May 2020

ALMOND BOARD PEST MANAGEMENT STRATEGY
DISCUSSION DRAFT

1 INTRODUCTION

The Almond Industry through the Almond Board of California has long invested in improvement of practices for pest management. A wide range of issues are driving the need to revise our Pest Management Strategic Plan: increasingly difficult state, national, and international regulatory environments (e.g., EU MRLs), new insect/weed/disease pressures, loss of longtime tools to resistance, increasing consumer concerns with the use of pesticides, and new technologies. Pest damage to almond trees reduces yields and potentially tree lifespan, thus reducing the efficiencies of inputs such as land, water, and fertilizer.

For pest management the strategic priority identified in a 2015 strategic planning session of the Production Research and Environmental Committees was: **"Implement measures for early detection of pests and utilize precision methods delivered through a suite of advanced technology tools."** In 2019, the Strategic Ag. Innovations Committee (SAIC) reviewed the priorities developed in 2015 and did not make fundamental changes in direction. The 2019 Board of Directors Strategic goal to "Increase use of Environmentally Friendly Pest Management by 25% by 2025" also sets a direction. Thus, the question for the pest management research program is how to ensure effective and economically viable pest management tools for almond growers, while minimizing risks to human health, beneficial and nontarget organisms, and the environment.

The principles of Integrated Pest Management (IPM) have guided development of this strategic plan. From the UC-IPM website definition of IPM:

> *IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment.*

In short, focus on prevention, use cultural practices where possible, monitor, and when necessary use pesticides in ways that minimize nontarget effects.

New technology provides opportunities to expand IPM in almond orchards and address regulatory and perception challenges, i.e., sensors that more easily monitor pest population dynamics and locations, robotic tools, drones, geospatial mapping, and new application technologies.

The following overarching IPM goals were applied to develop the more detailed pest by pest needs below:

- Understand pest biology within the California orchard agroecosystem to determine ways to prevent and/or exploit opportunities for cultural and biological control.

    - Where appropriate, seek development of resistant varieties/rootstocks
    - Depending on pest biology, consider pest management approaches across larger geographies (area wide or systems approaches)
- Improve monitoring tools and develop thresholds to inform chemical treatment decisions, focusing on treating only when pest levels are likely to cause damage, and reducing grower uncertainty of potential damage.
    - Seek technologies that improve precision of pest detection and localization
- Seek effective chemical and biological pesticides that minimize non-target effects to both humans and the environment, maintaining the ability to rotate between pest management tools.
- Seek technologies that reduce the off-site movement of pesticides through spraydrift and run-off while also improving efficacy.

While these larger principles should guide the pest management research program, the details of pest management are generally pest specific. Thus, the rest of this document reviews more detailed research needs by specific pests or pest categories.

2 Process and General Conclusions

This plan contains lists of current pest problems, IPM practices, needs, research gaps, outreach and policy priorities. Content was drawn from the UC-IPM website and ABC-funded research. Much of the bulleted content reflects discussions held with specialists, industry members and ABC committee members. The Pest Management Workgroup met twice (4/29 and 10/24, 2019), and the Strategic Ag Innovation Committee once (5/1, 2020), to review and help inform development of the needs analysis, and resulting strategic research, outreach, and policy engagement.

General conclusions of the Pest Management Workgroup:

- Prepare for tool losses due to EU and other regulatory pressures
- Increase understanding of pest biology to develop cultural practices minimizing pest pressures
- Increase strategic engagement with registrants on Bio-based pesticides
- Explore automation in order to reduce labor needed for monitoring and pesticide applications
- Continue to search for effective precision spraying methods
- Assess different forms of mating disruption (i.e., mating disruption, Sterile Insect Technology, introduced biocontrol)
- Integrate economic treatment thresholds into research, to ensure that current and new tools are applied when they make economic sense
- Explore impacts to pests due to replacement of older broad-spectrum chemistries with newer more narrowly targeted chemistries (e.g., increasing bug pressure)
- Look for opportunities to consolidate research projects
- Identify results of projects that have ended, facilitate wind-down of those that are ending, and facilitate those that should strategically continue
- Continue to assess efficacy of pesticide tools
- Explore continued opportunities for partnership with UC-IPM, farm advisors on research and extension

- Continue identification of new pesticides and technologies coming onto market through regular coordination with registrants

2.1 2025 Pest Management Goal

Board Strategic Goal: Increase use of Environmental Pest Management by 25% by 2025

Success in meeting this goal will predominantly rely on outreach focused on increasing adoption of key, proven IPM strategies that are included in the metric. There is a limited role that research is expected to play in achieving this goal. However, the goal does set a direction for the research program to increase the availability of environmentally friendly pest management options to almond growers.

Notes on Chemical Tool lists:
FRAC Mode of Action Group Number are in (parentheses).

Potential regulatory issues are signified with color coding:

Orange = potential for regulatory to affect ability to use

Red = regulatory issues affect ability to use

3 INSECTS

3.1 Navel Orangeworm (NOW)

As the industry's major insect pest, over 40 years of research investment by ABC has led to the current five-point plan (sanitation, monitoring, chemical tools, timely harvest, and mating disruption). Although damage levels have decreased from the 1970s, driving related reductions in aflatoxin contamination, there is still room for additional improvement through grower outreach and adoption of best practices.

The positive economics of reducing damage through practice adoption has been established, for example in presentations at the 2019 NOW Summit.

Chemical tools:
Methoxyfenozide/Intrepid (18) · Spinetoram/Delegate (5) · Chlorantraniliprole/Altacor (28) · Cyantraniliprole/Exirel (28) · Emamectin Benzoate/Proclaim (6) · · Bifenthrin/Brigade (3A) · Lambda-cyhalothrin!/Warrior (3A) · Fenpropanthrin/Danitol (3A) · Esfenvalerate/Asana (3A) · Spinosad/Success, Entrust (5) · Phosmet/Imidan (1B) · Aluminum Phosphide (post-harvest) (24)

There are opportunities for continued refinements in NOW management, including expanding adoption of mating disruption, addressing challenges of mummy nut removal (i.e., new self-fertile varieties, labor costs, abscission agent), developing thresholds and monitoring programs to target timing of applications in orchards with mating disruption, and new technologies (e.g., Sterile Insect Technology).

Current Practices and Issues. The species' long flight distance (Burks) and higher damage close to pistachio orchards means it is a ubiquitous pest across the Central Valley, potentially requiring area-wide control across multiple crops. Figs, pomegranates, and walnuts are also major hosts.

Resistance. NOW resistance to pyrethroids e.g. bifenthrin (Brigade) is established in certain areas, and research has explored how this resistance develops and the potential role of adjuvants in overcoming resistance (Berenbaum). A concern is that heavy use of methoxyfenozide (Intrepid) and chlorantraniliprole (Altacor) could also lead to resistance.

Rotation of pesticides is currently possible, but could be more limited if regulatory restrictions increase. Off-target pyrethroids are carefully monitored under the Irrigated Land Regulatory Program due to their sediment toxicity (parts per trillion kill certain benthic organisms). Esfenvalerate (Asana) is an EU Persistent-Bio-accumulative-Toxic (PBT). Chlorpyrifos (Lorsban) use has recently been cancelled in California and in the EU. Methoxyfenozide use in the EU is to be limited to greenhouses, which may impact almonds' ability to retain an MRL.

There are also issues with certain products. Emamectin (Proclaim) is reportedly used in excess due to the low cost, so may be at similar risk of resistance development. Spinosyns (Success) may be disruptive of predaceous thrips and some parasitoids, and methoxyfenozide (Intrepid) also affects beneficials. Thus, there is a need for additional Active Ingredients with different modes of action than 3A, 18, and 28 to reduce the development of resistance and account for possible regulatory losses.

Pheromone based Mating Disruption. Mating disruption (i.e., Puffer, Semios, Isomate, Cidetrak) is the newest practice, developed in part through ABC research funding, and it has significant room for grower adoption. Research has shown that mating disruption is effective in orchards as small as 40 acres (Haviland), so adoption should be considered as part of area-wide or neighborhood programs. Monitoring under mating disruption remains a challenge.

Monitoring. With adoption of mating disruption, there is a continued need to develop monitoring methods that aren't reliant on pheromones (Beck). Most recently a phenyl propionate (PPO) and kairomone blend (Burks), as well as trap design have been explored. Timing of application, residual activity (Siegel), and lifestages impacted (Zalom) are other important variables. Another alternative trap, Solarid, has also been tested (Symmes). While current monitoring helps with the timing of applications, it doesn't provide thresholds for when treatment is needed.

Winter Sanitation. Winter Sanitation aka mummy nut removal has been the backbone of the NOW IPM program for over 30 years, but adoption hasn't been universal for a variety of reasons. Those with only hardshell varieties may be less concerned about NOW damage. Their orchards however still provide overwintering habitat for NOW, which can then move into nearby orchards with soft shell varieties. Newer varieties have also been harder to shake during harvest, leading to more mummy nuts. Recent changes in labor regulations in California have made it a costlier practice.

Changing Growing Practices. ABC is exploring off-ground harvest, and potential costs and benefits for NOW management. Recent research has looked at the effect of increased cover crops on mummy management (Wilson).

Sterile Insect Technology Mating Disruption. A recent project is exploring use of NOW Sterile Insect Technology (NOW SIT) as another way to implement mating disruption. The effort, in collaboration with the pistachio industry, CDFA and USDA-APHIS, is ongoing to see if the technology can be made to work for NOW. It may also be a technology to consider for other almond insect pests. Previously the NOW genome has been sequenced (Berenbaum), potentially aiding a CRSPR sterilization approach.

<u>Needs</u>

- Improve trap and monitoring effectiveness, especially under mating disruption
- Improve shaking efficacy
    - Some varieties are hard to shake, leading to at least 4 sprays
    - Develop abscission agent
- Explore off-ground harvest costs/benefits (Harvest Work Group)

- Will earlier harvest (e.g., beginning hull split) and off-site mechanical drying reduce NOW damage and aflatoxins?
    - See early harvest data from 1970's
- Increase research/ outreach on economics of pest management
    - Is mummy nut removal economical?
- Explore area-wide approach
    - Follow-up on population sources in all host crops
    - Increase coordination and develop a system across and within crops
- Support development of beneficial predator populations
    - Lacewing (green and brown) should be looked at for predatory benefits
    - Revisit Ken Hagen UCB augmentation (30 years ago)
- Continue search for new conventional and biobased pesticides or other tools to avoid damage and aflatoxin; assess their efficacy
- Assess risk of resistance development in current pesticide tools
- NOW SIT
    - Funding received, area-wide plans in development, releases occurring in location with complete IPM program including mating disruption
    - Expand locations for large scale release testing?
    - Funding for research is now coming from USDA-APHIS
    - NOW Action Committee directing project; NOW-Technical Advisory Committee reviewing science
    - "Roadmap" prepared for ABC describes path forward, including alternate sterilization options being explored (CRSPR, x-ray)

<u>Research gaps</u>

- Determine cultural or chemical practices that support development of beneficial predator or pest populations
- Revisit study of the insects that are in orchards and that may be beneficial with the current orchard management (e.g., less broad spectrum insecticides)
    - See previous research (Chiu) on gut composition
    - How do pesticides affect beneficials, if present?
- Study relationship between pinhole damage and aflatoxins (e.g., Japan exports) or other sources of aflatoxin contamination
- Improve mating disruption and monitoring, to optimize pesticide timing
    - Burks and Beck (The Blend) research on NOW attractants in mating disruption orchards
    - Good thresholds still needed for NOW, although monitoring has been useful for timing of pesticide applications
- Develop abscission agent
- Physical survey of sanitation practices

<u>Outreach</u>

- Adoption of mating disruption by small farmers might remain low in the future. Need NRCS incentive for mating disruption, and area-wide approach.
- Economic benefits of NOW damage reduction

3.2 Mites

Chemical tools:
Abamectin/Agrimek (6), Bifenazate/Acramite, Clofentezine/Apollo (10A), Cyflumetofen/Nealta (23), Etoxazole/Zeal (10B),Fenbutatin-oxide/Vendex (12B), Fenpyroximate/Fujimite (21A), Hexythiazox/Onanger (10A), Propargite/Omite (12C), Spirodiclofen/Endivor (23), narrow range oil, Acequinocyl/Kanemite (20B)

Webspinning mites (*Pacific spider mite: Tetranychus pacificus, Strawberry spider mite: Tetranychus turkestani, Twospotted spider mite: Tetranychus urticae*), when unchecked, seriously damage the leaves causing premature leaf fall, thus reducing the photosynthetic energy for current and next year fruit development. The mites tend to flare under hot, water stressed, and dusty conditions. The use of certain insecticides such as pyrethroids for other pests can cause mite flares by killing beneficials that control mites.

Research is exploring the physiological and economic impacts of defoliation by mites, to determine what level of damage is sufficient to trigger treatment.

Current Practices and Issues. Reducing dust as well as avoiding water stressed trees are key practices to reduce mite flares. However, some level of water stress is unavoidable during harvest for shaking and drying of the nuts. Current harvest practices are dusty.

The use of a prophylactic application of abamectin (AgriMek) in late April/May before leaf hardening is widespread due to ease and price. The advantage of using abamectin is that it controls mites sufficiently to reduce the need to monitor if they are reaching critical levels. This is helpful particularly during harvest when trees are drought-stressed and dusty, and growers are busy. It also allows the use of pyrethroids for NOW control without worrying about flaring mites. There is concern about resistance development to abamectin due to its widespread use.

Recent Haviland/Rijal/Symmes research should improve grower confidence that by monitoring webspinning mites and predatory thrips populations, and tracking thresholds, growers can avoid treatment including a prophylactic abamectin spray. Research shows abamectin and pyrethroid applications kill beneficial thrips and other mite eating insects. If the beneficial populations are not adequate, there are several compounds available to growers when mite populations threaten to flare. Outreach will be needed to overcome barriers to adoption.

There are other chemical considerations. In addition to pyrethroids, spinetoram (Delegate) also reportedly kills beneficial thrips. If monitoring does not show sufficient beneficials, hexythiazox (Onager) with its longer PHI is preferred for a tank mix in the first hullsplit spray. Etoxazole (Zeal) with its shorter PHI is better for a second hullsplit spray. These do not have the same knockdown effect as abamectin, however.

Needs:

- Optimize thrips-mites IPM monitoring and thresholds, economic damage levels
- Confirm alternate chemical approaches
  - Wait 2-3 weeks after any May spray to tank mix etoxazole (Zeal) or hexythiazox (Onager) into hull split sprays, although they aren't contact toxins. Bifenazate (Acramite) is a contact toxin and top-rated by UC-IPM.
  - 2% Oil also effective
  - If using abamectin, 1% oil suggested as adjuvant

- Assess field conditions favorable to beneficial insects/predators (e.g. alternate row and cover crop mowing)
    - What helps the lacewings (e.g., alternate row mowing) which feed on mites?
- Understand how mites select certain trees to attack (Dykstra)
- Free ammonia from over application of N reported to attract mites. Spoonfeeding N can avoid this issue (Irrigation, Nutrition Soil Health Workgroup).

3.3 San Jose Scale

Chemical tools:
pyriproxyfen/Seize (7C) or buprofezin/Centaur, Applaud (16), carbaryl/ Sevin (1A), narrow range oil sprays

San Jose Scale can kill fruiting wood and branches by injecting a toxin into the wood.

Current Practices and Issues. This pest seems to be under good biological and targeted chemical control. Prior research established thresholds based on dormant spur sampling and sufficiency of dormant oil spray and/or insect growth regulator. There is a limited number of growth regulator chemicals available, but they should only be necessary occasionally. Continuing education on monitoring and thresholds may be needed.

Needs:

- Seen as largely under control
    - Nevertheless, may increase due to move away from dormant sprays. Over time seeing some build up in middle aged orchards.
    - Prior research established thresholds and sufficiency of dormant oil spray
    - Dormant treatment may increase due to tank-mixing with kasumin also applied in dormancy
- Improve sampling across almond varieties, to determine whether some are more or less susceptible
    - For sampling look across different varieties, as seeing more walnut scale in Independence, Monterey, and Avalon varieties (not Nonpareil).
    - Sticky traps are hard to monitor as they catch other things as well
    - Easier to scout and better to treat in dormant season

3.4 Southern Fire Ant & Pavement Ant

Chemical baits:
Pyriproxyfen/Esteem (7C);
Abamectin/Clinch Ant Bait (6);
Methoprene/Extinguish (7A);
Metaflumizone/Altrevin (22B)

Damage due to protein-loving ants increases in relation to the length of time nuts are on the ground. 10% of kernel damage is estimated to be from ants. Red Imported Fire Ant is found in some orchards and is a CDFA managed pest. They can chew on soft plant tissue and growing buds, while stinging behavior is hazardous to people. Sugar ants can clog irrigation lines and short-circuit electrical systems. Damage can peak when Nonpareil irrigation is turned off.

Current Practices and Issues. Ants are primarily controlled via ant baits containing insecticides, no longer via contact insecticides such as chlorpyrifos. The baits work well as long as they are put out well enough in advance of harvest to provide control. Double treatment with bait is common, although a single treatment product is desired. Pyriproxyfen (Esteem) is reported as top product, although it takes 10-12 weeks to work. When used, it can be an every other year product. Treatment mid-June uses growth regulators pyrproxifen or methoprene, while the stomach poison abamectin is used 3 weeks later.

If the industry moves to off-ground harvesting, there may be less need for pavement ant control.

Needs:

- Confirm Red Fire ant presence and potential for eradication possible (they are subject to quarantine regulations). Organic treatments other than boric acid?

3.5 Bugs

"Bugs" includes the leaffooted bug and various stinkbugs such as the green stink bug and the recently introduced non-native brown marmorated stink bug.

Current Practices and Issues. Regulatory pressures have resulted in the loss of key products e.g., chlorpyrifos (Lorsban) necessary for management of various bug pests. Research has been done on best chemical options for leaffooted bugs (Haviland). Chlorpyrifos use has been curtailed in CA, and will be cancelled entirely in 2020. Clothianidin is being cancelled in EU due to pollinator concerns, with potential loss of MRLs. Pyrethroid use can spike spider mites.

Chemical tools:
Bifenthrin/Brigade WSB (3A); Lambda-Cyhalothrin/ Warrior II with Zeon (3A); ~~Chlorpyrifos/Lorsban 4E (1B);~~ Clothianidin/Belay (4A). Abamectin (6A) and Esfenvalerate (3A) also for leaffooted.

With reduction of organophosphate and pyrethroid use for other pests, bugs that used to be indirectly controlled increased.

For leaffooted bugs there have been efforts at developing a monitoring program (Tollerup), understanding aggregating behavior, differentiating two predominant species (Joyce), and developing pheromone attractants for field monitoring (Millar).

Current research is focused on brown marmorated stink bug and estimating potential damage at different stages of nut development (Rijal).

Less common pests are red shouldered stink bug and green plant bug.

Needs:

- Continue focus on monitoring and regional/ varietal susceptibility
  - Stink bugs seem to each prefer certain varieties. Leaffooted bugs reported to attack Aldridge variety at greater rate
  - Bugs are hard to monitor, hide when look for them. Pyramid traps too expensive unless make yourself.
  - When do they move into orchard- assumed as certain times of day as hard to find despite damage (basic biology). Where do they come from- more problematic near grass lands.
  - Green stink bugs most common
  - Brown Marmorated stink bugs increasingly of concern; similar management to leaf-footed Bugs
- Continue focus on finding effective pesticides

    - Controlled with pyrethroids (1-2 sprays in April/May) but with associated issues (water quality, impacts on beneficials for mites)
    - Neonicitinoids -clothianidin/ Belay and acetamiprid/ Assail- effective against nymphs, but not over-wintering adults
    - Explore spirotetramat/ Movento and buprofezin/ Centaur effectiveness
- Determine need to focus on new pests:
    - Gill's mealybug – reduce nut size and yield
    - False Cinchbug – can be huge problem in young trees
    - Tenlined June Beetle- previous research (Zalom, Fichtner) didn't identify definitive chemical treatments, but may be cultural management options
    - Consperse stink bug- reported as issue. Pheromone available?

<u>Research gaps</u>

- Improve bug management- basic biology, identify predators, monitoring protocols, treatment thresholds, treatment timing (e.g., dormant aggregations, in-season), regional/ varietal susceptibility, address trap high cost
    - Revisit status of beneficials under current management with fewer broad- spectrum insecticides
    - Assess effect of practices (e.g. alternate row and cover crop mowing) that may be favorable to both beneficials and pests
    - Study effects of trees and habitat along perimeter of orchards (e.g., bugs)
    - Develop cheaper traps and monitoring methods for bugs
- Address treatment of brown marmorated stink bug, assess level of spread throughout Central Valley, location, control methods, and potential risk
- Provide guidance for thresholds (e.g., once shell hardens in June leaf-footed bug can't penetrate shell)
- Role of repellants for bugs?

<u>Outreach</u>

- Outreach around mites and impacts of defoliation research
- Education around proper use of ant bait (e.g., Pyriproxyfen/Esteem)
- Coordinate bug research funding with other groups
- Drive adoption of mite- beneficial thrip research
- Reduce weed pressure to control stink bugs
- Work with UC-IPM to develop provisional guidelines for brown marmorated stink bug (done for peach and apples)
- Develop guidelines on what scale varieties to scout for, outline dormant season treatment with oil

4 WEEDS

Post-emergence: Glyphosate/ RoundUp, Glufosinate/ Rely, Oxyfluorfen/ Goal, Rimsulfuron/ Matrix, Paraquat/ Gramoxone, 2,4-D/ Orchard Master, Saflufenacil/Treevix

Pre-emergence: Indaziflam/Alion, Oryzalin/ Surflan, Pendimethalin/ Prowl, Simazine/ Princep, Sethoxydim/Poast,Fluazifop-p-butyl/Fusilade, Clethodim/SelectMax, Norflurazon/Solicam, Flumioxazin/Chateau, Isoxaben/Trellis, Trifluralin/Treflan

Weed management in almonds is complex with different management needs of tree rows vs. middles, frost protection considerations, soil quality management, use of cover crops, clean orchard floors for harvest, etc. Growers have been using mixtures of herbicides -plus mowing middles- selected to cover a range of weed species. However, the widespread and repeated usage of glyphosate and other herbicides is leading to resistance in summer grass weeds (e.g., Junglerice) and perennial weed species (i.e. bindweed, field or nutsedge, yellow).

The following weeds are lacking sufficient chemical control: blackberries, junglerice, knotweed, nettle burning, puncturevine, sprangletops, and thistle. Most of barnyardgrass and Bermuda grass preemergence chemical control are from Mode of Action group 3. Therefore, the limited number of groups for barnyardgrass and Bermuda grass, and alternatives for summer grass weeds such as junglerice, are areas that need more attention.

Issues facing herbicide use include: public perception of glyphosate (e.g., EU); reductions of MRLs in the EU for paraquat (impact on human health), glufosinate/Rely, glyphosate likely; increased reliance on herbicides with Mode of Action group 1: sethoxydim/ Poast, fluazifop-p-butyl/Fusilade, clethodim/SelectMax.

With glyphsate/ RoundUp under regulatory pressure, and the target of health-related court cases, it makes reliance on one chemistry more tenuous. Addressing the potential loss of glyphosate (and glufosinate) requires developing alternatives, along with managing PR and EU MRL policy. Research has shown there are cultural and chemical methods available to improve methods of weed management (Hanson). With no new herbicide Mode of Action developed over the last thirty years, current strategy is to maintain existing products, improve their use and management, and find ways to reduce or eliminate residues picked up during harvest that could threaten marketing of product.

<u>Needs:</u>

- Continue investing in best practice development (Hanson)
- Pursue alternatives to post-emergent herbicides glyphosate/glufosinate
    - Enlist/ 2,4-D and glyphosate is a new product, but no new Active Ingredients
    - Acetyl CoA Carboxylase (ACCase) Inhibitors (e.g., Fusilade/ fluazifop-p-butyl, Poast/ sethoxydim) may become more attractive if lose glyphosate. Explore whether they have VOC or risk cup issues.
    - Paraquat worker safety concern
    - 2,4-D crop safety and drift concern
    - SelectMax/ clethodim recently approved for bearing use
- Pursue alternatives for pre-emergence tools
    - Not many
    - Treevix/ saflufenacil helpful, but not effective on all weeds

- Determine necessary dates for orchard middles to be clean
- Continue identifying orchard floor management opportunities in off-ground harvest research trials, as could relieve need for clean orchard floors (Harvest Workgroup)
- Identify the most challenging weeds and develop strategies accordingly
    - E.g., Alkali weed in pistachios resistant to glyphosate
- Address VOC limits 5/1-10/31
    - GoalTender/ Oxyfluorfen limited to 8 ounces / acre (ideally want 16-32 ounces) in the San Joaquin Valley due to VOC limits. Lower concentration doesn't work as well for burn down, works well for residual. Can formulation be changed to reduce VOC concerns? What does VOC compliant product look like?
- Address resistances issues (Hanson)
    - Concern that summer grasses increase due to resistance, climate change
    - Rye grass resistance to: glufosinate/ Rely. Some level or resistances to Fusilade/ fluazifop-P-butyl and Matrix/ rimsulfuron
    - Fleabane, horseweed, blue grass, rye grass resistance to paraquat
- Coordinate cover crop and weed management
- Determine whether residues come from pick-up (hulling & shelling), overspraying of windfall, or are systemic

Vulnerability assessment for annual weeds:

Assessment of chemical that provide verified control to Annual Weeds				
	POSTEMERGENCE		PREEMERGENCE	
Weed name	# of products	# of FRAC	# of products	# of FRAC
barnyardgrass	4	4	4	2
chickweed, common	4	4	7	5
crabgrasses	5	5	4	2
fleabane, hairy	4	4	4	4
foxtails	5	5	5	3
goosefoot, nettleleaf	4	4	6	4
horseweed	4	4	4	4
junglerice	2	2	4	1
knotweed, common	0	0	7	3
lambsquarters common	4	4	7	4
lettuce, prickly	5	5	5	4
mallow, little	3	3	4	3
nettle, burning	1	1	5	3
nightshades	5	5	5	4
pigweeds	5	5	8	5
puncturevine	3	3	1	1
purslane, common	5	5	8	5
sandburs	3	3	3	1
sowthistles	4	4	5	4
sprangletops	2	2	0	0
thistle, Russian	3	3	2	2

There is low number of products for the following weeds:

- No products: knotweed (post), sprangletops (pre)
- One product: nettle (post), puncturevine (pre)
- Two products: junglerice (post), sprangletops (post), thistle

For the following weeds, few modes of actions are available:

- Preemergence: barnyardgrass, crabgrasses, junglerice, puncturevine, sandburs, sprangletops, thistle
- Postemergence: junglerice, knotweed, nettle, sprangletops

The weeds that present the highest challenge given the above are junglerice, knotweed, sprangletops, nettle, puncturevine, and sandburs.

<u>Research gaps</u>

- Explore automation for robotic weed management tools to reduce labor
- Coordinated management of middles, beneficial insects and cover crops
- Explore how off-ground harvest could impact weed management (Harvest Workgroup), such as reducing herbicide treatment, and changing the purpose of weed management. As example, see how peaches manage orchard floors.
- Explore time, equipment (tier 4 engine), labor effects of mowing middles instead of herbicide treatment. When do middles need to be clear (e.g., March or April?)
- Explore whether adoption of single, self-compatible varieties change/improve ability to mow
- Potential for cover crops to out-compete weeds
- Develop a PHI for glyphosate (3 day PHI) and glufosinate (14 day PHI) that doesn't have residues (Hanson)
- Develop use data to correlate with residue data
- Develop new mower design other than flail, which can spread mites

<u>Outreach</u>

- Increase mowing of middles, instead of herbicide treatment
- Sharpen understanding of weed management and outreach, including aesthetic vs. agronomic desire for clean floors
- Advice for tree rows is to use a pre-emergent; however some growers use multiple post-emergent treatments
- Different options for smaller, medium or large farms, given different equipment

5 DISEASES

Diseases caused by viruses, bacteria and fungi can reduce almond production in various ways. Diseases of the wood accelerate tree death reducing orchard lifespan, foliage diseases reduce photosynthetic capacity impacting yields, and diseases of the fruit cause premature nut fall and damage to the nuts impacting yield and quality.

5.1 Trunk and Scaffold Cankers

Priorities in order: band canker, bacterial canker, Ganoderma.

5.1.1 Band Canker (complex of fungi: *Botryosphaeria dothidea, Diplodia seriata, Neofusicoccum mediterraneum, Neofusicoccum nonquaesitum, Neofusicoccum parvum*)

UC-IPM states that band canker has started showing more frequently in the last decade. Previously it was seen in localized areas near riparian areas or in proximity to walnuts. Recently it was seen in a uniform pattern across whole orchards. Concern that it was coming from nurseries, led to development of a new quantitative real-time PCR (qPCR) tool developed for early detection (Michailides). When symptoms of band canker appear, there isn't chemical control for management, although selected fungicide and biofungicides are being tested for efficacy when applied to trunk wounds (Trouillas). It is therefore seen increasingly as a problem.

- Band canker complex seen as major issue and top priority
  - Explore theories for uniform presence in orchards: lifestyle issue from pushing young trees to get 3rd year harvest and shaker spreading.
  - 3rd year crops can have significant shaker damage that may increase band canker (Shackel)
    - Drying tree out may help avoid bark damage
    - Varieties with peach genes (e.g., Independence) seem more sensitive to barking
- Explore whether chipped prunings increases band and bacterial canker
  - When tree biomass buried (e.g., whole orchard recycling/ WOR) it reduces survival of Botryosphaeria, but possible issue if on remains on surface
    - Hasn't shown up in WOR trials to date
  - More worried about prunings as not typically incorporated, worse if add as shredded material.
    - Need to maintain ability to burn for diseased wood

5.1.2 Bacterial Canker (*Pseudomonas syringae*)

More prevalent in sandy areas. Cultural management includes ripping soil before planting to break up hardpan areas. Control is possible with fumigation, rootstock selection, and proper nutrition. Telone use is subject to township caps, and fumigants are undergoing state and federal review, with CDPR exploring restrictions/mitigations for Telone. All soil fumigants require significant buffers to inhabited spaces.

> Chemical tools:
> 1,3 dichloropropene/Telone and chloropicrin. Annual nematicide treatments in October can reduce severity.

Recent studies have shown that when low-biuret urea is applied before leaf drop, canker size in infected trees is reduced.

- Identify new treatment products
- Identify right conditions for biological control
  - Current research (Adaskaveg)
  - Better nutrition seemed to help trees grow out of canker in younger orchards
  - Bt treatments could have efficacy
  - Sandy ground is "blast heaven"
- Alternative Soil Disinfestation (ASD) control costs still an issue
  - Haven't tried ASD in sandy bacterial canker prone area

    - Requires extra year before replanting and a hot summer. ASD stimulates growth and reduces nematode populations
    - Requires temporary increase in irrigation system to 6 lines. If enough growers have interest, trical would figure out how to lay drip lines.
    - Organic inputs are expensive, however ground almond hulls and shells can work and are less expensive
    - Not easy, and niche is in buffer areas where fumigation not possible.
    - Could it get carbon credits? Provide nutrition for trees?
- Stress as issue vs. carbohydrates

5.1.3 Ganoderma

- Butt Rot increasing problem in young trees
- Research shows that larger wood blocks can host Ganoderma underground
- New species G. adspersum is more aggressive than G. brownii. Seen on peach root stock in sandy soils.
- Site of initial damage at soil line, with theory that damage is related to shaking
- Prevention? Control? Shaker? Irrigation issue?

5.1.4 Phomopsis/lower limb die-back

- Given that it has been a research area for several years, interest but no consensus that more is needed. The causes are reported as potentially irrigation related (incidents vary by irrigation method), particularly if not using soil moisture monitoring tools. Some thought that there's a relationship to san jose scale, but others had counterexamples.
    - Research (Michailides, Lampinen) didn't identify a chemical solution
    - Overwatering an issue- double line drip worse than solid set sprinkler with same amount of water
    - Butte/Padre particularly at risk, but may be side effect of moisture management

5.1.5 Silver leaf

- Resurgence reported in young orchards, in certain regions and varieties
- May be associated with pruning timing
- UCIPM recommends management with Trichoderma on pruning cuts

<u>Research Gaps:</u>

- Correlate carbohydrates and disease, with teams linking physiologists and pathologists
- Test alternate band canker theories of shaker spreading, variety vulnerabilities, "lifestyle" factors. Research how to shake in young orchards, water management, training of shaker operators.
- Study ASD impact on bacterial canker in sandy soils
- Look at vectoring capacity of bugs, such as whether stink bug vectors spot or almond leaf scorch, as they feed on tender wood (Daane)
- Improve understanding of silver leaf biology

<u>Outreach</u>

- Avoid shaker damage in young orchards, in some soils shut water off sooner

- Don't allow bands to tighten around growing tree, keep trunk dry by using splitters
- Outreach of results from Trouillas lab, using Trichoderma for pruning wound protection
- Silver leaf identification and treatment

5.2 Leaf, Branch and Fruit diseases

Main issues are spray efficiency, EU regulations and resistance development.

> Chemical tools:
> Metconazole/ Quash (3), Difenoconazole/ Inspire (3), polyoxin d zinc salt/Ph-D (19), Pyraclostrobin/ Pristine (11), Boscalid (7), Fluxapyroxad/ Merivon (7), Fluopyram/ Luna Sensation (7), Trifloxystrobin (11), Difenoconazole/Inspire (3), Cyprodinil/ Inspire Super (9), Azoxystrobin/ Abound and Quadris Top (11), Penthiopyrad/ Fontelis (7), Iprodione/ Rovral (2), Narrow range oil

5.2.1 Alternaria leaf spot

Controlled with canopy training, orchard orientation, variety selection, avoiding poor drainage, reducing trunk wetness from sprinkler, and planting on berms.

Treatment begins mid- to late April. Current research into resistance development and treatment modeling; new fungicides.

- Most serious in southern San Joaquin Valley and Sacramento Valley
- Explore leaf surface for presence of bacteria that could provide Alternaria control
- Explore need for more environmentally friendly tools, such as biological control where have some options available
- Identify number of modes of action groups that will be left standing due to EU MRLs
  - Still have good materials but worry about resistance development with loss of broad spectrum and triazoles
  - How much resistance is being seen in the field?
- Alternaria prediction tool not being used

5.2.2 Hull Rot

Controlled with regulated deficit irrigation, avoiding standing water, managing nutrition at hullsplit, variety selection, and two spray program. Fungicide applied prior to hullsplit, tank mixed with NOW product. Current research into resistance development and treatment modeling; new fungicides; source pathogen; tests to identify source pathogen (A. niger).

> Chemical tools:
> Difenoconazole/Inspire (3), Cyprodinil/ Inspire Super (9), Fluopyram/ Luna Sensation (7), Trifloxystrobin/Gem 500SC (11), Metconazole/ Quash (3), Azoxystrobin/ Abound and Quadris Top (11), Pyraclostrobin/Pristine (11), Fluxapyroxad/Merivon (7), Boscalid (7), polyoxin D (PHD) for *Rhizopus*

<u>Needs:</u>

- Identify fungicide application timing and mix
  - Timing of NOW sprays at hull-split not ideal for hull rot application. Optimum application timing varies by variety: Monilinia 3-4 weeks before hull split (early June), Rhizopus 20% hull-split in September timeframe, aspergillus niger 2 weeks after hull split.
  - Making the tank mix alkaline seems to improve efficacy – outreach ready? Dicap seems to help, but alkaline looked best.
  - Need a treatment/ monitoring tool
  - Growers reluctant to apply 2 sprays
- Continue to identify bacteria variety

    - Hard to identify species, need tools, as only have history.
- Continue to explore impact of nutrition
    - Data on why spoon-feeding N would reduce hull rot? Does N affect all hull rot organisms equally?
    - What is optimum leaf N be throughout the season? Adaskaveg recommendation end of May, Brown recommendation by hull split.
    - 15% spoonfed N per week won't lead to excess hull rot (Brown), but need to develop maximum amount for N. Should study be expanded to other regions beyond southern San Joaquin Valley? See previous research (Doll, Holtz), and enhance existing research (Yagmour).
    - Need outreach on timing. Just before hullsplit, the May/kernel fill application, is identified as the latest desired to reduce hull rot, and should have 80% N applied. The remaining 20% should be applied post-harvest (Niederholzer).
    - Yaghmour trials not seeing influence of N for increased hull rot risk
- Continue to explore impact of water management
- Why does hull-rot impact some orchard blocs and not others?

5.2.3 Bacterial spot/*Xanthomonas arboricola pv. Pruni.*

> Chemical tools:
> Copper, Mancozeb

Wet springs increase disease pressure, with mummies as primary source of inoculum. Research on antibiotics such as Kasumin-manzate and mycin ongoing (Adaskaveg). Treatment dormant and late dormant. In-season treatment around rain events.

- Continue to research what conditions contribute to development, susceptible varieties
- Identify best chemical control
    - Check use of antibiotic, alone or with mancozeb
- Improve mummy removal
    - Mummies formed in spring due to disease are difficult to remove (nuts flattened and stuck tight)

5.2.4 Bacterial blast (Pseudomonas syringae)

Varieties affected include Butte, Independence, Aldrich, and Wood colony. It is associated with cold freeze events and high moisture.

- Secure chemical control
    - Secured Sec 18 for kasugamycin, due to significant impacts in previous year
- Research carbohydrates
    - Effect on CH reserve as some varieties show more damage

<u>Research Gaps</u>

- Develop an abscission agent to more effectively shake
- Timing of treatment thresholds and applications for hull rot control
- Bio-control to compete with hull rot fungi

Outreach

- N management for hull rot control
- Educate on new blast products
- Alternaria prediction tool

5.3 Bloom diseases

5.3.1 Anthracnose, Brown rot blossom blight (*Monilinia*), fruit russeting, green fruit rot, rust, scab, shothole

Treatment decisions based on bloom, leaf, branch, fruit monitoring prior to harvest; dormant spur samples; and rain predictions during bloom. Previous research into impact of fungicides on almond flower fertilization (Williams). Treatment timing varies by disease with fungicide treatments across range of pink bud, full bloom, post-bloom, dormant and delayed dormant.

Rust is treated based on history as can't monitor until too late, with spring sulfur application followed by fungicide in late spring/ summer. Outbreaks occur with late rains, and worse if orchard is higher density, due to high humidity. Need to treat prophylactically.

For scab, can see lesions on new twigs so know will be there next year, with treatment similar to that of rust.

Current research into resistance development, treatment modeling and new fungicides (Adaskaveg); also honey bee as vector to distribute biocontrol of blossom blight (Vanette).

Chemical tools:
Difenoconazole/Inspire (3), Fluxapyroxad/Merivon (7), Azoxystrobin/ Abound and Quadris Top (11), Fluopyram/ Luna Sensation (7), Metconazole/ Quash (3), Pyraclostrobin/Pristine (11), Trifloxystrobin/Gem 500SC (11), Boscalid (7), Chlorothalonil (M5), Propiconazole/Tilt (3), Captan (M4), Thiophanate-methyl/Topsin-M (1), Mancozeb/ Maneb/ Manzate (M3), Ziram (M3). Fenbuconazole/ Indar 2F (3), Cyprodinil/Inspire Super (9), Fluxapyrad/Merivon (7 & 11), Fluopyram/ Luna Sensation (7), Tebuconazole (7), Iprodione/ Rovral (2), Narrow range oil, Pyrimethanil/Scala SC (9), Fenhexamid/ Elevate (17), Myclobutanil/Laredo (3). Sulfur (M2), copper (M1)

Needs:

- Identify how many modes of action groups will be left standing given EU situation
    - Prepare for resistance management if lose materials
    - How much resistance is being seen in the field?
    - Environmentally friendly tools?
- Continue to explore bee impacts (Pollination Workgroup)
    - Concerns about bees and fungicide use
    - Hard to spray at night if using custom applicator
    - For pollination, avoid tank mixed insecticides
- Explore efficacy of aerial applications
    - Desire to avoid aerial spray restrictions, as need use of aerial treatments when ground too wet
- Incorporate economic analysis into research
    - Haven't focused on whether to spray, rather when to spray. So everything (e.g., Scab control) is insurance.
    - Determine economically beneficial thresholds for fungicide sprays for scab and hull rot.
- Bloom disease is big problem for organic growers

Research gaps

- Review past research, explore new research on effect of adjuvants on fungicide efficacy, due to potential bee impacts
- Economic analysis of damage compared to control
- As results of bee vectoring project are assessed, explore additional biological control projects for bloom disease
- Aerial application efficacy

Outreach

- Education around variable environmental conditions that can exacerbate diseases (e.g., east side hills and swales have more susceptibility to shothole and bot; blossom blight affects Sacramento Valley)
- When adjuvants are or are not useful

6 SOILBORNE PESTS AND DISEASES

Fumigation is a critical component of almond growing, particularly in areas with high levels of nematodes or replant disease (Doll). The loss of Methyl Bromide led to a search for alternatives, landing on Telone or Telone + chloropicrin, and spot fumigation (Doll). However, there is now significant regulatory pressure on Telone. In this sense, the need for alternatives has been continuous, and remains an important part of the research portfolio.

Past research using Telone has included testing TIF tarps with the strawberry commission (Gao) and site specific treatments (Upadhaya). A GPS system targeted fumigation method developed through this research has been adopted by Trical.

6.1 Crown and Root rot

6.1.1 Phytophthera (Niederhauserii, cinnamomi, etc.)

Control is to avoid poor drainage, reduce trunk wetness from sprinklers, and planting on berms. Fumigation isn't seen as a method of control.

Chemical tools: Mefenoxam/Ridomil Gold, phosphorous acid (phosphite)

Needs:

- Secure chemical control options
  - Current research (Adaskaveg) into new fungicides for treatment, with several new compounds showing effectiveness and awaiting registration
- Develop disease resistant rootstocks (Orchard, Tree, Rootstock Workgroup)
  - Many losses related to rootstock (Atlas/ Viking peach root stocks more susceptible)
- Identify cultural management options
  - Improved water and soil health management practices
  - Issues with late planted potted trees in summer-time with hydrophobic potting mix, requires emitter beside trunk, creating wetted trunks and disease
- Explore Ganoderma connection, which colonizes after phytophthera, and scope of issue

6.1.2 Oak Root Fungus (*Armillaria*)

Current research into ASD for control, WOR as potential inoculum, Ganoderma as source for disease.

- Explore alternative management strategies and efficacy (Adaskaveg)
- Need rootstock resistance (Orchard, Tree Rootstock Workgroup)
- Whole Orchard Recycling not recommended for infected orchards, as wood may provide inoculum

Chemical tools:
1,3 dichloropropene (Telone) and chloropicrin (Telone C-35).

6.1.3 Crown Gall

- Biological control is Galltrol; root dips help but don't control
- Resistance to chemical treatment is an issue in some areas but rootstocks can manage to some extent
- Problem for certain rootstocks (Hanson, Nemared)
- More of an issue near river bottoms

Chemical tools:
Agrobacterium tumefaciens (Formerly A. Radiobacter) K84; Gallex, Galltrol

Research gaps

- Address root stock varieties for resistance, and guidance on GMO/CRSPR options (Orchard, Tree, Rootstock Workgroup)
- As fumigant regulations increase, research impacts of certain mitigations, such as tarping and buffer distances
- Actions that can lower the cost of fumigation

Outreach

- Irrigation management

Policy

- Support registration of new products for Phytophthera

6.2 Nematodes

Control with soil sampling when planting or replanting, pre-plant fumigation and rootstock selection. Management varies by nematode type: root knot, root lesion, and ring.

Chemical tools:
1,3 dichloropropene (Telone),
chloropicrin.
Post plant fluopyram, spirotetramat.

Solid, strip, or spot fumigation applications recommended depending on almond variety and nematode type. New Peach Root Knot Nematode study being developed with CDFA. Alternative treatments being researched, including ASD aka biosolarization (Browne, Simmons).

Needs:

- Continue ASD research (aka Bio-solarization) research described above
  - Has shown benefits for nematode control, but not as effective as fumigation
- Improve nematode sampling methods
  - Soil sample tests helps, but proper method critical (timing, previous location of roots)

  - Follow nematode levels over several years
  - Not a good threshold model for treatment
  - If root, lesion or ring nematodes, or replant disease present, then treatment is necessary, but Telone applications are limited by township caps.
- Post plant chemical treatment
  - More info needed on fluopyram (Vellum 1), spirotetramat (Movento). No method to determine effectiveness, or when to stop using. Nematode population is reduced but unclear whether there are benefits for tree health.

6.3 Replant problem (i.e, replant disorder, Verticillium wilt)

Control with pre-plant fumigation, rootstock selection and ASD. Fallowing and cover crops before replanting help.

Avoid interplanting young orchards with susceptible cover plants, such as cotton, tomatoes, and melons. When replanting, remove as many roots of the previous crop as possible.

Prior research has been into factors affecting Replant Disease. There is current research into ASD for control (Browne).

Needs:

- Lower cost
  - Fumigation expensive
- Improve diagnostic tools
  - Certain soils, certain rootstocks help or worsen
  - Sampling variability will be an issue, but working on tools to assess extent of problem
  - May be present, but not economically impactful
- Explore fallowing as solution
  - Fallowing for a year and planting cover crops helps, but doesn't solve
  - Saves water for a year, so may be SGMA solution
- Interpret and consider continuation of ASD research (aka Bio-solarization) research described above

Research gaps

- Still need to better understand organisms that contribute to replant disorder
- Improve nematode, replant disease sampling methods
- Test post-plant fumigation methods
- Unexplored alternatives?
- Fallowing benefits and incentives, role of cover crops, other organic matter additions

7 VIRUSES (Yellow Bud Mosaic, Almond Brownline and Decline)

New issue of plum pox virus. Need to pay attention to insect vectors and cultural controls. Flood irrigation or soil cultivation can spread virus.

Needs:

- Increase engagement with APHIS FPS (Orchard, Tree, Rootstock Workgroup)
    - Coordinate with FPS, nurseries, and prunus industries to assess current status
    - Rely on FPS to reduce levels in nurseries
    - Explore whether APHIS FPS Virus Free program follows-up when a virus is seen in an orchard, or logged into database when and where found
- Improve vulnerability assessment
    - More viruses in younger orchards
    - Prunus necrotic ring-spot virus aka calico important, pollen spread, and incidents increasing
- Can better tools be provided to nurseries to do their own assessments?

Research gaps

- Follow-up with FPS (Orchard, Tree, Rootstock Workgroup)

8 VERTEBRATES

8.1 Squirrels

- Squirrels like green almonds more than anything else, so baits not effective

8.2 Gophers:

- Issue with label for burrow builder re: what bait formulations can be used
- CO machines are expensive ~ $20k. They work for gophers, but harder to get with fumigation because of tunnels systems.
- Zinc phosphide treatment ok if no nuts present

8.3 Coyotes

- Use hot sauce on drip tape but need to apply frequently when irrigating, washes off

8.4 Birds

- Worse in pistachios
- Use of noise making devices can help. Zong gun (propane tank, programmed), actual guns, and reflective tape are options. Birds get used to sounds, so need to change it up.
- Could drones be used to scare off birds?

8.5 Racoons

- Raccoons can set up “latrines” near riparian areas, creating potential food safety issue
- Must call a USDA trapper to get permit to trap and shoot, but need to change baits frequently

Research gaps

- Explore drones or robotic devices to scare off birds

9 GENERAL STRATEGIES

9.1 SPRAY TECHNOLOGY

Spray drift continues be a key driver for regulatory limits to pesticide use in tree crops, especially as the EPA looks at pesticide risk under the Endangered Species Act. At the same time, lack of spray efficacy especially towards the tops of trees limits the value of the pest control applications. A better way of getting pest control materials into trees is strongly needed.

Furthermore, the high costs necessary for all aspects of pest management -scouting, monitoring, spraying, tractor operation, and mummy nut removal- drive a desire to reduce the amount of labor required. There is a need to figure out less labor-intensive ways of determining pest treatment thresholds and the resulting field treatment, along with management tools (e.g., FieldIn), that can improve oversight of treatments.

There are a range of new technologies whose utility in almond production (or in conjunction with other tree crops) could be explored. There is a continued need to explore what technologies in development could be relevant to almond and tree crop pest management, and narrow the research focus.

<u>Needs:</u>

- Continue to identify and research alternative spray technologies
    - Tower sprayers provide better distribution across trees (e.g., hedgerow apples), but previous versions haven't been a good fit
    - Could Tenias harvesters be repurposed as a spray rig for younger orchards?
    - Drones
    - Robotic options, e.g. Roomba for weed management
    - Sniffer technologies
    - Remotely sensed pest monitoring
- Develop better mapping and communication about pest detections

ABC research includes:

- Spray Drift/Spray Efficacy/Remotely Piloted Aircraft (Siegel, Giles, Niederholzer, CURES, Higbee)
    - Sprayer speed is a major factor
    - Different types of sprayers, electrostatic, conventional
        - No real difference in efficacy/ drift
    - Smart Sprayers (Giles)
        - Reduced drift & amount applied some 30-40% in young orchards
- Over the top sprayers (Giles/Niederholzer)
- Coordination with new EPA effort to improve spray drift models for regulatory purposes (Larbi)
- Current funding for Spray Backstop (Pourezza)

<u>Research gaps</u>

- Identify and research alternative and effective precision spray technologies to reduce off-site movement/ drift and improve efficacy of pesticides
- Explore automation to reduce labor needed for monitoring and pesticide applications

- Repurposing over the top grape and olive harvesters as spray rigs, at least in young and high density orchards
- Sniffer technology, other technologies to detect insects and diseases within orchards
- Increase efficacy to reduce residue from dust and hullsplit products

Outreach

- Reference CURES materials on spray equipment (calibration, face inward, turn off end of rows)
- Increase efforts to drive grower adoption of what we know (go slow, sprayer calibration and nozzle selection)