee major difficulties in the methods and approaches described in Obj.1, 2, & 3 since all protocols described and similar experiments have been successfully conducted at Manosalva and Adaskaveg laboratories. There is a possibility that our *in vitro* or *in vivo* resistance assessment assays do not generate *Pc* resistant populations which might indicated either that methods need to be adjusted or the low risk of *Pc* to acquire resistance to these chemistries. In this case, we will test new methods to conduct the resistance assessment only for one of the fungicides (e.g., fluopicolide or oxathiapiprolin). For *in vitro*, we will subculture the isolates and exposing sensitive isolates for several generations to one of these fungicides until resistance arises as described by Miao *et al.* (2016)[8] and Childers *et al.* (2015)[11] **(Fig. 5).** For *in vivo,* we will use a detached leaf inoculated assay developed by the Manosalva lab to expose and test the parental sensitive population used in the *in vitro* and conduct resistance assessments as described by Massi *et al.* (2021)[12] **(Fig. 6)**. Based on the combined resistance risk assessment published by FRAC[13], soil-borne pathogens have a low-risk potential, the risk of FC 49 is low to medium & the agronomic risk is also low with less susceptible rootstocks resulting in a maximum combined risk of 4 to 6 of a possible total of 18. In contrast, a foliar Oomycota disease like grape downy mildew has a combined risk of 12-18 for a FRAC 49 fungicide.

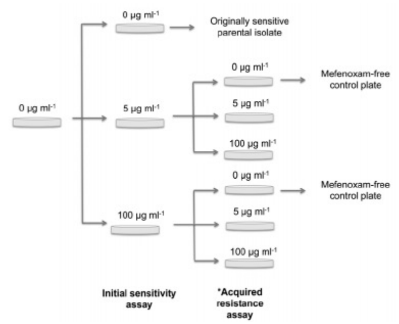

Figure 5. Fungicide exposure method to determine the resistant potential of *P. infestans* isolates to Mefenoxam described in Childers *et al*., (2015) using mycelial plugs plating method of increasing fungicide concentrations.

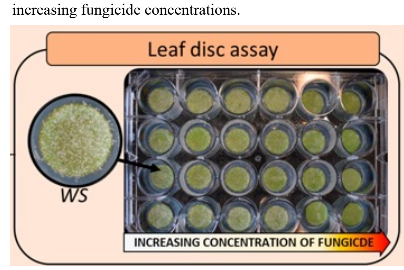

Figure 6. Leaf disc assay developed to determine the resistant potential of the oomycete *Plasmopara viticola* to fungicides described in Massi *et al*., (2021).

Objective 2. Fungicide efficacy field trials (Nov 2025- Sept 2028). For the continued evaluation of new Oomycota fungicides against avocado PRR, a 50-tree orchard of ‘Hass’ trees grafted on ‘Dusa’ located in the Temecula area of Riverside Co. will be used for treatment applications and data collections. PRR incidence and fungicide sensitivity for isolates before and after treatments have been monitored since 2022 and will be continued in this project after each treatment. Seven treatments will be applied twice/year (May & Sept): control (untreated), Orondis 4.8 fl oz/A, Presidio 4 fl oz/A, Elumin 10 fl oz/A, Presidio 4 fl oz/A + Elumin 10 fl oz/A, Orondis 4.8 fl oz/A + Ridomil Gold 14.4 fl oz/A, and Prophyt 64 fl oz/A using 7 trees per treatment in a complete randomized design. Fungicides will be applied to the soil dripline around each tree at the concentration recommended by the chemical companies. The grower will treat trees with PP as a control treatment, and several trees will remain untreated. We will make sure that each treatment contains trees with low-, medium-, and high populations of the pathogen. A second similar fungicide trial will be established in Ventura Co. by adding Orondis + ProPhyt combinations. Before establishing the trial, *Pc* soil populations will be determined. We will locate putative grower collaborators by communication with growers associated or surveyed before by the UCR rootstock breeding program and through advertisements that will be done with the assistance of farm advisors, CAS, and CAC. We will apply fungicides as described above. At two field sites with a very high incidence and level of PP resistance, we will evaluate the persistence of PP resistance. For this, we will apply rotations of non-PP fungicides for each of the three years of the project and determine if PP resistance levels are stable in the pathogen population or decline over time. We will calculate the efficacy of each treatment 6 months after each application as the reduction of PRR incidence, soil populations, tree health, and production data. Root health will be evaluated visually using a 0 to 4 rating scale with 0 = healthy and 1-4 increasing levels of discolored roots. Data analyses will be done by ANOVA followed by Tukey-Kramer HSD.

Caveats and pitfalls. We do not foresee major difficulties in the methods and approaches described in this objective since Dr. Adaskaveg has extensive experience, is an expert on these experiments, and he is already obtained important data at this trial site in Temecula **(Fig. 3).**

PROJECT OUTREACH. We will ensure that our project results, outcomes, and recommendations are delivered and translated into actionable recommendations for growers and other stakeholders with a robust and multi-faceted outreach plan. Manosalva and Adaskaveg research teams are in constant communication with avocado stakeholders including growers, nursery men, industry representatives including chemical companies, and IR-4 staff which will ensure the dissemination of our outcomes and recommendations. By being active collaborators, growers will test and will be direct observants of the results of the projects regarding the best chemical, mixture, and rotation protocols to better control PRR in their orchards decreasing the risk for emergence of fungicide resistance. Outcomes will be also outreached to stakeholders through presentations at CAC, CAS, Avocado Growers of CA (AGC), and UCANR- meetings, workshops. Stakeholders from these groups include conventional and organic growers. Our team will also participate in Avocado Café. We report our progress and outcomes in grower journals, newsletters, and social media.

MILESTONE TABLE

Obj.		Objective/Sub-task Description	Year 1 (Nov 25 - Oct 26)	Year 2 (Nov 26 - Oct 27)	Year 3 (Nov 27 - Oct 28)
1		**Survey orchards and determine current fungicide *in vitro* sensitivities**			
	1.1	Project advertisement and gather orchard & grower information			
	1.2	Visit orchards in CA and collect samples & information on cultural practices			
	1.3	Pathogen isolation, identification, and storage			
	1.4	Conduct *in vitro f*ungicide sensitivity assays			
	1.5	Assessment of resistant *P. cinnamomi* potential *In vitro* (laboratory)			
	1.6	Seed collection (Zutano, PP40, and PP45) for *in vivo* greenhouse studies			
	1.7	Assessment of resistant *P. cinnamomi* potential *In vivo* (*in planta*, GH)			
	1.8	Data analyses and Integration			
	1.9	Outreach and publications			
		ESTIMATE BUDGET FOR THIS MILESTONES ACTIVITIES	**$47,843.00**	**$48,942.00**	**59,724.00**
2		**Fungicide efficacy field trials**			
	2.1	Continue fungicide treatments alone and mixtures in Temecula trial			
	2.2	Continue data collection (Temecula):PRR incidence & tree health			
	2.3	Production data collection (Temecula). Depending on 'Hass' price market			
	2.4	Identify growers cooperators in Ventura and survey orchards			
	2.5	Design trial and conduct initial PRR assessments at the orchard (Ventura)			
	2.6	Start treatments (fungicide alone and mixtures)			
	2.7	Data collection (Ventura): PRR incidence & tree health			
	2.8	Production data collection (Ventura). Depending on 'Hass' price market			
	2.9	Data analyses and Integration			
	2.1	Outreach and publications			
		ESTIMATE BUDGET FOR THIS MILESTONES ACTIVITIES	**$53,423.00**	**$56,754.00**	**58,215.00**

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[13]https://www.frac.info/docs/default-source/publications/pathogen-risk/frac-pathogen-list-2019.pdf

PROJECT BUDGET

Table 1. Manosalva & Adaskaveg budget description	11/01/2025-10/31/2026	11/01/2026- 10/31/2027	11/01/2027- 10/31/2028
Personnel Salary			
Ph. D Graduate Student Researcher (GSR), Two academic quarters/year & Summer Quarter in Y3	17,801	18,335	28,327
Postdoc level I (Jim Adaskaveg)	37,141	39,864	41,059
Personnel Benefits			
Ph. D Graduate Student Researcher (GSR), Two academic quarters/year & Summer Quarter in Y3	374	385	595
Postdoc level I (Jim Adaskaveg)	8,282	8,890	9,156
Tuition & Fees			
Ph. D Graduate Student Researcher (GSR), Two academic quarters/year & Summer Quarter in Y3	13,668	14,222	14,802
Obj. 1 *Phytophthora cinnamomi survey, fungicide sensitivities, and resistance assessments*			
Rental Car to travel to Aprox. 10 orchards in Riverside & San Diego areas & 10 in Ventura & Santa Barbara areas			
UCR fleet Rental: Sedan car/Cargo Van@ 55.21/day and long rental 552.1/month.			
Field Pc isolate collection 2x/year			
5 days to collect data @ Southern CA			
7 days to collect data @ more Northern CA areas			
Total 12 days/year (2x)	$1,104	$1,104	$1,104
Hotel for field data collection/ 2 people/2x per year (@180/night/person)			
7 days to collect data @ Northern Trials	$4,320	$4,320	$4,320
Meals for field data collection/ 2 people/2x per year (@79/day/person)			
7 days to collect data @ Northern Trials	$2,212	$2,212	$2,212
Gas/mileage and incidentals	$364	$364	$364
UC Mix soil	1000	1000	1000
Germination pots	300	300	300
Lab general supplies, chemical, and consumables for pathogen isolation, identification, and fungicide in vito sensitivity	4500	4500	4500
Rent of 2 benches at GH11C at 130Sq/ft per bench at $100/month	1200	1200	1200
Sanger Sequencing service at UCR core for ITS sequencing @$10/sample	1000	1000	1000
Obj. 2 Fungicide field testing in Riverside and Ventura (Jim Adaskaveg)			
Hotel for field data collection/ 2 people/2x per year (@180/night/person)			
2 days to collect data @ Northern Trials	$2,836	$2,836	$2,836
Meals for field data collection/ 2 people/2x per year (@79/day/person)			
7 days to collect data @ Northern Trials	$800	$800	$800
Gas/mileage and incidentals	$364	$364	$364
Lab general supplies, chemical, and consumables for pathogen isolation, identification, and fungicide in vito sensitivity	4000	4000	4000
SUBTOTAL	101,266	105,696	117,939
		TOTAL	324,901

BUDGET JUSTIFICATION
Total UCR budget requesting for three years: $324,901

Personnel Salary ($182,527).
Funds are requested to cover the salary for: i) one Graduate Student Researcher (GSR) for two academic quarters each year of the project and one summer quarter in year 3 and ii) one Postdoctoral Researcher Level I at 50% EFT for every year of the project. The GSR will be working under the supervision of Manosalva and will be responsible to conduct all the field, greenhouse, and laboratory research activities described under Obj. 1. In addition, the GSR will be assisting Dr. Manosalva in all the grant reporting activities as well outreaching events to disseminate the results including the writing of publications describing our findings. Pathogen field surveys and collection at all fields will be conducted with the assistance of Manosalva. The GSR I will be working with the Postdoctoral Researcher I in the activities for Obj. 1.3 regarding the resistance assessments of registered products alone and in mixtures under laboratory and greenhouse conditions to estimate the risk of resistance/the potential of resistance and the development of fungicide rotation schemes to prevent emergence of resistant *Pc* populations and optimize efficacy in disease management protocols. The postdoctoral Research I will be working under the supervision of Co-PI Adaskaveg and will conduct the research activities described in Obj. 1.3 and 2. The postdoc will lead & conduct field trials in two locations (Temecula and Ventura Co.) and will be assisting Dr. Adaskaveg in grant reporting activities, outreach events, and writing of publications describing our findings.

Fringe Benefits ($27,682). Employee benefits are estimates, using the composite benefit rates agreed upon by the University of California. The composite benefit rate for the GSR I is 2.1% and for the Postdoc Level I is 22.2%. Subsequent years include increases based on recommendations by our campus administrative office.

Tuition Fees ($42,692). In addition to fringe benefits for the GSR, university policy requires inclusion of partial fees and tuition remission and Graduate Student Health Insurance (GSHIP) for GSR employed during each academic year with an appointment of 25% time or more.

Domestic travel ($36,000). Funds are requested to cover travel of the GSR and postdoc to cover all field activities for the project to conduct pathogen & sample collections, field treatments, and field data collection. **For Manosalva,** travel cost is estimated based on historical data of surveying and collecting samples for *Pc* isolations. We will survey orchards in major avocado growing regions including Riverside, San Diego, Ventura, and Santa Barbara Co. We will also obtain samples from central California areas such as Fresno and Visalia in the Central Valley with the assistance of rootstock breeding program collaborators (samples will be mailed to the Manosalva lab). Funds requested include the cost of a cargo van rental from UCR fleet services at a monthly rate of $552.10. *It is cheaper to rent by month than by day ($55.21/day) if we need to do more than 10 trips*. For Ventura and more northern orchards, travel cost includes lodging with an average rate of $180/night and meals at a per diem rate of $79/day. In addition, we have budgeted money to cover fuel that will be used to travel to collect samples @ $4.50/gallon and 20 miles/gallon. For Adaskaveg, travel costs will be based on traveling four times a year to two locations, one in Temecula and one in Ventura Co., for a total of 8 trips per year. Trips to Temecula will be day trips while trips to Ventura will be overnight using the hotel, meals, and fuel estimations as indicated above.

Supplies ($29,400). Funds are requested to cover greenhouse and laboratory supplies and consumables including UC Mix soil, pots, plant labels, chemicals to prepare solutions for fungicide treatments, fertilizers, tree sticks, ziploc bags for sample collection, media to prepare pathogen inoculum and for pathogen isolation, pipette tips, tubes, petri dishes, gloves, and PPE. In addition, we are budgeting money to cover molecular supplies and consumables to conduct *Pc* identification using ITS region Sanger Sequencing and *Pc*-Specific TaqMan qPCR assays. These supplies were estimated based on historical amounts and cost of similar research projects and activities in the Manosalva and Adaskaveg laboratories.

Services and others ($6,600). Funds are also requested to cover UCR greenhouse fees at a rate of $100 month for two benches each year of the project. This space will be used to conduct the greenhouse activities described in Obj. 1. We are budgeting funds to conduct Sanger Sequencing at the UCR sequencing core for pathogen identification in samples collected at different orchards in CA at a rate of $10/sample. Diversity of pathogen isolates will be critical for assessment of resistance potential studies and will be shared between the two labs in addition to sourcing isolates from the *Phytophthora* collection at UCR.

Project title: Creating a Weather Station Network to Guide Irrigation Decision of Avocados

Project leads: Andre Biscaro, Ben Faber
UC Cooperative Extension, Ventura County
asbiscaro@ucanr.edu; bafaber@ucanr.edu

Executive summary:

The two most important decisions for improving irrigation efficiency and its effect on yield and plant health are when to start the irrigation, and how long to irrigate. While soil moisture sensors are effective at telling when to irrigate, evapotranspiration (ET)-based scheduling is our best tool to determine how long (or how much) to irrigate. With many irrigations in a crop cycle, ranch managers and irrigators decisions of how long to irrigate are rarely data driven and are most commonly done on a calendar-basis.

While weather station data can provide fairly accurate information to guide irrigation decisions, it is essential that its data are representative of the area of interest. With several different microclimates and complex aspect situations based on landscape position in Ventura County and throughout California, increased numbers of stations are essential to ensure accuracy. This project proposal addresses two topics in irrigation management: the introduction of a network of weather stations managed and maintained by UC ANR, and to improve the accuracy of water and nutrient applications with the use of the Irrigation Calculator for example, which is currently funded by the Avocado Commission. Once the concept is implemented and tested in Ventura County, its expansion to other counties will be streamlined. This project proposal will also investigate how the accuracy of reference ET (ETo) data is compromised with decreased size of the grass area around the station. While the Department of Water Resources currently requires 8 acres of well-watered grass to site a CIMIS station, no information has been provided or is currently available to address the gains in accuracy with the increased size of the grass area. Most, if not all of the Department of Water Resource's CIMIS sites have considerably less grass footprint than 8 acres.

Therefore, the overall goal of this project proposal is to assess the viability of using a reduced size of grass for ETo weather stations, and to establish a network of weather stations that can improve the adoption of data-driven decisions to optimize irrigation water and maximize yield and plant health.

List of specific project objectives:

Identify three cooperating growers who, paid a fee, can establish and maintain a well-watered grass area of 100x100ft to host a weather station.

Purchase and install the stations.

Make sure the station's data is available online, free of charge.

Connect the stations to the irrigation calculator.

Identify one cooperating grower who, paid a fee, can establish and maintain a well-watered grass area of 4 acres to host a weather station with mobile sensors used to assess the difference in accuracy between ETo data collected from the center of the 4 acres vs different distances from the edge of the grass.

Analyze data from the grass area size comparison.

Extend the information and access to weather stations to growers.

List of project deliverables:

Free access to four weather stations' data.

Improved irrigation recommendations of the irrigation app addressing weather conditions in different micro-climates. That will most likely lead to increased adoption of the irrigation app among avocado growers.

Improved understanding of how different grass area sizes affect the accuracy of reference evapotranspiration (ETo) data, and therefore its impact on irrigation recommendations. This factor has a direct impact on the possibility of expanding ETo weather stations with grass area sizes that can be more easily accommodated by several growers (e.g.: 100x100ft, or even 50x50ft).

The deliverables described above are contingent on securing cooperating growers willing to host these stations (plant and maintain the grass areas).

Work Plan and Methods:

The locations for the three stations installed in 100x100ft (0.2 acre) grass area will be identified based on differences of microclimate where avocado is commonly grown, in addition to land availability and suitability. The location for the station with 4-acre grass area will be identified based on land availability and suitability, also in an area where avocado is commonly grown.

Hourly and daily ETo data will be compared between the station installed in the center of the 4-acre grass field (base station) and another mobile station placed at the following distances from the edge of the field, in the prevailing wind side: 50, 150 and 250ft. While the base station will be at the center of the field for the entire year, the mobile station will be moved among the three sites (50, 150 and 250ft) every 30 days, totaling 120 days at each of the three sites. Moving the mobile station monthly will allow the comparisons to include at least one month within all sites (3) and seasons (4). The accuracy assessment will be estimated with both hourly and daily ETo change from the base station's value. Irrigation recommendations will be created with data from both stations and compared to assess if the ETo differences are meaningful to growers in terms of total water recommendations.

The limitation of this method is that the wind will not always come from the prevailing direction (most mornings and during specific Santa Ana winds), and therefore the air flowing towards the sensors would have passed through different lengths of grass than expected for each site. This can be addressed by removing data for periods when the wind is not from the prevailing direction.

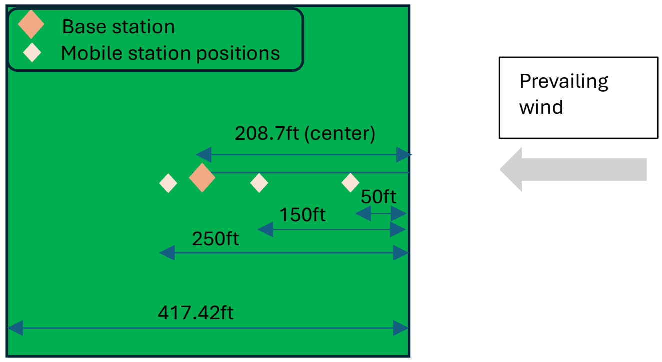

Figure 1. Illustration of how the base and mobile stations would be placed in the 4-acre grass field for the grass size assessment.

In addition to the method described above, ideally, one of the stations with the 0.2-acre grass will be sited very close to the station with the 4-acre grass, allowing for another type of comparison: 4.0 vs 0.2 acre grass areas, where both stations will be at the center of their respective grass areas for the entire year.

The main challenge of this study is to find suitable sites and willing cooperators to host each station. The sites must be within certain proximity of avocado grown areas, without buildings and/or trees blocking the wind, and with a grower (or a landowner) willing to plant and maintain (irrigate, fertilize, mow etc) the grass field.

Answer to the reviewers' comments on the concept proposal: while we would want to capitalize on existing weather stations from growers, there are significant limitations on how the data can be used in terms of accuracy, considering none of these stations are surrounded by well-watered grass. However, we will assess if solar radiation from some of these stations can be used to estimate ETo using the remaining data from the stations from this project.

Project outreach:

The results of this project will be shared through grower meetings, field days hosted at one or all of the weather stations sites, an article in the California Avocado Commission magazine From the Grove, and a newsletter article.

Milestone Table:

Milestone	**Activities**	**Scheduled Completion**	**Budget**
1	• Meet with potential collaborators and industry stakeholders to identify four sites	February 2026	$88,375

	where the stations can be installed. • Purchase and install the stations		
2	• Data collection, establish a maintenance routine for the stations, move the mobile station monthly, data analysis	June 2027	$4,368
		Total Project Budget:	**$92,746**

<u>Budget:</u>

Estimated total project cost:

$	Description
32,052	3 x $10,684 Campbell Scientific ETo stations
17,870	1 Campbell Scientific ETo station with mobile sensors
5,824	SRA time: 128h @ $26.86/h salary with 69.4% benefits; 32h for installation, and 8h per month to inspect and maintain/troubleshoot sensors x 12 months
2,000	Travel expenses
20,000	Grower incentive for planting and maintaining 4 acres of grass (lease, water, labor, 1 year)
15,000	Grower Incentive for planting and maintaining 0.2 acre of grass ($5,000 x 3 sites x 1 year)
92,746	Total Requested Funds

Budget Narrative:

Fiscal year 2025-26

$32,052: 3 x $10,684 Campbell Scientific ETo stations from the Western Weather Group. These stations will be installed at the 0.2 acre grass sites.

$17,870: 1 x Campbell Scientific ETo station with mobile sensors from the Western Weather Group. The base and mobile station will be installed at the 4-acre grass site to assess the grass area requirements.

$1,456: Staff Research Associate time to support the installation of the stations: 32h @ $26.86/h salary with 69.4% benefits.

$20,000: Grower incentive for planting and maintaining 4 acres of grass (lease, water, labor, 1 year). It is possible that a grower will charge less for this, but we want to make sure the amount offered is attractive.

$15,000: Grower incentive for planting and maintaining 0.2 acre of grass ($5,000 x 3 sites x 1 year). Yearly cost will be renegotiated with cooperator and additional funds will be requested after the first year in case promising results are obtained in the first year.

Fiscal year 2026-27

$2,000: Travel expenses. Funds will support travel expenses of UC Davis Biometeorologist Rick Snyder to assess project details after the installation of the stations and data analysis.

$4,368: Staff Research Associate time to support monthly inspection, maintenance and troubleshooting of the stations: 96h @ $26.86/h salary with 69.4% benefits.

Addressing the relationship between soil characteristics and soil salinity in California avocado orchards

Project lead: Jesse Landesman, UC Santa Barbara, (626) 240-9169
Project Cooperators:

- Jennifer King, UC Santa Barbara
- Maureen Cottingham, CamLam Farms
- Iris Holzer, UC Santa Barbara
- Anna Trugman, UC Santa Barbara
- Rick Shade, Shade Management

Executive Summary:

With increasing climate variability, soil salinization has significantly contributed to land degradation over the last century[1]. By 2050, it is predicted that 50% of arable land will be salinized because of decreasing precipitation, increasing surface evaporation, increasing weathering, and irrigation with poor quality water[2]. Since irrigation plays an important role in the salinization of soils, soil salinity is an especially pertinent problem in agriculture. Salinity is a major issue specifically for the avocado industry, a crop highly sensitive to increases in salinity. California produces 95% of domestically grown avocados, and salinity is an increasing issue due to the geographic distribution of avocado orchards along the California coast as well as increased pressure for farmers to irrigate with reclaimed water. Specifically, chloride ions cause the greatest harm in avocado trees[3]. While past research has documented the effects of salinity on avocado productivity, little is known about the mechanisms by which variation in soil properties affects accumulation of soil salinity and accompanying changes in soil health. Therefore investigating the effects of soil physical and chemical properties on soil salinity in avocado orchards is critical to the future of avocados. This research project is separated into three separate components. The first component is to highlight and understand the scope of the problem of soil salinization in California avocado orchards. The second component is to identify what soil physical and chemical properties are most correlated with soil salinity across hillslopes in contrasting parent materials. The third component is to understand how differing irrigation water chemistries interact with different soil types to retain and accumulate salts.

Research question 1: What California avocado-producing areas are most at risk of soil salinization?

Hypothesis: Areas with poorer quality irrigation water and more severe drought and unpredictable rainfall events will experience the greatest risk of soil salinization.

Objectives:

- Modify and run the HYDRUS (2D/3D) model to incorporate all necessary forcings for soil salinization risk mapping, including historical water quality data and climate change predictions
- Incorporate grower input in the form of a survey sent out via the GreenSheet to collect current and historical irrigation water data and assess growers' understanding of the chemistry and quality of their irrigation water

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[1] Shrivastava, Pooja, and Rajesh Kumar. "Soil Salinity: A Serious Environmental Issue and Plant Growth Promoting Bacteria as One of the Tools for Its Alleviation." *Saudi J Biol Sci.*, vol. 22, no. 2, Mar. 2015, pp. 123–31, https://doi.org/10.1016/j.sjbs.2014.12.001.

[2] Jamil, A., Riaz, S., Ashraf, M., & Foolad, M. R. (2011). Gene Expression Profiling of Plants under Salt Stress. *Critical Reviews in Plant Sciences*, *30*(5), 435–458. https://doi.org/10.1080/07352689.2011.605739.

[3] Acosta-Rangel, A. M., Li, R., Celis, N., Suarez, D. L., Santiago, L. S., Arpaia, M. L., & Mauk, P. A. (2019). The physiological response of 'Hass' avocado to salinity as influenced by rootstock. *Scientia Horticulturae*, *256*, 108629. https://doi.org/10.1016/j.scienta.2019.108629

Deliverables:

- A map of three categories of soil salinization risks (Table 1) across the areas where avocados are grown in the state of California
- A presentation at a CAC board meeting on secondary soil salinization risks across California avocados

Methods:

1. Create a biogeochemical model of secondary soil salinization to understand the most important forcings of salt accumulation in avocado soils.
2. Compile necessary data for model, including location of California avocado orchards, temperature and precipitation data, soil characteristics, irrigation water quality, and historical water quality data.
3. Send out a survey in CAC's Greensheet. Here are example survey questions:
    - What form of irrigation do you use (i.e. drip or microsprinkler)?
    - What are the sources of water to your orchard?
    - Do you know the chemistry/quality of your irrigation water? If not, would it be useful to have your irrigation water analyzed?
    - Does your irrigation water quality change seasonally?
    - Would you be willing to share your irrigation water quality data and/or any historical data you have on irrigation water quality?
4. Run the HYDRUS (2D/3D) model with collected survey data and compiled climatic and soil data to create soil salinization risk assessment map.
5. Randomly select 8 sites on the map to visit and collect ground-truth data to test the accuracy of the model in its current form, without the climate change projections.
6. Present results of the model to the CAC board and to the greater scientific community.

Work plan timeline:

- May 2025: read literature on modeling soil salinization and compile data (steps 1 and 2)
- July 2025: send out grower survey in CAC GreenSheet (step 3)
- August 2025: run model and create risk assessment map (step 4)
- October 2025: visit field sites to collect samples to validate the model (step 5)
- November 2025: present model results at Soil Science Society of America meeting and to CAC board of directors (step 6)

Table 1: Three levels of soil salinization risk that would be used in the risk assessment map

Color	Soil electrical conductivity	Avocado yield reduction
	0 - 0.8 dS/m	None
	0.9-1.19 dS/m	10%
	1.2 and higher dS/m	25%

(ANR Publication 8562, 2016)

Research question 2: What soil physical or chemical properties are most correlated with soil salinity across hillslopes in contrasting parent materials? How do differences in salinity affect tree health and soil health, measured by tree thermal stress and soil microbial respiration?

Hypothesis: Soil salinity will be higher at the bottom of the slope (toeslope) than in the backslope and summit. Soil salinity will be higher in soils with marine sedimentary alluvium parent material. Trees at the top of a slope will be more water stressed, with a higher tree water deficit (TWD) and microbial activity will be limited.

Objectives:

- Identify how soil physical and chemical properties and soil salinity changes along a hillslope gradient across different parent materials in Hass avocados on Toro Canyon rootstock
- Identify how avocado tree thermal stress changes along a hillslope gradient and across two different soil parent materials, using thermal infrared (TIR) imaging from drone flights
- Quantify how soil microbial respiration and community composition changes across hillslopes in contrasting parent materials

Deliverables:

- A map of tree water deficit for CamLam farms using drone imagery
- Principal component analysis (PCA) figures of various physical and chemical soil properties colored by hillslope location and soil parent material
- Figures showing continuously collected data over a two year time period of soil moisture and soil electrical conductivity (EC) across hillslopes in contrasting parent materials

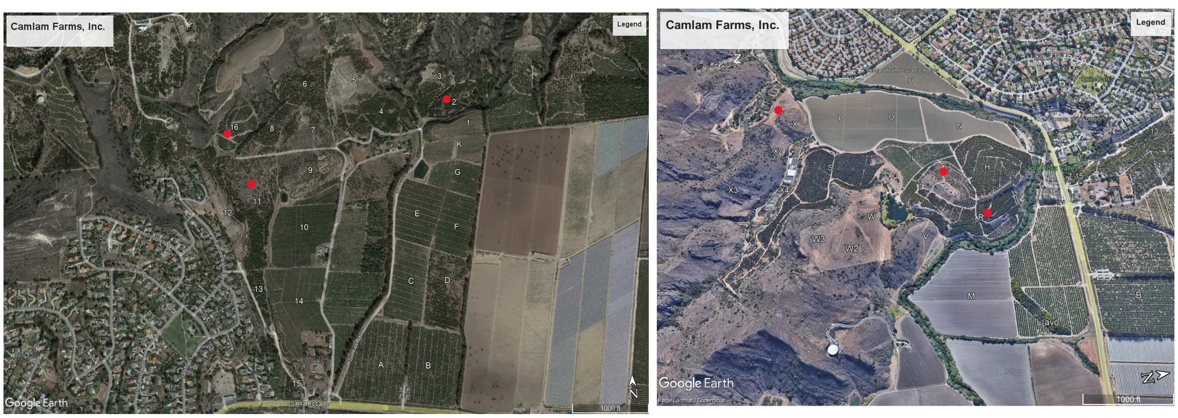


Figure 1: Red dots are site locations. At each site, there will be sensors and sampling occurring at 3 hillslope locations; the summit, the backslope, and the toeslope. The North side is dominated by marine and non-marine sedimentary materials (left panel) and the South side is dominated by volcanic materials (right panel)

Methods:

1. Collect soil samples from three hillslopes in the north section of CamLam Farm and three hillslopes in the south section. The hillslope locations are identified as locations where Hass avocados are grown on Toro Canyon rootstock, to try and control for differences in salinity stress that may occur based on having differing amounts of tolerance to salinity in the rootstocks. At each hillslope location, there will be samples collected at the summit, backslope, and toeslope. Five depths will be sampled at each of these locations, resulting in a total of 90 soil samples. Soil physical properties will also be measured in the field, including:
    - Infiltration
    - Aggregate stability
    - Depth to bedrock
    - Penetration resistance

    - Equivalent soil mass
2. A hillslope in the north side and south side will be selected that are the most similar to each other (i.e. same aspect, etc). Soil matric potential moisture sensors, soil EC sensors, and soil respiration flux bots will be placed at three different depths at three different locations at the two hillslopes, to collect continuous soil moisture, soil EC, and soil microbial respiration data.
3. Using a drone with a TIR imaging camera, we will conduct a flyover of the orchard to collect tree thermal stress data.
4. Soil samples collected in the field will be analyzed in the lab for specific various physical and chemical properties. Here are the measurements we are interested in:
    - Cation exchange capacity (CEC) and base saturation
    - Soil texture analysis
    - Specific concentrations of ions: Na+, Cl-, Ca2+, Mg2+
    - Phospholipid-derived fatty acids (PLFAs)
    - Soil mineralogy by XRD
    - Total organic carbon (TOC), Total inorganic carbon (TIC)
    - pH
5. In-field soil sensors will continue collecting data for two years, but researchers will return to the field to do seasonal drone flyovers for tree thermal stress data and collect season measurements of the following same soil chemical properties:
    - EC and specific concentration of Na, Cl, Ca, Mg
    - pH
    - PLFAs
6. Data will be analyzed to determine the relationship between soil physical and chemical properties and soil salinity, as well as soil salinity and tree thermal stress and soil microbial respiration and community composition.

Work plan timeline:

- July 2025: Begin field campaign and soil sampling and place in-field soil sensors (steps 1 and 2)
- August 2025: First drone flyover to assess tree thermal stress (step 3)
- September 2025: Begin laboratory soil analyses (step 4)
- February 2026: Return to the field for drone flyover and soil sampling (step 5)
- July 2026: Return to the field for drone flyover and soil sampling (step 5)
- February 2027: Return to the field for drone flyover and soil sampling (step 5)

Research question 3: How do different soils react differently to different irrigation water chemistries, specifically in regards to chloride ion retention? How does the addition of biochar alter the retention of chloride?

Hypothesis: Soils with higher clay content and more soil organic matter (SOM) will retain more chloride ions because clay accumulates water and SOM binds chloride. Soils amended with biochar will retain more chloride and less will be present in the leachate.

Objectives:

- Identify a quantitative relationship between soil properties and chloride retention
- Identify a quantitative relationship between biochar applied and chloride retention

Deliverables:

- Reports for farmers on what their soil characteristics mean for irrigation practices
- Quantitative information on the viability of biochar as a possible soil salinity solution
- Information packet on how soil characteristics interact with irrigation water chemistry and how growers should incorporate this into their irrigation management and leaching of salts
- Presentation at a CAC field day

Methods:

1. Using the soils with the most distinctive differences in salinity that we observed from R2 at CamLam Farms, collect 40 cm PVC pipes of soil from six different locations, with replicates of four soil samples per location, leading to a total of 24 PVC pipes of soil. Collect additional soil samples to analyze for:
    - Soil texture
    - Soil mineralogy
    - TOC and TIC
    - Infiltration
    - Aggregate stability
    - Equivalent soil mass
    - Penetration resistance
2. Bring soil samples back to the lab and analyze soil for these characteristics. Amend one soil column per site with biochar. Apply high salinity water to a regular soil column and a biochar column, low salinity water to a soil column, and distilled water for a control column.
3. Collect leachate below the soil column and analyze the leachate chemistry. Continue applying respective irrigation water and collecting leachate for next 90 days.
4. After 90 days, analyze the chemical properties of the soil in the columns again to see how they have changed with their respective irrigation water treatment.
5. Analyze the data on leachate chemistry of the different irrigation water qualities and compile an information packet on how irrigation water interacts with different soils.
6. Present this information at a CAC field day.

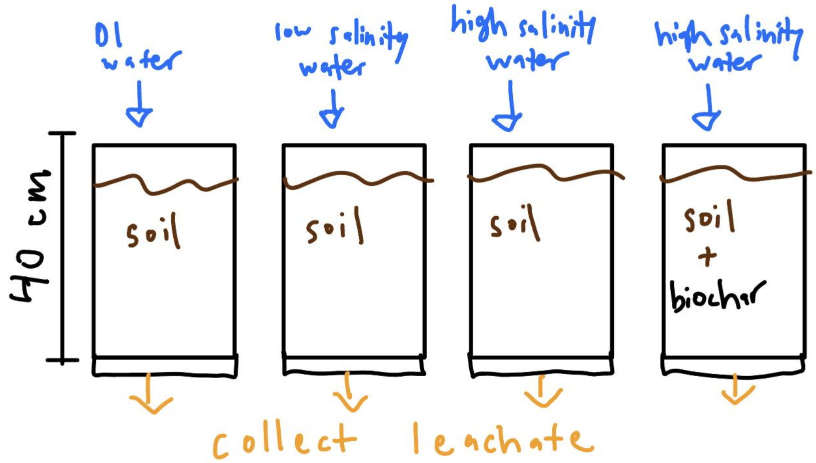


Figure 2: Soil column laboratory experiment set up with soils collected from six different sites

Work plan timeline:

- June 2026: Collect soil samples (step 1)

- July 2026: Analyze soil samples and begin irrigation water addition (step 2)
- September 2026: Finish analyzing collected leachate chemistry and analyze soil chemical properties (steps 3 and 4)
- October through November 2026: analyze data and present results at a CAC grower field day (steps 5 and 6)

Project outreach: Throughout the project, I will continually ask for grower feedback and input from CAC's Production Research Committee. I will utilize the GreenSheet to disperse information on grower surveys that will be used to assess the geography of soil and irrigation water chemistry. Once I have results, I will participate in on-site field days and grower meetings to communicate and create more opportunities for application of the findings.

Milestone table

Task accomplished	**Research objective**	**Date**	**Estimated cost**
First draft of soil salinization risk assessment map	R1	09/01/25	$2,702
Visit avocado field sites to collect water and soil samples to validate model output	R1	10/01/25	$300
Present model results at SSSA in Salt Lake City	R1	11/10/25	$755
Attend a California avocado grower meeting to present results and risks across the state	R1	01/26	$0
Deploy soil sensors in field site	R2	07/15/25	$11,868
Collect first round of soil samples at field site and complete first drone flyover	R2	8/01/25	$4,460
Analyze first round of soil samples	R2	10/01/25	$28,260
Compile data into meaningful figures and publish the findings	R2	09/01/27	$0
Collect soil samples for soil columns	R3	07/01/26	$3,960
Run and collect data for soil column experiment	R3	10/01/26	$792
Present data on relationship between soil type, irrigation water, and biochar at a CAC grower field day	R3	11/01/26	$0
Compile information packet for farmers on soil characteristics and irrigation and advocate for on-farm biochar trials	R3	06/01/27	$0
		TOTAL	**$53,097**

Project title	Addressing the relationship between soil characteristics and soil salinity in California avocado orchards				
Time period	07/01/2025-10/31/2027				
	Description	**Research objectiv**	**Quantity**	**Year 1 cost**	**Year 2 cost**
Salaries					
Undergraduate research assistant	work 3 months/year, 10 hours/week, at $16.50/hr	R2 and R3	2	$3,960	$3,960
Benefits					
Undergraduate research assistant	benefits at 1.5%	R2 and R3	2	$59.40	$59.40
Travel					
Travel to SSSA Conference 2025	plane ticket to SLC	R1		$425	
SSSA Conference attendance	SSSA conference registration fee	R1		$355	
Travel to field site	Vehicle miles traveled, $0.70/mile	R1, R2, R3	600 miles	$420	
Supplies					
Soil electrical conductivity sensor	METER TEROS 12 5 meter, $258 each	R2	18	$4,644	
Soil moisture matric potential sensor	METER TEROS 21 5 meter, $274/each	R2	18	$4,932	
Soil respiration fluxbot	Do it yourself, at $362/each	R2	6	$2,172	
iPad	for in-field data collection	R2	1	$349	
Supplies for soil columns	PVC pipe, stands, miscallaneous laboratory supplies	R3	18	$300	
Contracted services					
soil salinization model software	HYDRUS (2D/3D)	R1		$2,702	
Soil texture analysis	Laser diffraction particle size analysis, $109/sample	R2	90	$9,810	
Soil microbial community composition	PLFAs, at $90/sample	R2	90	$8,100	
Soil mineralogy analysis	by X-Ray diffraction, $25/sample	R2	90	$2,250	
Cation exchange capactiy	$60/sample	R2	90	$5,400	
Exchangeable ions	$30/sample	R2	90	$2,700	
Drone consultant	Collaboration with drone pilot with TIR imaging capabilities	R2		$500	
			TOTAL	$53,097.80	

Budget Narrative, as broken down by budget category

Salaries and benefits, $8,038.80

The salaries and benefits section adds up to $4,019.40 per year, over the span of two years, totaling $8,038.80. This category will go directly toward paying undergraduate research assistants to help collect soil samples and process and analyze laboratory samples. Since the cost of living in Santa Barbara is quite high, being able to pay undergraduate research assistants is important to ensure their commitment and ability to do their best work. Since this is a large-scale soil sampling campaign, it is necessary to have multiple people involved to get the work done in a reasonable amount of time. It will also provide undergraduate students with important and unique opportunities to get involved in agricultural research and laboratory measurements.

Travel, $1,200

The money allocated in the travel category will mainly go towards the attendance of an annual conference. The specific conference, the tri-societies meeting, convenes the Agronomy Society of America, the Crop Science Society of America, and the Soil Science Society of America. This will be an important opportunity to present the work and gain exposure for the issue of soil salinization in California avocado orchards. The rest of the funds in the travel category will go towards vehicle miles traveled reimbursement for travel to the field site and to other orchards to collect samples to validate the model in R1.

Supplies, $12,397

The supplies category consists mainly of the in-field sensors that will be deployed at the field site. These sensors are important because they will allow us to collect continuous data without having to disrupt day to day operations at the working farm. Since soil EC and soil water are quite closely coupled, it is important to have both of these sensors at different depths and locations. The soil respiration sensors will allow us to measure an important variable of soil biological health that is often linked with soil health. Having an iPad to collect data in the field is also important specifically for the collection of soil physical properties like penetration resistance and infiltration, since those measurements will be taken in the field. Lastly, it is important to have the supplies to create the soil columns in the laboratory so that we can carry out R3.

Contracted services, $31,462

The contracted services category is the largest section of our budget. It consists of the purchase of the soil salinization model, HYDRUS (2D/3D) in order to model soil salinity risk throughout California avocado orchards. It is possible that we will be able to get this software at a discounted rate with collaborations with UC Riverside. The bulk of the contracted services come from sending soil samples for various laboratory analyses to measure various chemical and biological soil properties. These may also come at a cheaper rate as I continue to establish collaborations with UC Davis and UC Riverside and some soil processing capabilities that they have at their campuses. The final contracted service is to compensate my colleagues from the GROVE lab for their time and use of their drone to obtain thermal infrared imaging of the field site.

1. Project Title: Development and Demonstration of a Cost-effective Electrodialysis Reversal (EDR) Process for Chloride Removal from Avocado Irrigation Water

2. Project Lead: Haizhou Liu, PhD, PE; Department of Chemical and Environmental Engineering, 900 University Ave, University of California, Riverside, CA 92521. Email: haizhou@engr.ucr.edu; Phone: 951-827-2076. (UCR contracting point of contact: Victoria Sissac, Principal Contract and Grant Officer, Email: victoria.sissac@ucr.edu; T: 951-827-3377)

3. Project Cooperator: Lindsey Pedroncelli, PhD; Interim Director, UC Agricultural South Coast Research and Extension Center, Irvine, CA, Email: lrpedroncelli@ucanr.edu

4. Executive Summary:

This project aims to address the priority topic to pursue promising desalination technologies to help mitigate chloride in groves. Elevated chloride in irrigation water is one of the greatest threats to avocado productivity for many growers in California. The development of efficient, cost-effective on-site desalination technologies to selectively remove chloride from the irrigation water at Californian avocado groves will significantly increase the yield of avocado trees, provide reliably high-quality irrigation water, and consequently increase the profits and competitiveness of Californian avocado groves. Based on a previously funded phase-one feasibility study to develop chloride mitigation technologies from irrigation water at Californian avocado groves, the project team at UC Riverside has identified electrodialysis reversal (EDR) as the most promising chloride removal technology uniquely fitted for avocado groves on-farm applications. This selection is based on a comprehensive selection criteria including chloride removal efficiency, economics and operational easiness. EDR process is estimated to incur the lowest total cost among all candidate technologies (60-80% lower cost than membrane-based and ion exchange technologies), and saves more than 70% cost than directly purchasing treated water from municipal water districts. To further pursue this promising technology platform, this phase-two project aims to develop and optimized a prototype EDR apparatus to removal chloride from California grove irrigation water, and demonstrate and validate the pilot-scale EDR treatment process to produce fresh irrigation water via chloride removal from irrigation water onsite at a California grove.

5. List of specific project objectives

This 3-year project has the following three main objectives:

1. Develop a prototype EDR apparatus and conduct chloride removal studies at lab scale using salinity-elevated irrigation water collected from an avocado grove. Optimize the EDR process by evaluating different options including ion selective membranes, applied voltage and water recovery to maximize chloride removal selectivity, minimize emerging consumption and capital/operational cost.
2. Demonstrate a pilot-scale electrodialysis reversal (EDR) operation on site on a California avocado grove to remove chloride, produce low-salinity irrigation water. to generate accurate data on chloride removal efficiency, water production rate, energy consumption rate and capital/maintenance cost.
3. Quantify the operational and capital cost of the pilot-scale demonstration and estimate the total cost for future full-scale operation in comparison to other chloride removal technologies.

6. List of specific project deliverables

The project has the following performance objectives and deliverables:

Performance Objectives	Data Requirements	Deliverables
Construct a prototype EDR system at laboratory scale	Design schematics, images, and videos of the prototype.	Fully functional prototype EDR system with interchangeable membrane and electrode configurations.
Test chloride removal efficiency using different ion-selective membranes and electrode materials with salinity-elevated irrigation water from an avocado grove.	Analyze chloride concentration before and after treatment for each prototype configuration.	Achieve chloride concentration reduction to **< 100 mg/L**.
Evaluate energy consumption and operational cost for each prototype configuration.	Conduct cost analysis based on each prototype configuration.	a. Determine **cost per gallon** to reduce chloride to **< 100 mg/L**. b. Select optimal prototype configuration for on-site demonstration.
Assess chloride removal efficiency through an on-site demonstration at a California avocado grove.	Conduct chloride concentration analysis before and after on-site treatment.	Reduce chloride concentration to **< 100 mg/L** for real irrigation water.
Evaluate energy footprint and cost for both pilot-scale and full-scale operations.	a. Analyze operating and maintenance (O&M) costs. b. Assess capital costs based on pilot-scale EDR demonstration.	Determine **cost per gallon** to reduce chloride to **< 100 mg/L**.
Operational consistency	Maintain complete recordkeeping of system uptime.	Achieve **80% uptime** during planned operations.
System robustness and ease of maintenance	Document system operations and troubleshooting procedures.	Ensure the treatment process is easy to implement and maintain.

7. Technology Description

Electrodialysis (ED) and electrodialysis reversal (EDR) are advanced desalination technologies that use an electric field and ion-selective membranes to remove chloride and other charged ions from water. In ED/EDR, chloride ions (anions) migrate toward the anode, while sodium ions (cations) move toward the cathode. These ions are blocked by alternating anion- and cation-selective membranes, resulting in two separate streams: purified water with reduced ion concentrations and a concentrated brine waste stream (**Figure 1**). However, a major drawback of ED is the buildup of charged particles on the membrane surface, which reduces efficiency over time.

EDR improves upon traditional ED by periodically reversing the electrical polarity, which helps prevent membrane fouling and ensures more consistent performance. This self-cleaning feature makes EDR particularly well-suited for agricultural irrigation, especially for water with low-to-moderate total dissolved solids (TDS). EDR offers several key advantages: 1. Selective Chloride Removal – EDR removes over 95% of chloride while preserving beneficial minerals such as sulfate and other divalent ions, which are essential for crop health. 2. Higher Water Recovery – EDR achieves a significantly higher water recovery rate (90-95%) compared to reverse osmosis (RO) and nanofiltration (NF), which typically discard a larger portion of water as brine waste. Additionally, EDR requires minimal pretreatment and does not need anti-scalants, unlike RO/NF. 3. Reduced Brine Waste – EDR generates much less brine, only 5-10% of the feedwater volume, making it more environmentally friendly and cost-effective for disposal.

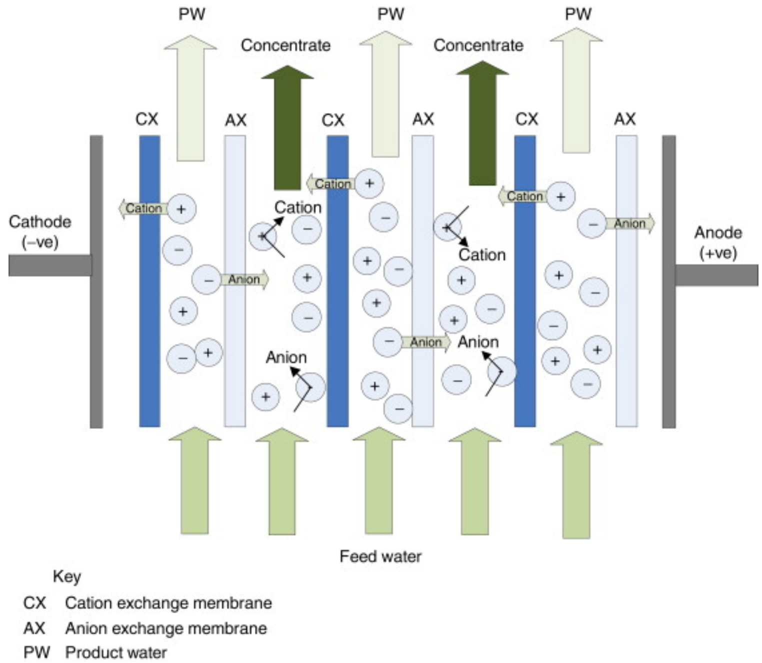


Figure 1. A schematic diagram to illustrate the working principle of the electricity-driven EDR membrane process.

For agricultural applications, EDR stands out compared to RO and NF. While RO/NF remove nearly all dissolved salts, including essential nutrients, and require expensive pretreatment chemicals, EDR selectively removes unwanted chloride without depleting beneficial minerals. Its ability to operate efficiently on water with low-to-moderate TDS makes it an ideal choice for irrigation. Although EDR does not remove uncharged contaminants like boron, this is generally not a concern for freshwater sources used in agriculture, particularly in California. Given its high efficiency, lower operating costs, and targeted desalination approach, EDR is a superior choice for agricultural irrigation water treatment.

8. Work plan and methods

As part of the bench-scale work and field demonstration, the team will collect sufficient data to properly develop, demonstrate and validate the ***electrodialysis*** system for irrigation water chloride removal. Chloride concentration in untreated and treated water samples will be quantified by an ion chromatography coupled with a conductivity detector. Conductivity of the water samples will be measured using a conductivity meter. Sample analysis will follow strict Quality Assurance/Quality Control (QA/QC) requirements.

Task 1. Pre-field bench-scale testing and prototype buildup – Year 1

To baseline the operational parameters of the pilot-scale system and properly select the type of EDR unit and operational parameters required for the treatment of the irrigation water samples that will be used in the field demonstration, we will conduct a series of bench-scale tests by assembling a bench-scale EDR system that will operate in a recirculation mode in the lab at UC Riverside. Real salinity-elevated irrigation water will be collected from the University of California South Coast Research and Extension Center (SCREC) in Irvine, California and used as the feedwater for treatment (*see attached letter of support from Dr. Pedroncelli, Director of SCREC*). SCREC has 200 acres of fields in an arid/semi-arid region used for growing avocados, various fruit trees and agronomic crops. The irrigation water at SCREC is recycled water produced by Irvine Ranch Water District as a municipal wastewater effluent. This irrigation water is elevated in salinity, with a chloride concentration in the range of 150 to 250 mg/L. This provides an ideal sample of real-world feedwater to evaluate and demonstrate the EDR treatment efficiency.

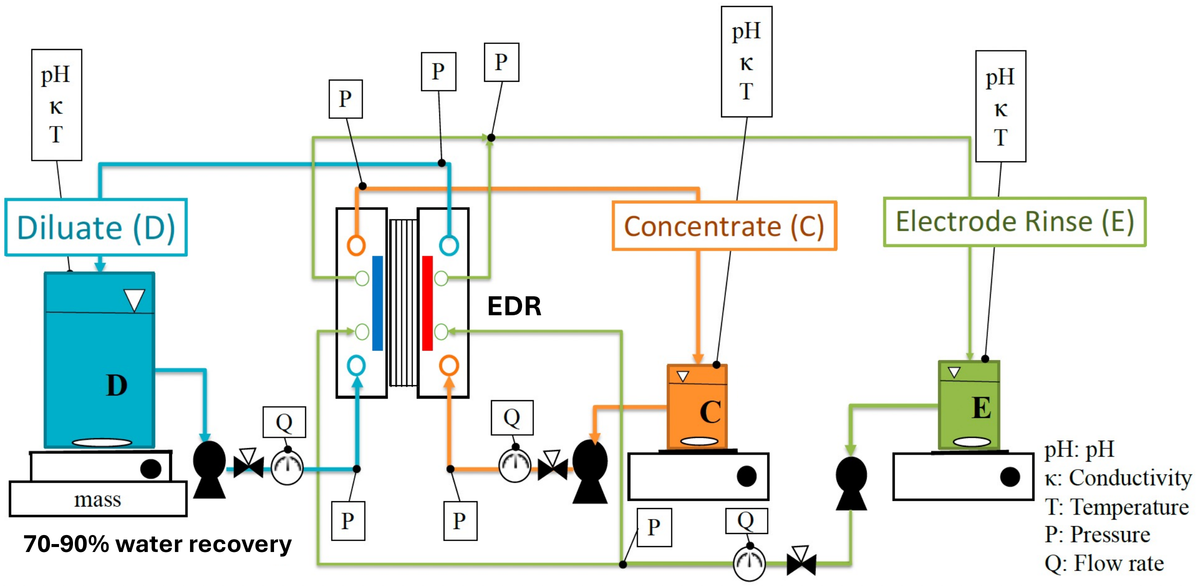


Figure 2 Schematics of the bench-scale electrodialysis (ED) experimental apparatus in recirculation mode.

We will assemble the EDR system and it will mainly consists of the electrodialyzer and three streams: diluate (D), concentrate (C), and electrode rinse (E) (**Figure 2**). The electrodialyzer includes the anode, the cathode, and two end-plates. Between the anode and the cathode, multiple pairs of cation and anion exchange membranes (CEMs and AEMs, respectively), separated by thick plastic woven screen spacers to allow solution flow, are aligned in a repeatable manner (e.g., CEM – spacer – AEM – spacer - … - spacer - CEM). The anode and cathode will consist of expanded titanium with platinum/iridium coating and are secured to polypropylene end-plates. A small voltage per cell pair will be applied to the electrodialyzer throughout the EDR experiments, and the EDR system will be operated under constant voltage mode.

In this task, each of the three streams will be circulated by laboratory-scale gear pumps. both dilute and concentrate solutions begin with the same feed water. As the system operates, their concentrations change. The water is recirculating throughout the experiment, causing the dilute concentration to decrease and the concentrate concentration to increase. The rinse solution will be made of sodium sulfate with an ionic strength similar to that of the feed water. The flow rates (Q) for the concentrate and diluate will be controlled by digital liquid flow controllers (McMillan Liquid Flo-Controller Model 400-6-A4).

The goal of the treatment is to achieve 70%-90% of the water recovery as diluate treated water, and chloride removal to achieve a final treated water with less than 100 mg/L chloride. To optimize the EDR system to achieve these treatment goals, several EDR operational parameters will be investigated to achieve the best EDR treatment performance. First, three different ion exchange membranes will be evaluated for the EDR system to achieve the best chloride removal efficiency, including two conventional ion exchange membrane with different surface functional groups, and a third monovalent ion selective membrane that targets chloride removal. Second, we will evaluate the tuning of voltage of applied to the EDR system. The range of voltage applied to each cell pair will be from 0.5 to 5 V. Third, we will optimize the water recovery percentage and match it with the chloride removal goal. It is expected that a higher water recovery combined with a lower voltage applied can achieve the desirable chloride removal.

Task 2. Field Demonstration of Pilot-Scale EDR System – Years 2-3

In this task, a pilot-scale electrodialysis reversal (EDR) system will be deployed and demonstrated over a 3 to 6-month period at a selected avocado grove in Southern California. The system will be designed to treat chloride-impacted irrigation water at a significantly larger scale, processing approximately 2,000 gallons at a flow rate of 1–2 gallons per minute (gpm). The EDR system will operate in recirculation mode, ensuring optimal chloride removal. If a single pass through the system does not achieve the desired chloride reduction, the treated water will be recirculated back to the start of the block flow diagram for additional treatment. The treated water will be used for irrigation of avocado trees, and its impact on tree growth and productivity will be evaluated. The production rate of the trees irrigated with low-chloride treated water will be compared to a control group of trees irrigated with high-chloride irrigation water to assess the benefits of chloride reduction on crop health and yield. To monitor chloride removal efficiency, daily grab samples will be collected and analyzed for chloride concentration throughout the demonstration period, enabling continuous process evaluation and optimization.

Task 3. Estimate the energy and total cost of the pilot-scale and future full-scale operation – Year 3.

An economic analysis of the EDR chloride removal technology will be developed to predict cost of future scale operations based on the results from the field demonstration and chloride removal kinetics. Capital, operating and maintenance (O&M) costs will be included in the economic analysis. Capital costs of treatment components will be estimated using "Cost Build-up Approach" which is based on vendor quotations, cost estimating guides, and best professional judgment. The annual capital cost will be estimated from an appropriate capital recovery factor using the net present value (NPV) method. The O&M costs will be calculated based on experimental results in this study that considers the electric energy and chemical consumption costs. In addition, the limited volume of brine concentrate disposal options will be evaluated and incorporated into the overall cost.

9. Project Outreach

Considering the urgency, relevance, importance and promise of chloride removal from irrigation water, the development of efficient water treatment technologies to selectively remove chloride can become a game-changer for the Californian avocado industry to increase its profit and enhance its global competitiveness. Outreach methods will include extension publications with SCREC websites, article publication and progress update via the in the California Avocado Commission's quarterly magazine *From the Grove*, on-site field days at SCREC, in-person or virtual grower meetings, communications with CAC committees and other industry partners as appropriate. The PI has conducted these proposed outreach activities during the Phase-one chloride technology review CAC project.

10. Milestone Table

The research work plan of individual tasks and significant milestones is developed as below.

Task 1: Preliminary Testing at UCR	
Subtask 1: Construct the EDR system in recirculation mode	**Year 1**
Subtask 2: Collect feedwater from Extension SCREC Partner	**Year 1**
Subtask 3: Evaluate EDR lab-scale optimization for chloride removal	**Year 1**
Subtask 4: Collect data and Quantify the total energy dosage requirment	**Year 1**
Task 2: Field demonstration and testing at SCREC	**Year 2**
Subtask 1: Design and construct the field demonstration pilot	**Year 2**
Subtask 2: Update site readiness	**Year 2**
Subtask 3: Transport and install the pilot system	**Year 2**
Subtask 4: Conduct EDR pilot demonstration at Extraction Point	**Year 2-3**
Subtask 5: Perform analytical pause and validate performance	**Year 2-3**
Subtask 6: Decommission the pilot system	**Year 2-3**
Task 3: Data energy cost calculation and final report	**Year 3**
Subtask 1: Anlayse data	**Year 3**
Subtask 2: cost calculation	**Year 3**
Subtask 3: final report	**Year 3**

Budget Table

	CAC FY 1 11/01/25 to 10/31/26	**CAC FY 2** 11/01/26 to 10/31/27	**CAC FY 3** 11/01/27 to 10/31/28	**Total**
Principal Investigator (PI) salary	$19,945	$20,743	$21,572	**$62,260**
PI benefits (7.9% of salary)	$1,576	$1,639	$1,704	**$4,919**
Graduate Student Researcher (GSR) salary	$40,174	$43,288	$46,643	**$130,105**
GSR benefits (2.1% of salary + tuition fee remission)	$22,282	$23,223	$24,211	**$69,716**
Travel	$1,000 (Car rental $400, and lodging $600)	$1,000 (Car rental $400, and lodging $600)	$1,000 (Car rental $400, and lodging $600)	**$3,000**
Materials and Supplies	$10,000	$10,000	$10,000	**$30,000**
Total	**$94,977**	**$99,892**	**$105,131**	**$300,000**

Budget Narrative

This budget requests $300,000 for three years beginning November 1, 2025. Details of this request are provided below.

Personnel
Haizhou Liu, Professor of Chemical and Environmental Engineering, (1.0 summer months in each project year) will serve as the PI of this grant/project and will assume its administrative responsibility. In addition, he will oversee the design and implementation of the whole project, and supervise the graduate student researcher (GSR) who will work on this project. The salary requested is based on actual rates, and escalated by 4% annually, as per institutional policy.

One TBN Graduate Student Researcher (GSR), starting at increment 1, is requested at 4.5 academic months and 1.92 summer months for each project year. This GSR, under the supervision of Prof. Liu, will work on all proposed research tasks. The salaries requested are based on the University's published salary scale for GSRs.

Benefits
The University's Federally approved composite benefit rates (CBR) are for the period July 1, 2024 through June 30, 2025, and provisional thereafter per Department of Health and Human

Services (DHHS) agreement dated April 9, 2024. The CBR for faculty summer is 7.90% and that for students is 2.10%. The University includes graduate student tuition/fee remission in benefits. These costs are as follows.

Student fee remission 2025-26 AY	$21,439
Student fee remission 2026-27 AY	$22,314
Student fee remission 2027-28 AY	$23,232

Travel
This budget requests $1,000 for each project year for domestic travel by the PI and GSR to attend the California Avocado Society Annual Meeting and another agriculture-themed national conference, as well as and periodical visits of partner avocado groves to collect salinity-elevated irrigation water for technology testing and demonstration. For each year, $600 is requested for lodging and $400 for transportation. This estimate is based on the PI's experience from previous travel.

Materials and Supplies
$10,000 is requested for each project year for the purchase of lab consumables that are critical to the operation of the chloride desalination system and analytical consumables that measures chloride, including tubing, ion exchange membranes, water chambers and containers, peristatic pumps, holding tanks, metal beams, timers and pressure valve for pilot-system setup, electrodes for the electrodialysis units, ion chromatography sample vials, analytical columns that measure chloride, conductivity probe, beakers, volumetric flasks needed to carry out the proposed work. This estimates is based on the PI's experience from previous similar purchases.

UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources

South Coast Research and Extension Center

March 14, 2025

Production Research Committee
California Avocado Commission

Re: Letter of Support from UC ANR South Coast Research and Extension Center

Dear California Avocado Commission Production Research Committee:

I am writing this letter to enthusiastically support Dr. Liu's proposal titled "*Development and Demonstration of a Cost-effective Electrodialysis Reversal (EDR) Process for chloride removal from Avocado Irrigation Water*". As the director of the South Coast Research and Extension Center (South Coast REC), I will collaborate with Dr. Liu to provide recycled wastewater effluent as irrigation feedwater and the site for his team to demonstrate the treatment of recycled wastewater effluent to remove chloride from irrigation water.

As part of the University of California (UC) division of Agriculture and Natural Resources (ANR), South Coast REC was established in 1956 as a representative site for agricultural and horticultural research in California's south coastal plain-temperate climatic zone. South Coast REC serves as a regional field laboratory for UC scientists to conduct agricultural and natural resources management research and extend research-based information to a wide spectrum of audiences. The Center provides land, irrigation water, labor, equipment, and other facilities, and it serves as a repository for germplasm collections of many subtropical plants. Intensive research efforts are focused on fruits and vegetables. The Center is also complemented by supporting work in entomology, plant pathology, biological control, and integrated pest management. Staffing at South Coast REC consists of multiple full-time equivalent employees engaged in administration, education outreach, and agricultural field and physical plant operation. South Coast REC is also home to the UC Cooperative Extension Orange County office, with multiple full-time programmatic and research academics and staff.

I am excited about this opportunity to collaborate with Dr. Liu on this project and look forward to new collaborations with Dr. Liu at South Coast Research and Extension Center.

Sincerely,

Lindsey Pedroncelli

Lindsey Pedroncelli, Ph.D.
Interim Director, South Coast Research and Extension Center

7601 Irvine Blvd. Irvine, CA 92618 — Lrpedroncelli@ucanr.edu — (760) 385-8332

Title: Continued Research at the San Luis Obispo Rootstock Trial Site (2025-2027)

Project Lead
Lauren Garner
Professor, Plant Sciences Department
Cal Poly
1 Grand Avenue
San Luis Obispo, CA 93407
Lgarner@calpoly.edu
805-756-2479

Project Cooperator
Patty Manosalva
UC Riverside
pmanosal@ucr.edu

Executive Summary
If approved for funding for 2025-2027, I propose to continue to maintain the orchard plot and collect and analyze the data required for the multi-site rootstock study and to build on this long-term, joint investment by continuing to keep the orchard plot well-maintained. This research plot could be utilized by other PIs as a northern site for any pest surveys and/or potential biocontrol releases that CAC may fund in other **priority topics (e.g. 25, 28-30, and/or 39)**. All studies and data collection will be conducted at the rootstock trial plot at Cal Poly and will be overseen by a Master's student to be recruited for this purpose. That student will oversee undergraduate research assistants in data collection and entry and will work with me and Andrew Schaffner (Professor, Cal Poly Statistics Department) to analyze the data and to continue to prepare reports for the CAC and UCR and to co-author presentations and manuscripts for dissemination to growers and the wider scientific community. Additionally, the Master's student can work with any CAC-funded PIs to coordinate and/or conduct on-site pest surveys and/or biocontrol releases.

Background
In 2019/2020, a collaboration began between Cal Poly, UCR, and the CAC, resulting in the establishment of a rootstock trial site on Cal Poly's campus in San Luis Obispo. This is the northern-most site in the statewide rootstock trial currently being conducted by the CAC and UCR. With financial and in-kind support from the CAC, members of the avocado industry, and Cal Poly, an avocado orchard was established at a site on campus with a documented and recent history of *Phytophthora* root rot (PRR). Trees of 'Hass' avocado grafted on 'Dusa', 'PP35, 'PP40', or 'PP45' 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 rootstock treatment in 3 blocks for a total of 384 trees, which are planted on berms at a 15' x 20' tree spacing.

In keeping with the protocols established for the statewide rootstock trial, all trees were measured and their health assessed 2 months after transplanting (August 2020) and during flushing in spring (March/April 2021-24), summer (July 2021-24), and fall (October 2021-2024), and harvest data was collected in 2023 and 2024. Our work to date has resulted in several presentations (at grower meetings and scientific conferences), contributions to all intermittent and annual reports required by me and/or Patty Manosalva to meet CAC milestones, one Master's thesis, and numerous undergraduate senior projects and class projects. Since planting, funding to support this research and maintain the orchard plot has come from ~$85K from a grant I had from the Agricultural Research Institute (end date June 31, 2023) and from the California Avocado Commission (funding cycle November 2023 through October 2025).

Project Objectives

1. Continue to collect and analyze tree growth, health, and yield data for the multi-site rootstock study
2. Continue to maintain the orchard plot to provide a well-maintained northern growing region study site for CAC-funded pest surveys and/or potential biocontrol releases

Project Deliverables

Objective 1
Reports will be submitted to the CAC. Data will be shared regularly with UCR as part of our continued participation in the multi-site rootstock study. Presentations and/or manuscripts will be prepared for dissemination to growers and the wider scientific community.

Objective 2
The orchard will be maintained for continued use for the rootstock trial study, as a potential site for CAC-funded pest surveys and/or biocontrol releases and as a site for grower field days.

Workplan and Methods

Objective 1

Data to track tree growth, health, and productivity will be collected during the spring (2026, 2027), summer (2026, 2027), and fall (2026, 2027) flushes, and during harvest (2026, 2027). Data collection will include tree height, trunk diameter, canopy volume, yield, and rating salinity damage, heat damage, vegetative flush and bloom. All data collection will be overseen by the Master's student to be recruited for this purpose. That person will oversee undergraduate research assistants in data collection and entry and will work with me and Andrew Schaffner (Professor, Cal Poly Statistics Department) to analyze the data and to continue to prepare reports for CAC and UCR and to co-author presentations and manuscripts for dissemination to growers and the wider scientific community.

Objective 2

In addition to employing students as research assistants, having student orchard assistants will allow us to dedicate weekly efforts to regular management and maintenance issues, including tasks such as pruning, weeding, walking irrigation lines, scouting, and harvesting. Additionally, Cal Poly's Plant Sciences Department has a long and successful history of collaborating with outside research entities to serve as a study site to monitor agricultural pests and for biocontrol releases. Our educational mission and fully functioning farm make us uniquely suited to such collaborations.

Project Outreach

Project results will be communicated to California avocado growers through presentations at grower meetings, on-site field days and direct interaction with industry members at meetings and visiting the campus site.

Budget:

Total estimated 2-year cost (2025-2027): $58, 065
See attached budget and budget justification.

Milestones Table

Milestone	Activities	Scheduled Completion	Budget
1	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	January 2026	$6000
2	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	April 2026	$6000
3	• Collect tree health and harvest data at Cal Poly orchard. • Orchard maintenance	July 2026	$9,500
4	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	October 2026	$7732
Year 1 total cost			**$29,232**
Milestone	**Activities**	**Scheduled Completion**	**Budget**
5	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	January 2027	$6000
6	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	April 2027	$6000
7	• Collect tree health and harvest data at Cal Poly orchard. • Orchard maintenance	July 2027	$9,500
8	• Collect tree health data at Cal Poly orchard. • Orchard maintenance	October 2027	$7333
Year 2 total cost			**$28,833**
Project total cost			**$58,065**

Sponsor:	CA Avocado Commission
Title:	New and Continuing Avocado Research Trials
Project Term:	11/1/25–10/31/27
Proposal #:	25_242

						Quarter Year 1	Quarter Year 2	Total
Personnel	WTUs							
Principal Investigator	0.0	0.00% Release @	$133,837	/AY		$0		$0
(no compensation)		0.00 months sum @	$16,730	/MO		$0		$0
Statistics Professor	0.0	0.00% Release @	$180,344	/AY		$0		$0
		20.00 hours overload @	$86.70	/HR		$1,734		$1,734
		15.00 hours overload @	$91.04	/HR			$1,366	$1,366
Undergraduate Student Research Assistants		490 hours @	18.50	/HR		$9,065		$9,065
		490 hours @	18.50	/HR			$9,065	$9,065
Graduate Student Research Technician		129 hours @	21.00	/HR		$2,709		$2,709
		129 hours @	21.00	/HR			$2,709	$2,709
					Subtotal Personnel	**$13,508**	**$13,140**	**$26,648**
Fringe Benefits								
Faculty summer & overload		Statistics Professor	8.5%			$147	$116	$263
Undergraduates		Undergraduate Student Resea	2.5%			$227	$227	$454
Graduate Students		Graduate Student Research T	8.5%			$230	$230	$460
					Subtotal Fringe Benefits	$604	$573	$1,177
					TOTAL Personnel Services	**$14,112**	**$13,713**	**$27,825**
Other								
Tuition						$15,120	$15,120	$30,240
					SUBTOTAL Other	**$15,120**	**$15,120**	**$30,240**
					TOTAL Other Direct Costs	**$15,120**	**$15,120**	**$30,240**
					TOTAL DIRECT COSTS	**$29,232**	**$28,833**	**$58,065**
Indirect Costs								
Cal Poly Recovered F&A Base						$14,112	$13,713	$27,825
Cal Poly Recovered F&A		0.0% of Modified Total Direct Costs				$0	$0	$0
					TOTAL SPONSOR COSTS	**$29,232**	**$28,833**	**$58,065**

Budget Narrative:

PERSONNEL:

- Lauren Garner, Cal Poly- Plant Sciences Professor; PI overseeing project; no support requested
- Andrew Schaffner, Cal Poly- Statistics Professor; Statistical support; 20 and 15 hours per year in year 1 and 2, respectively
- Graduate Student, Cal Poly- Research technician to oversee data collection and analysis and undergraduate research assistants; 129 hours/year
- Undergraduate employees, Cal Poly- student research assistants 290 hours/year (data collection and entry) and student orchard employees 200 hours/year (assist in orchard management)

SALARIES AND WAGES: The salary and wage rates are based on the California Polytechnic State University (CPSU) and Cal Poly Corporation (CPC), jointly Cal Poly, established salary and wage rates paid during the 2024-2025 Fiscal year (July 1 – June 30). In general, faculty duties at CPSU consist of fifteen units in each of three Academic terms per eight-month Academic contract year, exclusive of academic breaks and summer sessions. Faculty 12-month appointments may include a combination of academic and administrative duties and encompass academic breaks and summers. Cal Poly will transition from three academic year terms to two academic year semesters by Fall 2026, but this is not expected to affect institutional base salaries, and faculty duties will still consist of 15 units per semester term. The salary and wage rates for faculty and non-student staff generally include a projected 5% salary increase per year. The rates shown are for budgetary purposes; the rates in effect at the time the work is performed will be charged to the project.

FRINGE BENEFITS & EMPLOYER PAYROLL TAXES:
Benefits for CPSU Faculty summer and overload work include FICA, SUI and Workers Compensation and are calculated at the proposed DHHS pooled rate of 8.5%.

CPC undergraduate student benefits include SUI and Worker's Compensation. The proposed DHHS pooled rate of 2.5% is used for budgetary purposes.

CPC graduate student fringe benefits include SUI and Worker’s Compensation which would result in the proposed DHHS pooled rate of 2.5%. CPC graduate students convert to intermittent employees if the graduate student is not fully enrolled when the work is performed, resulting in the addition of FICA to fringe benefits and the current intermittent fringe benefit rate of 8.5%. Cal Poly elects to budget graduate student fringe benefits at the proposed DHHS pooled intermittent rate of 8.5%, assuming that the graduate students will not be fully enrolled. It is not feasible to assess enrollment status at the time of proposal submission.

The rates in effect at the time the work is performed will be charged to the sponsor.

OTHER COSTS: Tuition for a graduate student is requested at $15,120/year.

FACILITIES AND ADMINISTRATIVE (F&A) COSTS:
Per sponsor guidelines, “It is the policy of the California Avocado Commission to only pay direct project costs, indirect or overhead costs are not allowed.”

Title: Impact of Natural Vegetation on Insect Pollinators in Agroecosystems

Principal Investigator: Carson Loudermelt, graduate student, Cal Poly Pomona
Co-Principal Investigator: Dr. Hamutahl Cohen, Assistant Entomology Advisor, Ventura, UC ANR
Co-Principal Investigator: Dr. Adam Lambert, Associate Researcher, UC Santa Barbara
Co-Principal Investigator: Dr. Elizabeth Scordato, Associate Professor, Cal Poly Pomona

Research Problem & Project Synopsis

The demand for pollination services in agriculture frequently exceeds the supply (Mashilingi et al. 2022). This is a particular problem for the avocado industry. Avocado growers typically rely on managed honeybee populations for pollination of avocados, but the most effective pollinators of this crop are likely solitary bees, wasps, and flies. In fact, when wild pollinators are present, avocado crops can have a more than 25% increase in production (Lara-Pulido et al 2021). Furthermore, declining wild pollinator populations have been shown to adversely impact avocado yields (Biesmeijer et al., 2006). However, it is unclear which species are the most common avocado visitors and how growers can support these wild pollinator populations through management practices (Lara-Pulido et al 2021), especially in Ventura County. While avocado visitors have been identified in Mexico and Central America (Can-Alonzo et al. 2005), the pollinators of avocados have never been described in California. We know that crop visitation by pollinators and pollinator diversity increases with the surrounding natural habitat, which improves crop yield (Eeraerts et al 2021). However, there is no consensus on the optimal distance from orchards or the size of natural vegetation patches required to achieve these benefits. While many growers already take steps to protect wild bees, we still have a limited understanding of how land management practices at different spatial scales affect bees and other insects that are potentially pollinating avocado flowers. This gap in knowledge leaves avocado growers without relevant guidelines for using non-crop vegetation to support pollinators, even though many show interest in enhancing natural habitats for improved ecosystem services (Esquivel et al 2021). Avocados are likely dependent upon a unique community of pollinator species, so it is important to address how these pollinators respond to natural vegetation at different spatial scales (Sagwe et al 2022). The goal of this project is to **provide clear, applicable recommendations to help growers establish natural vegetation on orchard margins to enhance pollinator visitation and diversity, ultimately supporting avocado yields.** We will share the results of our work through at least one field day, a minimum of two blog posts through the UC ANR Topics in Subtropics blog, and communication with the California Avocado Society.

Objectives

The <u>first objective</u> of this project is to identify the species of pollinator insects that are responsible for pollination in avocado crops. We hypothesize that certain species of bees, flies, wasps, and other insects may play a key role in the transfer of pollen between avocado flowers. To achieve this objective, we will conduct visitor observations along our transects during the blooming period of avocado trees in our orchards. This will provide information on what species may be contributing to the pollination of avocados, possibly providing evidence of any flies, solitary bee species, or other types of insects pollinating avocados.

The <u>second objective</u> of this project is to evaluate how different features of orchards, both at local and landscape scales, influence pollinator diversity and abundance. To achieve this objective, we will be sampling pollinators within our orchards that have varying quality and diversity of natural habitats surrounding the orchards, at local and landscape scales.

Study Design

This study will be conducted in eight avocado orchards and four riparian sites throughout Ventura County. At each orchard site, we will establish a transect that is 150 meters long, running from the edge of an orchard block to the center of the block. Half of the orchard research sites will have bare margins and half will have vegetated margins (either planted hedgerows or naturally-occurring native vegetation). Additionally, the sites vary in distance to natural riparian habitat on the landscape scale. We will use sites in the riparian channel to catalog pollinator species that could be found in orchards, therefore using them as a control for pollinator diversity (Figure 1).

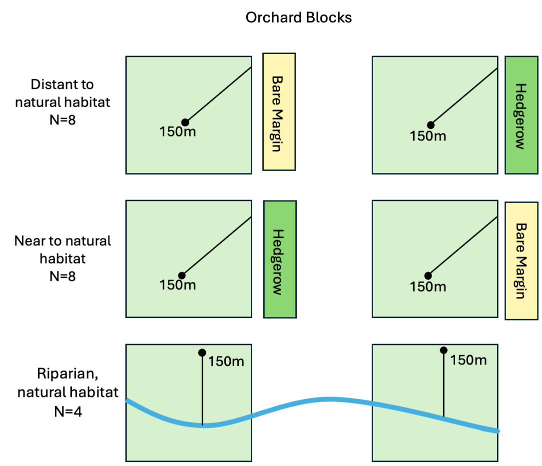


Figure 1. Study design in the SCRV

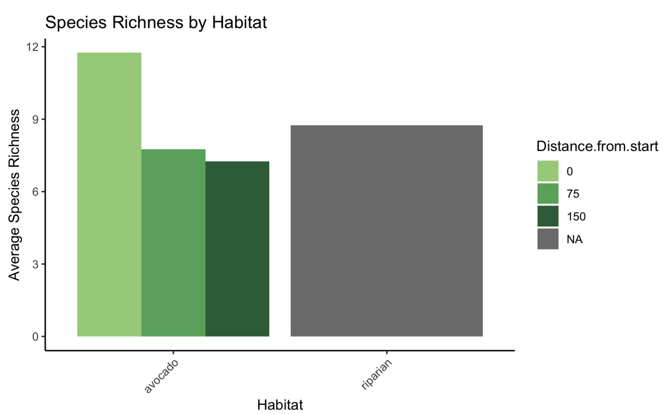
To accomplish objective 1, we will conduct pollinator visitation surveys along our transects. Observers will implement three-minute visual observations within one meter-squared quadrant at eight trees along the transect, followed by three minutes of vouchering to collect insects observed in the visual survey. Visual observations will include all specimens seen touching parts of an open flower. The quadrants will be flagged and we will return 5 months later to count fruits and measure height and width.

To accomplish objective 2, we will survey pollinators using pan traps and blue vane traps at each site. These traps will be set in openings next to trees at the 0m, 75m, and 150m points along the transect, and insect pollinators will then be transferred to the lab for identification to the lowest taxonomic unit possible. We will characterize variations in pollinator abundance, diversity, and community structure among riparian transects, orchards adjacent to the riparian corridor, and orchards distant from the riparian corridor. To assess how hedgerow (small-scale plantings along orchard margins) and larger riparian landscape composition and structure impact pollinator communities, we will collect and incorporate data on non-crop vegetation and flower abundance and diversity. Information on the composition and structures of the hedgerows, located along the margins of some of the orchards, will be used to understand how local-scale vegetation features affect pollinator communities within different landscapes. Additionally, flower abundance and diversity will be measured along the transects at the 0m, 75m, and 150m points, to assess floral resource availability at different orchards and riparian sites. To assess the impacts of landscape composition on pollinator communities, we will evaluate the percent of non-crop vegetation within 100, 250, 500, and 1000-meter buffers around transect points using ArcGIS. This data will provide insight into the broader landscape vegetation structure that could potentially serve as habitats or resources for pollinator communities. By examining the combination of these local and landscape features along with pollinator communities at each site, we aim to determine what characteristics of these heterogeneous landscapes support more diverse and abundant communities of pollinators.

Data Analysis
With the collected data, we aim to explore the relationship between pollinator diversity, abundance, and various environmental variables at local and landscape scales. We will use generalized linear mixed models (GLMMs) to explore how vegetation/floral composition and structure at the local and landscape scales influence pollinator diversity and abundance. Predictor variables will include transect flower cover and vegetation composition and the percentage of non-crop vegetation at the landscape scale, with site included as a random effect to account for site variation. Additionally, we will use Non-Metric Dimensional Scaling (NMDS) with Bray-Curtis dissimilarity to examine the overall community structure of pollinators to visualize patterns of how community composition relates to our environmental variables. This approach will allow us to better understand the local and landscape features that impact pollinator communities and affect agricultural production.

Preliminary Data
Preliminary analysis shows that average bee species richness and abundance are similar in both avocado and riparian sites. Riparian sites and points on the margins of our avocado orchards (0 meters) have higher species richness than points within the interior of the avocado orchards (fig. 2a). We also found that the average bee abundance is higher in avocado orchards than riparian, with the trees adjacent margins, (at 0 meters along our transect), harboring the highest abundance (fig. 2b). From preliminary analyses, we are also seeing that as non-crop vegetation increases within all of our buffers (100, 250, 500, and 1000 meters) bee species richness within avocado orchards increase as well, shown in figure 3 in the 250-meter buffer. Here, we propose to expand this work by collecting more insect pollinator data at more transects. More visual observations and pollinator samples at more transects will help us be more sure that our data captures the true pollinator communities and how they respond to the natural landscape.

a



b

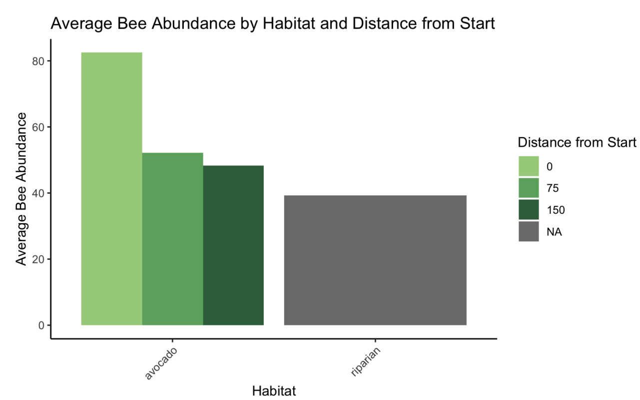


Figure 2. (a) Average bee species richness in avocado and riparian transects, with color corresponding to distance from the orchard margin with 0 being exterior and 150 being 150 meters into the interior. (b) Average bee abundance between avocado and riparian transects, with color corresponding to distance from the margin of the avocado orchard.

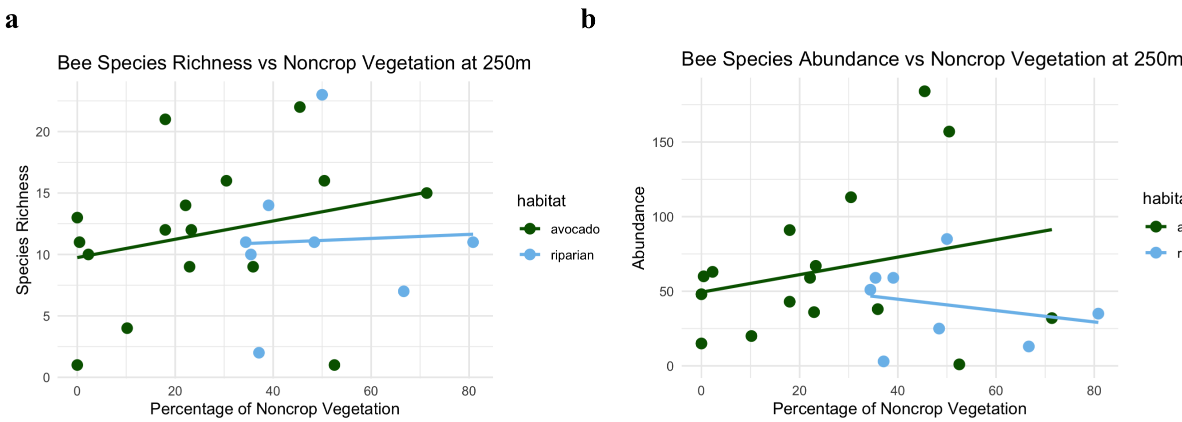


Figure 3: (a) Bee species richness across percent noncrop vegetation within a 250-meter buffer, colored by habitat type (avocado and riparian) (b) Bee abundance across percentage of noncrop vegetation within a 250-meter buffer.

With this project, we hope to enhance our understanding of the relationship between pollinator diversity, abundance, avocado yields, and local and landscape vegetation features to provide tractable and actionable recommendations to help support sustainable avocado farming and preserve essential pollinator communities within these agroecosystems.

Support from CAC

Support from CAC is critical for the success of this project and supports the training of PI Carson Louderment, a graduate student interested in pursuing entomology and agricultural research. Furthermore, this project will support the training of one undergraduate assistant in field methods in Ventura County, which faces a lack of trained agricultural sciences personnel.

Budget	**Description**	**Year 1** (July 1, 2025 - Oct 31, 2025)	**Year 2** (Nov 1, 2025 - Oct 31, 2026)
Travel to the field and outreach events from Pomona	Gas & mileage: 67 cents/mile ~ 180 miles round trip ~40 miles between sites ~ 7 trips	$516	$516
Accommodations	Hotel 2 nights/trip ~7 trips ~$200/night	$1,400	$1,400
Food per diem	$25/day One assistant ~3 days per trip ~7 trips	$525	$525
Collection equipment	nets, pans, vials, coolers, vane traps	$300	--
Identification costs	Insect pins, Cornell drawers,	$250	$250

	shipping samples to experts		
Undergraduate Insect Identification Assistant	$17/hour ~100 hours	$850	$850
Undergraduate field assistant	$16.50/hour ~21 field days ~120 hours	$990	$990
			Total: $9,362

Milestone table

Milestone	**Estimated Completion Date**	**Estimated budget amount**
Complete surveys in SVRC	July 2026	$6,130
Complete identification of surveyed insects	September 2026	$2,200
Complete data analysis	September 2026	-
Outreach events	July 2026	$1,032
Submit research for publication	October 2026	-

References

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