Annual Report - 2022

Prepared for the California Cling Peach Advisory Board

Title:	*Management of brown rot, bacterial blast/canker, and peach leaf curl diseases of peach in California*
Status:	2nd of 3 Years
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SUMMARY OF RESEARCH ACCOMPLISHMENTS DURING 2022

We continued our research on major diseases of flowers, leaves, woody tissues, and fruit of cling peach in California, including brown rot blossom blight and fruit rot, powdery mildew, leaf curl, and bacterial blast and canker.

1. **Brown rot blossom blight** did not develop in two trials on 'Fay Elberta' peach at UCD. At KARE, on 'July Flame' and 'Ryan Sun' peach treated at 35-40% bloom, as well as on 'Summer Flare' and Summer Fire' nectarine' treated at 25% or 65% bloom, respectively, all treatments significantly reduced the incidence of blossom blight from the control with no significant differences among treatments. Luna Experience, Cevya, Sercadis, Mibelya, and Miravis Prime had the lowest incidence of disease. Because the EPA proposed cancellation of iprodione, we argued for re-registration based on the fungicides' high performance, importance in resistance management being the only FRAC Code 2 registered, and that having multiple modes of action (MOA) prevents overuse of any one product.
2. **Preharvest fungicide applications** were evaluated for the management of **postharvest brown rot decay** on three peach and two nectarine cultivars in four orchards. On non-wounded 'Fay Elberta' peach with 6- or 7-day PHI applications, all conventional (Cevya, Fontelis, Regev, Miravis Duo, Miravis Duo, Mibelya, Quadris Top, Sercadis, and numbered compounds) and biological (AVIV, Cinnerate, EcoSwing, ProBlad, Serenade ASO, Botector, Guarda, Thymox) treatments significantly reduced brown rot incidence from the control. Among biological treatments, Thymox and EcoSwing resulted in the lowest incidence of decay, and among conventional fungicides, Sercadis, Miravis Duo, Miravis Prime, Mibelya, and several experimentals were most effective. On 'July Flame' (7 days PHI) and 'Ryan Sun' peach (14+7 days PHI), most of the conventional fungicides were also highly efficacious. Biological treatments reduced disease incidence to between 12% and 29% as compared to 56.8% in the untreated control, whereas most conventional fungicides evaluated had 2%-12% incidence. Thus, the performance of biologicals is still lower than that of most conventional fungicides. Because these fungicides comprise several MOA, effective resistance management can be practiced.
3. In vitro EC_{50} values for ipflufenoquin, a new mode of action (FRAC Code 52), were determined for ***Monilinia laxa*** and ***Botrytis cinerea***. Values ranged 0.005 to 0.022 ppm for *M. laxa* and 0.002 to 0.091 ppm for *B. cinerea*.
4. Evaluation of brown rot **blossom blight susceptibility among peach genotypes** of the UC Davis breeding program of Dr. Tom Gradziel was not done in 2022. Cold, dry weather during bloom and continued COVID restrictions prevented these studies from being done.
5. In a **powdery mildew** study with full bloom and shuck split applications, biologicals (ProBlad and Serenade ASO) and single-site conventional fungicides all moderately, but significantly reduced the disease as compared to the control. AVIV was less effective than the other treatments. Premixtures of conventional fungicides had the lowest incidence.

6. For the management of **peach leaf curl**, single applications were done Dec. 9 and 10, 2021. In the first trial, mixtures of Ziram or Bravo with the low-MCE copper products MasterCop or Cueva were highly effective. In the second trial, mixtures of copper products with Ziram or Bravo reduced the disease to non-detectable levels, whereas Cuprofix or Champ 2F by themselves were slightly less effective. Reduced-MCE copper products and low rates of Ziram or Bravo were used in highly effective mixture treatments. These trials will help justify keeping ziram and chlorothalonil registered and demonstrate strategies for reducing fungicide rates.
7. Kasumin has a PRIA registration date on peach set by the EPA as March 2023. In 2022, oxytetracycline (e.g., FireLine) was registered for managing bacterial diseases of peach in California. We continued to identify potential natural products for managing **bacterial canker** and **bacterial blast.** A mixture that included ε-poly-L-lysine (EPL) and cinnamaldehyde was completely inhibitory in vitro to several bacterial pathogens of tree crops. EPL is still in development with two registrants providing new agricultural formulations.

INTRODUCTION

In California, **brown rot** is caused by the fungal pathogens *Monilinia fructicola* and *M. laxa* and is the most important disease of stone fruits. Ascospores produced from apothecia (*M. fructicola*) and conidia from mummified fruit or twig cankers (*M. fructicola* and *M. laxa*) infect blossoms to start the annual disease cycle. Diseased flowers supply fresh inoculum (i.e., conidia) for in-season fruit infections and thus, management of blossom blight is critical in preventing fruit rot. Fruit rots do not cause major losses in most years due to the dry California summer climate. Occasional rains in spring and summer, however, can cause quiescent infections of fruit and fruit decay epidemics that may result in significant losses. **Powdery mildew** caused by *Podosphaera pannosa* (formerly *Sphaerotheca pannosa*) occurs sporadically, and some peach cultivars are more likely to be affected than others. Efficacy data for selected biological and conventional treatments were obtained in 2022 in a trial on Fay Elberta.

Considerable effort has been made to have highly effective fungicides with different modes of action available and to develop peach cultivars that are less susceptible to brown rot. In recent years, an increasing number of 'biological' treatments including biocontrols and plant extracts have become available, and we are evaluating these for organic cling peach production, as well as for conventional production under less conducive disease conditions. Currently, properly timed treatments with conventional fungicides are the most effective method to control brown rot blossom blight and fruit rot. We evaluated many of these fungicides of different FRAC codes (FCs) representing different modes of action for their effectiveness, optimal rates, and potential combinations with other fungicides and helped to register them. Recently registered compounds include Cevya (mefentrifluconazole, FC 3) and the pre-mixture Miravis Duo (difenoconazole, FC 3 + pydiflumetofen, FC 7). Pre-mixtures that combine these active ingredients provide excellent control, consistency, a wider spectrum of activity, and resistance management because they have two modes of action. Products available include Inspire Super (FC 3/9), Luna Experience, the recently registered Mibelya and Miravis Duo (FC 3/7), Quadris Top (FC 3/11), Luna Sensation, Merivon, and Pristine (FC 7/11), as well as the experimental Miravis Prime (FC 7/12). Single-site mode of action fungicides like Kenja (FC 7) may also be mixed with FC 3 or FC 11 compounds. Still, additional new compounds are being developed, and we continue to test them alone and in mixtures.

In our evaluations of biological treatments, we included biocontrols (*Bacillus subtilis* – AVIV and Serenade ASO, *Aureobasidium pullulans* – Botector), plant extracts (*Swinglea glutinosa* – EcoSwing, *Lupinus albus* – ProBlad), and naturally occurring essential oils (cinnamon oil – Cinnerate, thyme oil - Guarda and Thymox). These and previously evaluated biologicals demonstrated moderate to good brown rot blossom blight control. Many have exempt status in the United States, and some are certified by the Organic Materials Review Institute (OMRI) for use in organic production of stone fruits including peach. In 2018/19, a formulation of polyoxin-D, Oso 5% SC, gained organic approval and is OMRI listed because it is a natural fermentation product. Rotation programs need to be designed even for biocontrols to prevent the overuse of any one mode of action. Fungicides and biologicals evaluated in 2022 are listed in Table 1.

Table 1: Fungicides, bactericides, and biologicals used in 2022 studies*.

Pesticide	FRAC code /chemical group	Trade name	Active ingredient
Single active ingredients	M1	MasterCop	copper sulfate pentahydrate
	M1	Cueva	copper octanoate
	M1	Champ 2F	copper hydroxide
	M1	Cuprofix	basic copper sulfate
	M3	Ziram	ziram
	M5	Bravo WeatherStik	chlorothalonil
	3	Cevya	mefentrifluconazole
	7	Fontelis	penthiopyrad
	7	Parade	pyraziflumid
	7	Sercadis	fluxapyroxad
	52	Kinoprol	ipflufenoquin
Premixtures	3 + 7	Luna Experience	tebuconazole + fluopyram
	3 + 7	Miravis Duo	pydiflumetofen + difenoconazole
	3 + 7	Mibelya	mefentrifluconazole + fluxapyroxad
	3 + 11	Quadris Top	difenoconazole + azoxystrobin
	3 + BM01	Regev	difenoconazole + tea tree oil
	7 + 11	Luna Sensation	fluopyram + trifloxystrobin
	7 + 12	Miravis Prime	pydiflumetofen + fludioxonil
	3 + 7 + 11	Miravis Neo	difenoconazole + pydiflumetofen + azoxystrobin
Experimentals	not disclosed	GF-4536	not disclosed
	not disclosed	GF-5003	not disclosed
	not disclosed	GF-5249	not disclosed
	not disclosed	A23089C	not disclosed
Biopesticides and other Biologicals	BM01	Cinnerate	cinnamon oil
	BM01	EcoSwing	extract of *Swinglea glutinosa*
	BM01	Guarda	thyme oil
	BM01	ProBlad	*extract of Lupinus albus*
	BM01	Thymox	thyme oil
	BM02	AVIV	*Bacillus subtilis*
	BM02	Botector	*Aureobasidium pullulans* strains DSM 14940/DSM 14941
	BM02	Serenade ASO	*Bacillus subtilis* strain QST 713

* - Alphabetical by trade name for each Fungicide Resistance Action Committee (FRAC) code or mode of action. Some fungicides were used with adjuvants such as Breakthru or DyneAmic.

Another objective of our cling peach research is the development of fungicide baseline sensitivity data (as reference points for the detection of resistance) for major pathogens. In previous years, this was done for FC 3 (e.g., propiconazole, tebuconazole, metconazole, mefentrifluconazole), FC 7 (fluopyram, fluxapyroxad, penthiopyrad, pydiflumetofen, isofetamid, and pyraziflumid), FC 9 (e.g., cyprodinil), and FC 19 (polyoxin-D) products. In 2021, sensitivities to the new FC 21 fenpicoxamid were determined for *M. fructicola* and *M. laxa,* and in 2022, sensitivities of *M. fructicola* and *B. cinerea* were evaluated for the FC 52 ipflufenoquin.

In evaluations of **natural host resistance** to blossom blight in cling peach, we are identifying in cooperation with Dr. Tom Gradziel new genotypes derived from cultivated cling peach and wild almond parental lineages that are less susceptible. Comparisons of numerous genotypes were done, and several showed consistent reduced susceptibility to blossom blight as compared to standard commercial cultivars in 4 or 5 of 5 annual evaluations. The identification of less susceptible genetic lines will help in the development of molecular markers that can assist in breeding. Evaluations were suspended in 2020-21 due to COVID-19 restrictions prohibiting collaborative in-person efforts. In 2022, cold, dry weather and continued COVID restrictions again prevented these studies.

Peach leaf curl outbreaks are associated with high rainfall in the winter and early spring and can significantly reduce production if left unmanaged. The disease can be effectively managed by fungicide programs that we helped develop for California conditions. Because the use of copper in agriculture is currently under review by EPA with expected lower annual amounts permitted and because in 2022 EPA-proposed cancellation of dithiocarbamates (e.g., ziram) and is currently reviewing chlorothalonil, we continued to evaluate alternative treatments, including new formulations of copper with lower metallic copper equivalent (MCE), mixtures with other modes of action, and lower application rates of each mixture component. Chlorothalonil, ziram, and dodine by themselves or in mixtures with copper at reduced rates were highly effective and consistent in their performance. These studies were continued in 2022 and were part of our rebuttal to EPA requesting non-cancellation but mitigating alternatives (e.g., lower rates, long REI, limited number of applications).

Bacterial blast and canker of peach and other stone fruit crops that are caused mainly by the bacterium *Pseudomonas syringae* pv. *syringae* are other important diseases where new management strategies are needed. Blossom blast develops after cold injury, causing bud and flower death, as well as spots on leaves and fruit. The disease is more commonly found on early blooming varieties that are more likely to experience cooler, wet environments in the spring. Bacterial canker causes dieback from infection of pruning wounds and other injuries. The disease weakens trees, and in severe cases, trees may die. Copious amounts of amber-colored gum may exude from trunk and bark cankers. Copper resistance in the pathogen is widespread in California, and currently, no effective treatment alternatives are available.

Based on our efforts, advances have been made in bacterial disease control with the identification and development of the antibiotics kasugamycin and oxytetracycline. Kasugamycin is not used in animal or human medicine. The California registration on pome fruit, walnut, and sweet cherry was approved in January 2018. Full registration petitions for almond and peach are under review with a PRIA date of March 2023. Based on our efforts, oxytetracycline (e.g., FireLine) was registered in California in 2022. This past year, we continued to identify anti-bacterial products that may be registered as agricultural biopesticides.

OVERALL OBJECTIVES

I. Management of brown rot using conventional, biological, and biopesticides
II. Management of peach leaf curl using conventional, biological, and biopesticides
III. Evaluate the efficacy of new treatments against bacterial canker and blast
  a. Evaluation of conventional bactericides – Registered bactericides
  b. Evaluation of organic alternatives – Registered biocontrols
  c. Evaluation of potential biopesticides – Generally Regard as Safe - food additives

OBJECTIVES FOR 2022

I. Management of brown rot and powdery mildew
  A) Evaluate the pre- and post-infection efficacy of new fungicides, pre-mixtures, biofungicides, and biocontrols and natural products representing different modes of action in lab and field trials
  B) Baseline sensitivities of brown rot fungi to new fungicides (i.e., ipflufenoquin)
  C) Natural host resistance of new peach genotypes to blossom blight and fruit decay
II. Management of peach leaf curl
  A) Evaluate combinations of chlorothalonil (Bravo), ziram, biologicals (e.g., Botector), and new copper formulations with low MCE in tank mixtures of these products
III. Evaluate the efficacy of new treatments against bacterial canker in twig inoculation studies
  A) Conventional bactericides – kasugamycin and oxytetracycline combined with adjuvants
  B) Biocontrols – AVIV, Botector, Serenade
  C) New natural product (plant extracts) bactericides – Cinnerate, and the fermentation products nisin and Ɛ-poly-L-lysine (EPL)

PLANS AND PROCEDURES

I. Management of brown rot

Evaluation of fungicides for management of brown rot blossom blight and fruit rot. Trials were established to evaluate fungicides for control of brown rot blossom blight on 'July Flame' and 'Ryan Sun' peach, as well as 'Summer Flare' and 'Summer Fire' nectarine at the Kearney Agricultural Research and Extension Center (UC-KARE) in Parlier, CA, and on 'Fay Elberta' peach at UC Davis. A single application of each treatment was made at 40% full bloom to 'July Flame', at 35% bloom to 'Ryan Sun', at 80% bloom to Fay Elberta peaches, and at 25% bloom to 'Summer Flare' and at 60% to 'Summer Fire' nectarines using an air-blast sprayer calibrated for 100 gal/A.

For fruit rot studies at UC Davis, fungicide treatments were applied 6 or 7 days before harvest (PHI) to 'Fay Elberta' peach in the two orchards. In the KARE trials, treatments were applied 7 days PHI to 'July Flame' peach, as well as 'Summer Flare' and 'Summer Fire' nectarines, and at 14+7 days PHI to 'Ryan Sun' peach. Four single-tree replications for each treatment were randomized in complete blocks. Fungicides evaluated are indicated in Figs. 2 and 3. Twenty-four fruit were harvested from each replication in the UC Davis trial and 48 fruit in the KARE trials. Fruit were spray-inoculated with *M. fructicola* (20,000 spores/ml) and incubated for 5-7 days at 20-25C, >95% RH. The incidence of fruit infection was expressed as a percentage of infected fruit per total fruit used in each replication. Data were analyzed using analysis of variance and mean separation procedures of SAS 9.4.

In vitro sensitivity of* M. laxa *and* B. cinerea *to ipflufenoquin, a fungicide with a new mode of action. Thirty isolates each of *M. laxa* and *B. cinerea* were used to determine inhibitory concentrations for mycelial growth using the spiral gradient dilution method. In the assay, conidial suspensions were streaked along fungicide concentration gradients in corn meal agar, and mycelial growth was measured after 3 days. EC_{50} values were calculated as described previously, and data were summarized in histograms.

Evaluation of natural host resistance of peach to blossom blight and fruit decay. We attempted to access the genotypes in the breeding program of Dr. Gradziel, however, COVID restrictions again prevented in-person collaborative research and cool, dry weather prevented the development of natural incidence of disease. We will work with Dr. Gradziel to summarize genotype susceptibility to brown rot blossom blight as compared to commercial genotypes of cling peach.

Management of powdery mildew. Applications of each fungicide were done on 2-23 (50% bloom) and 3-17-22 (shuck split) using an air-blast sprayer at a rate of 100 gal/A. Disease was evaluated on 4-19-22, and data were analyzed using analysis of variance and mean separation procedures of SAS 9.4.

II. Management of peach leaf curl

Single applications in combination with 1.5% Omni spray oil (see Fig. 6) in two experimental 'Fay Elberta' orchards at UC Davis were done as dormant treatments on Dec. 9 and 10, 2021, using an air-blast sprayer at 100 gal/A. Six single-tree replications of each treatment were used. Trees were evaluated for disease in the spring of 2022. For this, the number of shoots with leaf curl infections was determined for 100 shoots on each tree. Data were evaluated using analysis of variance and mean separation procedures of SAS version 9.4.

IV. Management of bacterial canker and blast

Field studies were not conducted in the winter and spring of 2022 due to relatively warm, dry environmental conditions that were not conducive for disease development. Bactericides including Timorex ACT, a yeast-yeast extract formulation (CWP), cinnamon oil (Cinnerate), cinnamaldehyde (Seican), and mixtures of cinnamaldehyde with EPL or nisin were evaluated for their toxicity against *P. syringae* in laboratory studies. The amended agar assay was used where the pathogen is in continuous contact with the test substance. A bacterial suspension was streaked on the agar surface, and growth was rated after 2 days of incubation at 25C as '+++' = growth similar as on non-amended agar, '++' = growth inhibited by <80%, '+' = growth inhibited by >80%, and '-' = growth completely inhibited.

RESULTS AND DISCUSSION

Management of brown rot

Efficacy of fungicides for management of blossom blight. At UC Davis, blossom blight incidence on control trees of Fay Elberta peach was less than 1%, and no efficacy data could be obtained. In trials on two peach and two nectarine cultivars at UC KARE, however, incidence of disease was between 5.0% (i.e., July Flame peach) and 13.8% (i.e., Summer Flare nectarine). On all four cultivars, all treatments significantly reduced the incidence from that of the control, and there were no significant differences among treatments (Fig. 1). Numerically, the lowest amount of blossom blight occurred on July Flame peach after treatment with Luna Experience (0.5% incidence), Cevya (1%), or Sercadis (1%); on Ryan Sunpeach after treatment with Cevya (0.3%) or Mibelya (0.7%); on Summer Flare nectarine after using the

Fig. 1. Efficacy of fungicide treatments for management of brown rot blossom blight of peach and nectarine cultivars at KARE 2022

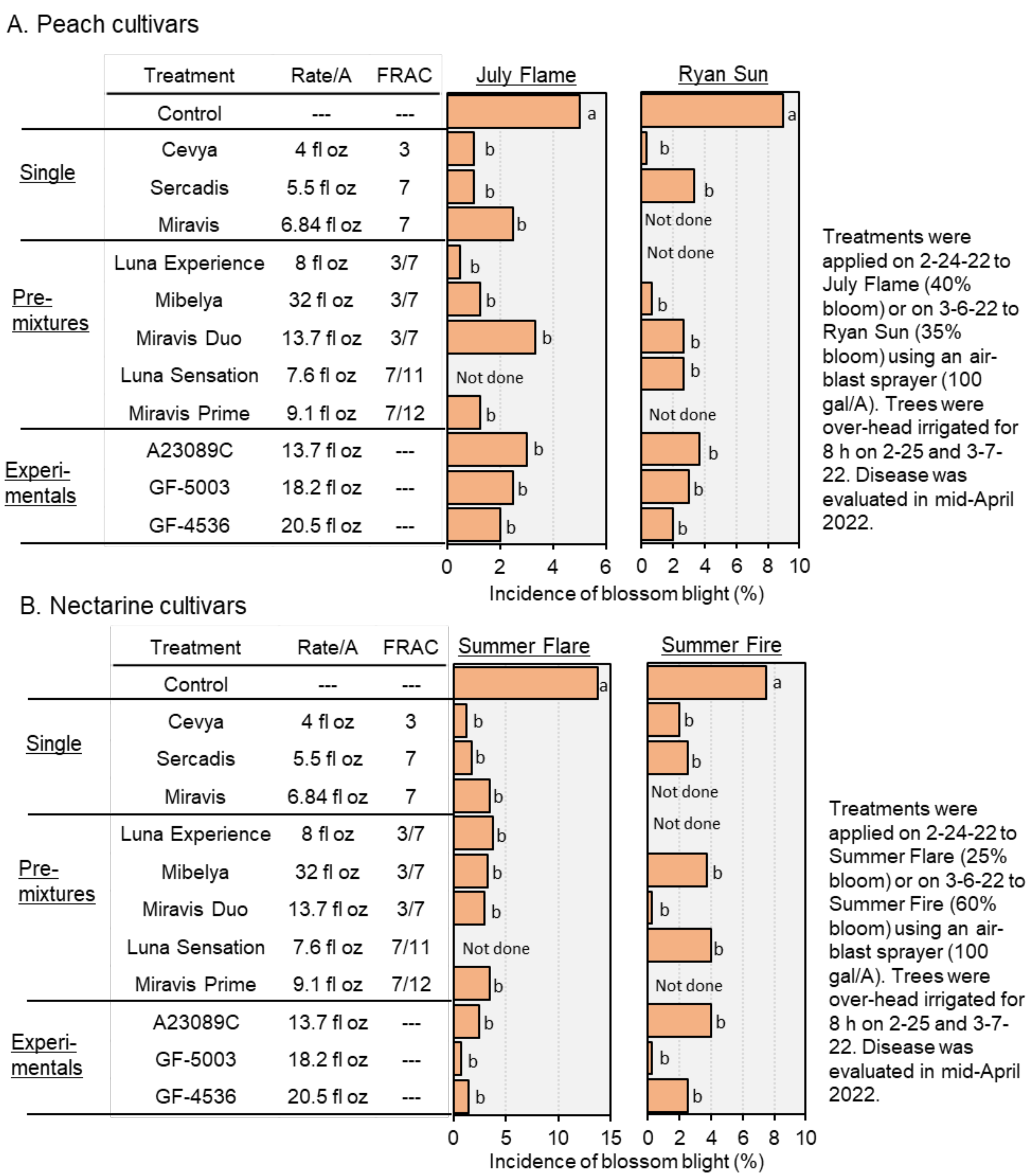
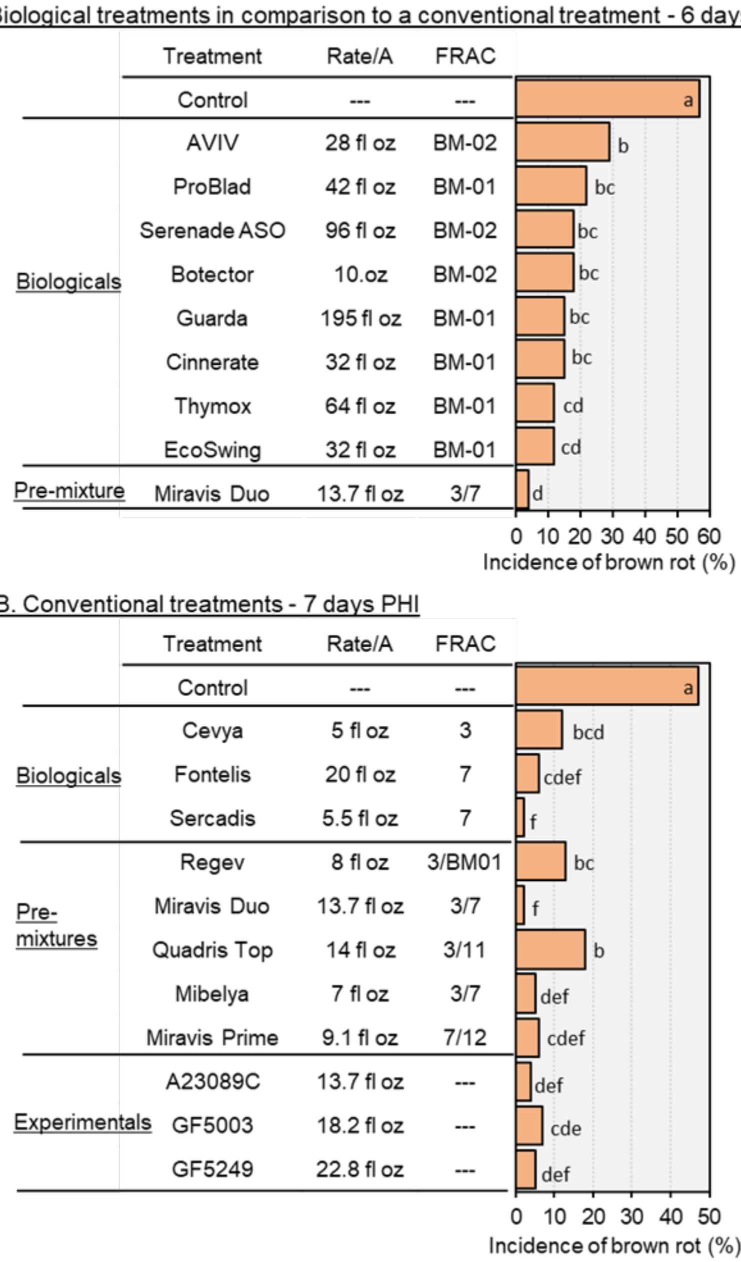


Fig. 2. Efficacy of preharvest treatments for management of postharvest brown rot of Fay Elberta peach in field trials at UC Davis 2022

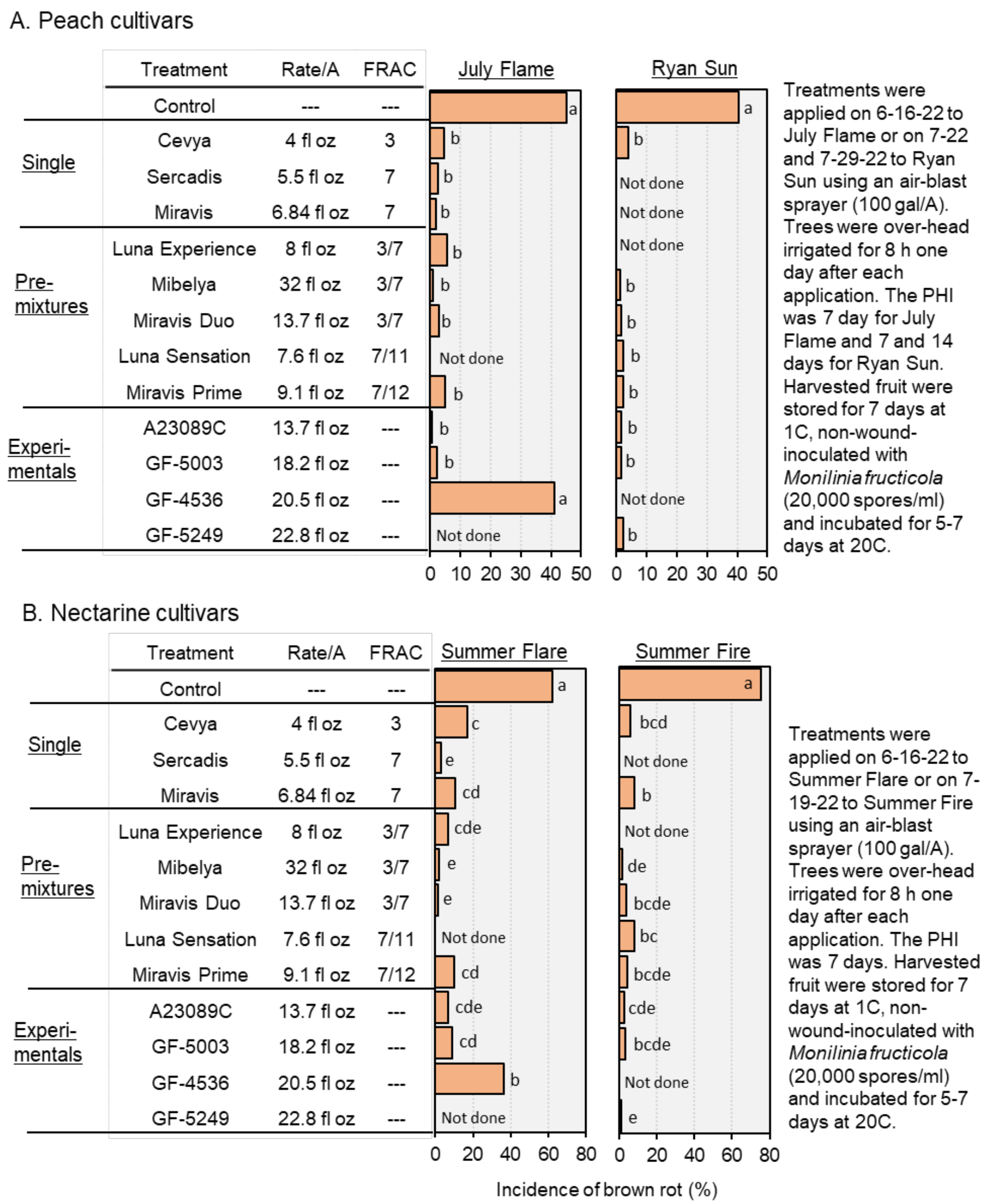


Treatments were applied on 7-22 (plot A) or 7-21-21 (plot B) using an air-blast sprayer at 100 gal/A. Fruit were harvested (24 fruit from each of four single-tree replications), non-wound spray-inoculated with *M. fructicola* (30,000 spores/ml) and incubated for 8 days at 20-25C.

experimental GF-5003 (0.8%) or Cevya (1.3%); and on Summer Fire nectarine after using Miravis Duo or the experimental GF-5003 (both 0.3%). Thus, single applications of selected conventional treatments that were done at between 25% and 60% bloom were highly effective in managing blossom blight during the low-rainfall bloom season in 2022. Although in 2022 the EPA proposed cancellation of iprodione, we support the re-registration based on its high performance, the need for iprodione (FC 2) in resistance management programs, and having multiple alternatives minimizes the use of anyone mode of action. EPA's decision is still pending.

Efficacy of preharvest fungicides for management of fruit decays. A total of six studies were conducted on three peach and two nectarine cultivars where harvested fruit were non-wound inoculated. In

Fig. 3. Efficacy of preharvest treatments for management of postharvest brown rot of peach and nectarine cultivars in field trials at KARE 2021



the first trial at UC Davis on 'Fay Elberta' peach, 6-day PHI applications were done with a range of biological treatments that were compared to a conventional fungicide (Fig. 2A). Brown rot incidence of the control was 56.8%. Among biological treatments, the natural products Thymox and EcoSwing were significantly more effective than the biocontrol AVIV, and the remaining treatments had intermediate efficacy. Incidence of brown rot was lowest using the conventional Miravis Duo (4% incidence) but was not significantly different as compared to Thymox and AVIV. In the second study on Fay Elberta with conventional treatments applied at 7 days PHI, 47.2% of control fruit developed brown rot. Sercadis and Miravis Duo resulted in the lowest brown rot incidence with 2 %, but treatments with Mibelya, Miravis Prime, or three different experimentals were also highly effective (Fig. 2B).

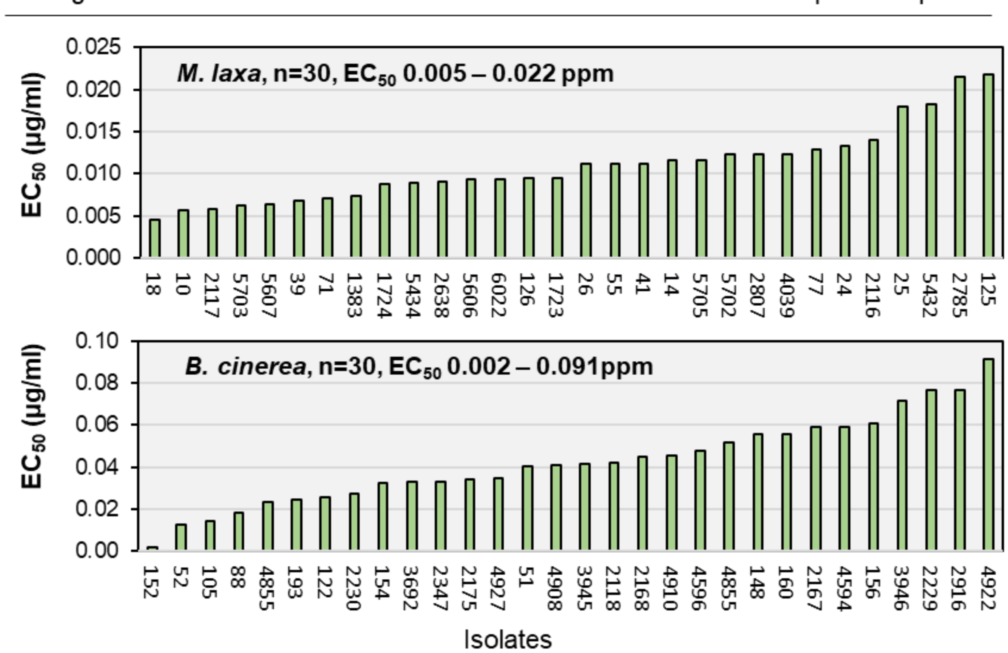
In studies at KARE on two peach and two nectarine cultivars, between 40.4% and 75.1% of control fruit developed brown rot decay (Fig. 3). On July Flame (7 days PHI) and Ryan Sun (14+7 days PHI) peach (Fig. 3A), all treatments except the experimental GF-4536 were highly effective in reducing the incidence of decay with no significant difference among the effective treatments. All 7-day PHI applications to Summer Flare and Summer Fire nectarine, except the experimental GF-4536, again were highly effective (Fig. 5B). Statistically, Sercadis, Mibelya, and Miravis Duo were most effective on Summer Flare (1.6%-2.8% decay incidence), whereas Mibelya and the experimental GF-5249 were the most effective on Summer Fire (1.6% and 1.1% incidence, respectively).

In summary, we demonstrate that preharvest treatments with many of the newer conventional treatments can be reduced to very low levels. Highly effective treatments that we identified belong to FC 3, 7, 3/7, 3/11, 7/11, or 7/12 as well as possibly new FCs of the experimental fungicides. An additional benefit of preharvest applications with FC 3 (DMI) or 11 (QoI) fungicides is that they continue to have benefits into fall by reducing the incidence of rust. This ensures that a rust epidemic is less likely to develop in the subsequent spring season. Pre-mixtures of different FCs overall have improved efficacy, are consistent, have a broader activity range, and have built-in resistance management if both active ingredients are inhibitory to the pathogens. Mixture and rotation programs should be used in bloom and preharvest applications to prevent over-use of any one FC and any subsequent development of resistance. Several OMRI-approved treatments including Thymox and EcoSwing also provided acceptable decay control for organic cling peach production although their performance over the years has not been as consistently high. Additionally, biological treatments are mostly protective and will not prevent fruit decay from injuries that occur after treatment. This contrasts with the locally systemic DMI fungicides. Although not much is known about resistance development against biological treatments, they also should be rotated.

Effective brown rot control treatments need to be available to the industry to protect fruit in the orchard from infection when occasional rainfall occurs during the fruit ripening period or when harvested fruit cannot be processed in a timely manner. Preharvest applications are best done within 7 to 14 days of harvest. On later maturing fruit, a two-spray program within 14 days of harvest may be beneficial because of higher disease pressure due to more quiescent infections and higher inoculum levels in the orchard later in the season. Two applications also ensure good coverage and high residue levels at harvest when many infections occur on ripening fruit. Altogether, the information provided will help growers to make choices in their management programs for brown rot blossom blight and fruit decay, as well as powdery mildew.

In vitro sensitivity of* M. laxa*, and* B. cinerea *to ipflufenoquin, a fungicide with a new mode of action. Isolates of *M. laxa* and *B. cinerea* that were never exposed previously to the new FC 52 fungicide ipflufenoquin

Fig. 4. Baseline sensitivities of *Monilinia laxa* and *B. cinerea* to ipflufenoquin



In vitro sensitivities were determined using the spiral gradient dilution method.

were evaluated in spiral gradient dilution assays for their sensitivities to this fungicide. For 30 isolates of *M. laxa*, the sensitivity range was narrow with EC_{50} values of 0.005 to 0.022 ppm; whereas for *B. cinerea,* a wide range was detected with EC_{50} values from 0.002 to 0.091 ppm (Fig. 4). The fungicide is being registered on almonds, and we are requesting to include stone fruit in subsequent registrations. Because it was also proposed as a medical treatment, the registration for agricultural uses may be limited or rejected.

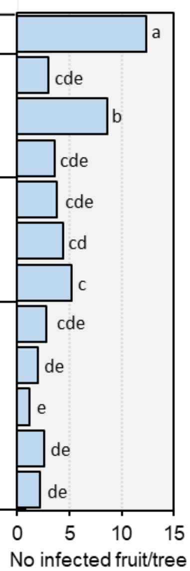
Host susceptibility of F1-progeny of Bolinha peach and other selections to brown rot blossom blight. Evaluation of brown rot blossom blight susceptibility among peach genotypes of the UC Davis breeding program of Dr. Tom Gradziel was not done in March due to cold weather and low rainfall.

I. Efficacy of fungicides for management of powdery mildew.

Powdery mildew on young fruit developed in a trial at UC Davis. All evaluated treatments moderately, but significantly reduced the disease as compared to the control with an average of 12.4 infected fruit per tree (Fig. 5). AVIV was significantly less effective (average of 8.6 infected fruit/tree) than the other treatments. No significant difference in efficacy among the remaining treatments (average of 1.2 to 5.2 infected fruit per tree) was observed that included biologicals such as Problad (where a single application was done on 3-17-22) and Serenade ASO, as well as conventional fungicides. Overall, the premixtures of conventional fungicides had the lowest incidence of mildew. Thus, one bloom and one shuck-split application demonstrated the performance of the treatments when evaluated at pit hardening.

Fig. 5. Efficacy of fungicide treatments for management of powdery mildew of Fay Elberta peach at UC Davis 2022

	Treatment	Rate/A	FRAC	Applications 2-23	Applications 3-17	
	Control	---	---	---	---	a
Biologicals	Problad	40 fl oz	BM-01	---	@	cde
	AVIV	28 fl oz	BM-02	@	@	b
	Serenade ASO	96 fl oz	BM-02	@	@	cde
Single	Cevya	4 fl oz	3	@	@	cde
	Fontelis	20 fl oz	7	@	@	cd
	Parade	3.1 fl oz	7	@	@	c
Pre-mixtures	Quadris Top	14 fl oz	3/7	@	@	cde
	Miravis Duo	13.7 fl oz	3/7	@	@	de
	Mibelya	6 fl oz	3/7	@	@	e
	Miravis Neo	13.7 fl oz	3/7/11	@	@	de
	Miravis Prime	9.1 fl oz	7/12	@	@	de



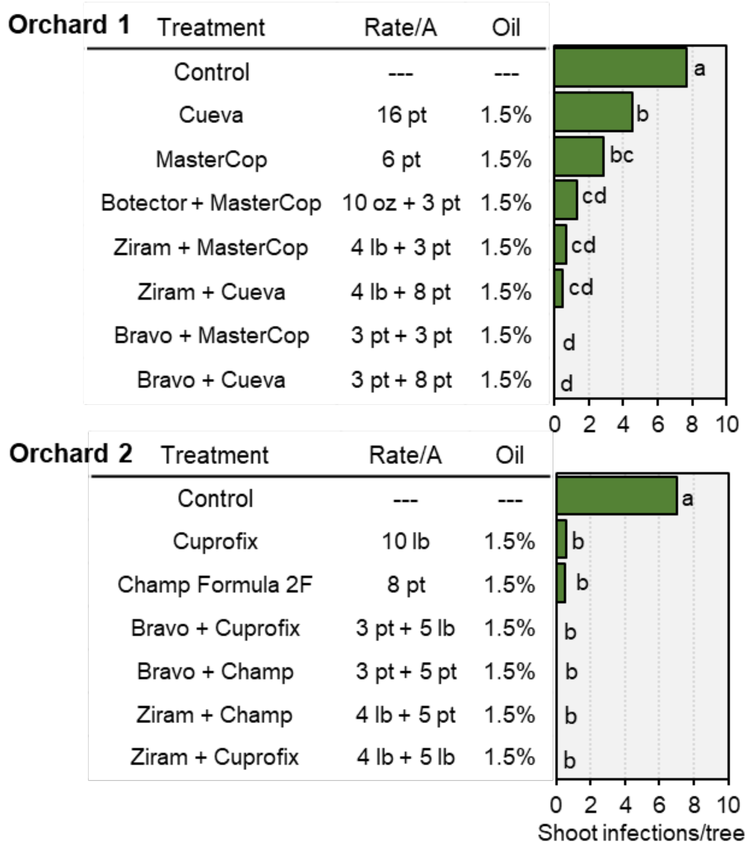
Treatments were applied using an air-blast sprayer (100 gal/A). Evaluation was done on 4-19-22. For this, the number of infected fruit per tree was counted in a 1-min period.

II. Management of peach leaf curl

Two studies were conducted in winter 2021/spring 2022 on ‘Fay Elberta’ peach at UC Davis with single treatments applied in combination with 1.5% Omni spray oil in early/mid-December. Disease incidence in spring 2022 on control trees was low. In both studies, all treatments significantly reduced peach leaf curl as compared to the untreated control (Fig. 6). In the first orchard, mixtures of Ziram or Bravo with the low-MCE copper products MasterCop or Cueva reduced the disease to the lowest levels. A mixture of Master Cop with Botector was also very effective, whereas MasterCop or Cueva by themselves were less effective. In the second orchard, all treatments reduced the disease to very low levels.

These studies, conducted in the low rainfall winter of 2021/22, indicate that reduced-MCE copper products such as Cueva and MasterCop in combination with Ziram or Bravo can be highly effective in managing peach leaf curl. Additionally, the biocontrol Botector in combination with an OMRI-certified copper product also showed good efficacy and provides a treatment option for organic growers. Ziram,

Fig. 6. Efficacy of fungicide treatments for management of peach leaf curl of Fay Elberta peach at UC Davis 2021/22



Treatments were applied in the field using an air-blast sprayer (100 gal/A) in combination with a spray oil 1.5% Omni oil) on 12/9 and 12/10/2021. Six single-tree replications were used for each treatment. Disease evaluation was done on 4/23/2022. For this, the number of infections per tree was determined.

chlorothalonil, and also dodine (not evaluated in 2021/22) represent valuable components of a leaf curl management program and are alternatives to copper fungicides. With increased EPA regulation to reduce copper levels on most registered crops, identifying alternatives including low-MCE copper products is important for the industry. Over several years of trials, the efficacy of copper by itself has been inconsistent in our evaluations of different products and rates, and Ziram, Bravo, and mixtures of these products have been the most effective and consistent treatments. These three fungicides, the biocontrol, and new formulations of copper are currently registered for use in California. Thus, several options are available for conventional and organic growers to manage the disease. Because in 2022 EPA-proposed cancellation of dithiocarbamates (e.g., ziram) and is currently reviewing chlorothalonil, we continued to evaluate alternative treatments, including new formulations of copper with lower MCE, mixtures with other modes of action, and lower application rates of each mixture component. We are supporting the continued registration of ziram and chlorothalonil for targeted use on peach and other crops. Lower rates, longer re-entry intervals (REI), and multiple modes of action available that prevent overuse of any one product were arguments used to support their re-registration rather than their cancellation.

Management of bacterial canker

Based on previous years' studies and our trials on other stone fruit crops over several years, kasugamycin and oxytetracycline have currently the best potential for bacterial canker and blast management on peach and other crops. With widespread copper resistance in the bacterial pathogen *P. syringae* pv. *syringae* in California, new effective treatments are needed to manage these diseases because they can impact yield and fruit quality in seasons with favorable environmental conditions as well as long-term orchard health. Registration of kasugamycin (FC 24) with a PRIA date of March 2023 and registration of oxytetracycline (FC 41) in 2022 on peach allows to implement resistance management practices, similar to those done with fungicides. Mixtures or rotations of different modes of action or FCs are effective usage strategies to prevent the selection of resistant populations of the pathogens targeted.

***In vitro toxicity of new bactericides against* P. syringae.** As indicated above, due to relatively warm temperatures during bloom, no field studies on bacterial blast were conducted in the spring of 2022. The toxicity of new bactericides was evaluated in the laboratory. In amended agar studies, the tea tree (i.e., Timorex ACT) and yeast/yeast extract (i.e., CWP) products did not inhibit growth of *P. syringae* at 1000 ppm (Table 2). Cinnamon oil (i.e., Cinnerate), cinnamaldehyde (i.e., Seican), and EPL completely inhibited growth at 750, 500 ppm, and 1000 ppm, respectively. EPL at 500 ppm was not inhibitory, but when mixed with cinnamaldehyde at 100 ppm, no growth occurred. Thus, this EPL-cinnamaldehyde mixture is synergistic and needs to be evaluated under field conditions in future trials. Both components potentially could be approved for organic production.

Table 2. In vitro toxicity of new bactericides against *P. syringae* in laboratory amended agar tests

Treatment	Concentration (ppm)	Growth rating
Control	---	+++
Timorex ACT - tea tree oil	1000	+++
CWP - yeast + yeast extract	1000	+++
Cinnerate - cinnamon oil	500	+++
	750	-
Seican - cinnamaldehyde	100	+++
	250	+
	500	-
EPL	500	+++
	1000	-
Nisin	1000	+++
EPL + cinneraldehyde	500 + 100	-
Nisin + cinneraldehyde	1000 + 100	++

Nutrient agar was amended with selected concentrations of bactericides and a suspension of *P. syringae* was streaked out. Growth was evaluated after 2 days at 25C. '+++' indicates that growth was similar as on non-amended agar, '+' indicates that growth was inhibited by >80%, and '-' indicates that growth was completely inhibited.