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Production Research Focuses on Grower Needs

When I began working for the California Avocado Commission in 2012, the Production Research budget was more than $1 million annually. At that time, CAC staff worked with the Production Research Committee to develop an annual request for proposals that included a general list of research priorities, but the proposals received were largely at the discretion of the researchers.

Over time, the PRC made the decision to make the annual RFP more focused, listing specific topics on which proposals were needed. And in recent years, the RFP process has been eliminated entirely in favor of asking specific researchers for proposals on specific topics that the PRC has decided are needed to address critical issues within the industry. As a result, the annual Production Research budget has been reduced to about $200k to $300k annually, but is focused on projects that will, hopefully, have a direct impact on growers.

Avocado Rootstock Development

The largest project — both in scope and investment — CAC is currently funding is for the development of new rootstocks. Three years ago, the PRC recommended and the Board approved no longer funding active breeding of new rootstock selections. Rather, the decision was made to focus on evaluating rootstock selections that had been previously made but never fully evaluated.

Through discussions with Dr. Patricia Manosalva, the current University of California rootstock breeder, five rootstocks that showed promise for having phytophthora root rot and/or salinity tolerance were selected to move into commercial-scale trials to decide whether to release them commercially. The five rootstocks selected are known by their code names PP35, PP40, PP42, PP45 and PP80. The traits of these rootstocks are shown in the accompanying table.

Since 2019, these five rootstocks have been planted by growers from San Diego County to San Luis Obispo County under a range of conditions. Each planting has at least 100 trees of one or more rootstocks. The growers selected to plant these trials have groves that exhibit one or more of the following conditions: high phytophthora root rot pressure, high chloride levels, heavy soils prone to saturation, high salinity irrigation water, alkaline irrigation water, and high soil pH.

Dr. Manosalva is preparing the patent paperwork for PP35 and PP40 with the hopes that these two selections will become commercially available to growers in 2023. The remaining rootstocks likely will be released in 2024 and 2025.

Phenology and Ecology of the Avocado Lace Bug

The avocado lace bug is an invasive pest that has been in California since 2004, when it was found infesting backyard avocado trees in the National City/

Adult avocado lace bugs and their eggs on the underside of an avocado leaf (left). Avocado lace bug feeding damage, "necrotic islands," seen on the upper surface of avocado leaves.

Chula Vista area of San Diego County. From the original find in late 2004 until late 2017 there was no known movement of ALB out of backyard trees in the National City/Chula Vista area. However, in October 2017 there were several reports of ALB in commercial avocado groves in the Oceanside and De Luz areas of northern San Diego County. Since then, the pest has continued to spread and is now known to be as far north as Los Angeles County. Given the new movement of the pest and its apparent change in aggressiveness as an avocado pest, the PRC began funding a project with Dr. Mark Hoddle in late 2021 to better understand the biology of this pest to help determine control strategies.

Dr. Hoddle and his team have been conducting quarterly surveys of ALB in commercial groves in Bonsall and Oceanside. Their findings to date tentatively indicate that ALB populations tend to decline in spring and increase in summer through fall. They also have observed several generalist predators—including predatory thrips, predatory mites, ladybugs, and spiders—associated with ALB populations. However, they note that none of these natural enemies are particularly numerous or synchronized with ALB populations.

Genetic analyses completed in 2005 following the original ALB finds in California found that the population in southern San Diego County was from Nayarit, Mexico. However, genetic analyses of northern San Diego County specimens indicated that this population matched populations in Florida and the Caribbean, indicating a second introduction of ALB into California. Dr. Hoddle and his team are now reevaluating the populations in southern San Diego County to determine if the original Mexican genotypes have been replaced by the more aggressive Florida/Caribbean genotypes. Additional ALB populations in Mexico have been sampled and are being analyzed to get a better impression of the overall genetic diversity of this pest.

Feeding damage from avocado seed weevil larvae, Heilipus lauri, on Hass avocado fruit (top). An adult avocado seed weevil (bottom). Photos credit, Dr. Mark Hoddle.

Lastly, Dr. Hoddle and his team are trying to understand how temperature affects the development of ALB. They have conducted their own trials in the lab at UC Riverside and also have been able to access some unpublished data from a study in Cuba. Their analysis of these data shows that ALB has a minimum development temperature of about 48 °F and a maximum development temperature of about 98 °F. These data aid in understanding how temperature, in particular high temperatures such as during heat waves, will affect ALB development and survivorship.

The Avocado Seed Weevil, *Heilipus* Species

Another project currently being funded with Dr. Mark Hoddle is titled, "Proactive Management of Avocado Seed and Stem Feeding Weevils, *Heilipus* species." This project is partially funded by CAC, with the balance of funding coming from a new initiative from the California Department of Food and Agriculture to conduct proactive research on potential invasive pests. CAC has long been aware of the invasion potential of the avocado seed weevil and this threat has been leveraged to prevent or limit the importation of avocados from certain countries.

This was a great opportunity to leverage the funding offered by CDFA

to help us develop early detection tools for this pest so that any potential introduction could be detected early and hopefully, quickly eradicated. Thus, a key component of this research is to purify, synthesize and test under field conditions the aggregation pheromone of the avocado seed weevil.

Using avocado seed weevils in the quarantine facility at UC Riverside, Dr. Hoddle and his team determined that the major component of the aggregation pheromone for this pest is a chemical named grandisol. This compound is well known as it is the major chemical in the pheromone of the boll weevil. This allowed Dr. Hoddle and his team to test their own synthesized version of a grandisol mixture as well as commercially available boll weevil lures for effectiveness in the field. Unfortunately, both failed to attract avocado seed weevils in the field in Mexico.

Grandisol exists in two different forms, which are mirror images of one another. Chemically, these two forms are known as enantiomers. Only one of these forms exists naturally, but commercially synthesized grandisol is an equal mixture of the two forms and biological systems can discriminate between the two. Thus, Dr. Hoddle hypothesizes that the "unnatural" grandisol may be causing interference and inhibiting responses to the natural enantiomer in the field. They are working with cooperators in India to produce the pure natural enantiomer of grandisol. They are planning to test this formulation in the field in Mexico in late spring or early summer of 2023.

Oviposition holes (egg laying holes) from the avocado seed weevil (Heilipus lauri) on Hass avocado fruit. Photo credit, Dr. Mark Hoddle.

Herbicides for Use in Bearing Avocado Groves

Only 10 herbicide active ingredients are registered for use in bearing avocado groves in California. Of these, paraquat is a restricted use chemical making it difficult to use. Glyphosate is under continuous scrutiny and many weed species have developed some level of resistance to it. Thus, there is a need to have more tools in the toolbox so growers effectively can manage weeds in their groves. In 2019, CAC began funding a project to evaluate herbicides currently registered for use on citrus in California for potential use in avocados. Looking at products already registered on another subtropical crop in the state would significantly reduce the timeline and hurdles to registration.

Alion (Indaziflam) was a promising product that provides pre-emergence control of broadleaf and grass weed, including many glyphosate-resistant species. However, Bayer would not support registration of the product due to concerns with the shallow rooting of avocado and the potential for root uptake. Similarly, Treevix (Saflufenacil), which provides good control of broadleaf weeds including those resistant to glyphosate, was not supported by BASF due to issues they have observed on avocados in Chile.

Matrix (Rimsulfuron) — which provides contact and extended residual control of grasses and broadleaf weeds, including glyphosate resistant weeds such as fleabane — was supported by Corteva for registration on avocados. This product will be entering IR-4 trials in 2023 to complete residue studies. If everything goes smoothly, Matrix may be available for California avocado growers by late 2024.

Shadow (Clethodim) is used for postemergence control of grasses and was also supported by its manufacturer, Arysta. Similar to Matrix, Shadow will be entering the IR-4 program in 2023 for residue trials.

What is the IR-4 Program?

The IR-4 Program is a federally funded program that is a partnership between the USDA National Institute of Food and Agriculture and the Agricultural Research Service, U.S. Environmental Protection Agency, the agrochemical industry and commodity groups. The project was formed in 1963 to address the "minor use problem."

In the U.S., fruits, vegetables, nuts, herbs, spices, and ornamental landscape plants are known as specialty crops. This is in contrast to corn, soybean, cotton, wheat, and other small grains that are known as major crops. The agrochemical industry lacks the financial incentive to conduct the efficacy trials and residue studies needed to register agrochemicals on specialty crops (minor crops) like they do on major crops where the chemicals can be sold for use on millions of acres. This became known as the "minor use problem."

The mission of the IR-4 program is to: "Facilitate Regulatory Approval of Sustainable Pest Management Technology for Specialty Crops and Specialty Uses to Promote Public Wellbeing."

Thus, when a specialty crop like avocados needs to have a new chemical registered it does not have to spend the hundreds of thousands to millions of dollars necessary to complete the registration process. We can, given sufficient efficacy data and the support of the chemical manufacturer, submit the product to the IR-4 Program to complete the registration process.

Chloride Mitigation Strategies for Avocado Irrigation Water

Chlorides in irrigation water are a major issue for almost all California avocado growers since avocados are generally considered the most chloride sensitive of all tree crops. However, the issue of managing chlorides has proven intractable. In 2021, the PRC was introduced to Dr. Haizhou Liu, an associate professor of chemical engineering at UC Riverside, who is an expert in chloride mitigation in wastewater treatment systems. CAC funded a one-year project with Dr. Liu to review what technologies exist that could potentially be used at the grove level to treat avocado irrigation water.

Dr. Liu and his team reviewed avocado irrigation water analyses provided by cooperating growers as well as the analyses from samples they collected. The purpose of this evaluation was to conduct a holistic review of the chloride chemistry in agricultural irrigation water. They input this data into chemical modeling software to understand how chloride molecules interact in saline irrigation water. This told them that chloride exists as negatively charged anions as well as in metal-chloride clusters, particularly with calcium, magnesium, manganese and iron. Thus, they could

look for technologies that would specifically handle these conditions.

Next, Dr. Liu and his team reviewed chloride removal technologies that could be a fit for avocado irrigation water. Their review found several candidate technologies, including nanofiltration, electrodialysis, and capacitive deionization with carbon electrodes.

Nanofiltration is a physical separation technology that uses low pressure and low energy input compared with traditional reverse osmosis systems. Furthermore, the membrane materials can be tailored to the specific irrigation water being treated.

Electrodialysis exposes water to low electric voltages using submerged electrodes. During this process, the chloride ions migrate toward an anode via ion exchange membranes, thus separating the chloride from the water.

Capacitive deionization is an example of newly emerging technologies that can be more energy saving and selective by choosing specific electrodes. In these systems, chlorides are removed as solid precipitates eliminating the difficulty of disposing brine solution from traditional reverse osmosis systems.

Dr. Liu and his team will be completing their evaluations and submitting a final report to CAC in February 2023. From this, CAC will be able to determine if there are technologies worth investing research dollars into for on-farm chloride mitigation.

Avocado Crop Coefficient for Optimized Irrigation

The final project currently being funded by CAC is a new project with Dr. Ali Montazar, an irrigation and water management farm advisor with UC Cooperative Extension. This project, like the seed weevil project, leverages CDFA funding. Dr. Montazar had received funding from CDFA to conduct research to re-evaluate the crop coefficient of avocados, but that funding limited his work to a few sites in San Diego and Riverside counties. With CAC's additional funding, Dr. Montazar can expand his study to Ventura County to have data from a broader range of avocado groves.

The crop coefficient (K_c) explains the relationship of a specific crop's evapotranspiration (ET)—the amount of water used by a crop through both evaporation and transpiration—to that of a reference crop. In California, the reference crop is defined as a well-watered pasture grass field.

Systems such as the California Irrigation Management Information System (CIMIS) provide reference crop ET values. To use this information to calculate irrigation needs for avocados a crop coefficient is needed. For example, the irrigation calculator on avocadosource.com uses a crop coefficient of 0.86. This means if the CIMIS data shows a reference ET of 1 inch of water, avocados would need 0.86 inches for the same period.

The current crop coefficient for avocados was cobbled together from several different studies, none of which were specifically designed to calculate the crop coefficient, and using some guestimates from citrus. The current value of 0.86 does not account for any seasonal variation nor does it account for variation in location (e.g., coastal vs. inland valley).

When completed, this new study will provide growers with a robust crop coefficient that accounts for seasonal and geographic variation as well as how irrigation water quality affects the crop coefficient value. This will help growers with their overall irrigation efficiency, which should directly benefit growers' bottom lines since we know irrigation is the single greatest cost in producing avocados.