Epidemiology & Management of Almond Brown Rot, Jacket Rot, Shot Hole, Rust, and Hull Rot in CA

Project No.: **17-PATH4-Adaskaveg**

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Objectives:

I. Disease management strategies: Evaluate new fungicides and develop efficacy data based on spectrum of activity, systemic action, and persistence.
   a. Evaluations of new products against brown rot, jacket rot, and shot hole, (as well as rust if the disease occurs during the season).
      - New fungicides (e.g., pydiflumetofen, Aproach - picoxystrobin, pyraziflumid, UC-1, EXP-13, F 4406-3), fungicide pre-mixtures (e.g., IKF-5412, UC-2, EXP-AD), and registered products such as Fontelis, Luna Experience, Luna Sensation, Merivon.
      - New biologicals (Fracture-Organic formulation, Serenade Opti, Botector, Stargus).
      - Persistence and post-infection activity of selected fungicides in laboratory studies for management of brown rot.
   b. Hull rot management: evaluate application timing and new fungicides.
      - QoIs, DMIs, SDHIs, polyoxin-D, experimental fungicides, and pre-mixtures.
      - Foliar applied dipotassium-phosphate and alkaline treatments by themselves or in combination with fungicides
      - Minimal time before applying nitrogen before hull split (e.g., 60 days, 30 days, etc.)

II. Baseline sensitivities of fungal pathogen populations against new fungicides and potential shifts in fungicide sensitivity.
   a. Sensitivities of *Monilinia* species against UC-1 and SDHIs (e.g., F 4406-3, and others).
   b. Fungicide sensitivities at locations where disease was not satisfactorily managed after fungicide treatments.

III. Evaluate the new almond variety orchard at UC Davis under simulated rainfall for susceptibility to brown rot blossom blight, shot hole, and other diseases.

In this annual report, we can only include 2018 data for the springtime diseases brown rot, shot hole, and gray mold (Jacket rot). Trials on hull rot are ongoing, and thus, 2017 data are presented (not included in last year's report).

Interpretive Summary:

In 2017-18, we again evaluated new treatments against major foliar and fruit diseases of almond in California in field and laboratory studies. New fungicides evaluated included the experimental FRAC 7 pyraziflumid, as well as UC-1, UC-2, EXP-AD, F4406-3, GWN 10320, and IKF-5412 to 5414 (FRAC groups not disclosed). These new treatments were compared to registered single-active-ingredient and pre-mixture compounds belonging to the DMIs (FRAC 3), SDHIs (FRAC 7), anilinopyrimidines (FRAC 9), QoIs (FRAC 11), and polyoxins (FRAC 19). Under California conditions for almond production, the availability of fungicides with different modes of action will prevent the selection and build-up of resistant pathogen populations when these FRAC codes are applied in rotation or mixture programs. Furthermore, the use of pre-mixtures and tank mixtures expands the spectrum of activity and allows management of several diseases with a single treatment. Incidence of brown rot was low, whereas that of shot hole was high at our trial sites in the spring of 2018. For brown rot management on cv. Drake, treatments with numerically the lowest amount of brown rot included F 4406-3, GWN 10320, the FRAC 7 pyraziflumid (at 4.7 fl oz), as well as the pre-mixtures Helmstar (FRAC 3/11), Luna Sensation (FRAC 7/11), and EXP-AD. In a laboratory study on gray mold, the lowest levels of disease developed using Rhyme, Luna Experience, F4406-3, and EXP-AD, but other treatments also significantly reduced the disease. For shot hole, UC-1 and UC-2 were most effective on cvs. Drake and Sonora almond, whereas on cv. Drake, Rhyme, F4406-3, GWN 10320, Luna Experience, Merivon, Helmstar, and EXP-AD were also highly effective. Studies on the management of hull rot were conducted in orchards with *Rhizopus stolonifer* as the main pathogen. Several fungicides containing FRAC Groups 3, 7, 11, or 19, as well as GA-142 and the alkalizing foliar fertilizer dipotassium-phosphate (di-KPO_4) reduced the incidence of hull rot over the last two years. Alkalizing treatments were applied to possibly neutralize fumaric acid that is produced by hull rot pathogens. Acid production is responsible for dieback symptoms on almond spurs. Alkalizing treatments could also be used in organic almond production and may have other benefits in balancing the nutritional content of the hulls especially regarding nitrogen. Phytotoxicity was not observed with di-KPO_4 and GA-142. We are currently recommending a two-spray program for hull rot management, with one pre-hull split treatment in early/mid-June (mainly targeting the *Monilinia* pathogen) and another one at early hull split (mainly targeting the *Rhizopus* pathogen). Efficacy studies need to be done with *Aspergillus niger* and other hull rot pathogens. In our studies, 60 to 75% control was consistently obtained with one brown rot and one Rhizopus rot application for a total of two applications on Nonpareil, Padre, Monterey, or Wood Colony. In baseline sensitivity studies, isolates of *M. laxa* were highly sensitive to the new SDHIs pyraziflumid, pydiflumetofen, and isofetamid. A much wider range in sensitivities was determined for *B. cinerea,* and sensitivity characteristics of isolates were similar for pydiflumetofen and pyraziflumid. This indicates that cross resistance is present among SDHI sub-groups and that SDHI fungicides should always be rotated with different FRAC codes. In evaluation of natural host resistance to diseases in our almond variety block at UC Davis, data were obtained for brown rot, shot hole, and scab for 23 varieties or genotypes in the spring of 2017 and 2018.

Materials and Methods:

Fungicide evaluations for management of brown rot, gray mold, and shot hole in experimental orchards - 2018 Research. Field trials were conducted at UC Davis on cvs. Drake and Sonora, and at the Kearney Agricultural Research and Extension (KARE) Center on cvs. Wood Colony, Sonora, and Padre. Treatments were done as single-fungicide, mixture, pre-mixture, or rotation programs. Two applications were done at UC Davis and a single application was done at KARE using an air-blast sprayer. For brown rot evaluation, the number of strikes per tree was counted for each of four or six single-tree replications. Selected fungicides were also evaluated in laboratory studies on detached blossoms of cvs. Drake and Wood Colony that were inoculated with conidia of *M. laxa* (20,000 conidia/ml) either 20 h before or after treatment. The incidence of stamen infections was determined after 5 days of incubation at 20C. Gray mold was evaluated on detached flower petals of cv. Drake in the laboratory. For this, flower petals were placed onto moist vermiculite, hand-sprayed with selected fungicides, air dried, and incubated for 5-6 days at 20C for the development of natural incidence of gray mold.

Fungicide evaluations for management of hull rot - 2017 Research. Field trials were conducted in cv. Nonpareil orchards in Colusa Co. where hull rot was mostly caused by *R. stolonifer* and on cvs. Padre and Wood Colony in Fresno Co. Treatments to evaluate fungicide efficacy were mostly done as a two-spray program with applications at pre- and early hull split. In addition to fungicides, an alkaline fertilizer, calcium hydroxide (agricultural lime), and a natural product were used to neutralize fumaric acid from *R. stolonifer*, a pathogenicity/ virulence factor that is responsible for causing dieback symptoms of hull rot. Hull rot was evaluated by counting the number of shoot infections per tree.

Develop baseline sensitivities of fungal pathogens of almond against new fungicides - 2017-18 Research. Isolates of *M. laxa* and *B. cinerea* from fruit trees in California were evaluated for their in vitro fungicide sensitivities of mycelial growth to three new SDHI fungicides (isofetamid, pydiflumetofen, pyraziflumid) using the spiral gradient dilution method as described previously (Forster et al., Phytopathology 94:163-170).

Evaluation of natural host susceptibility against diseases in a new variety orchard - 2017-18 Research. A research block with 23 almond varieties/genotypes on two rootstocks at UC Davis that was established in the spring of 2014 was evaluated for brown rot, as well as shot hole and scab on fruit in the spring of 2017 and 2018. Brown rot strikes per tree were counted, and the incidence of fruit with shot hole or scab lesions was assessed.

Statistical analysis of data. All data were analyzed using analysis of variance and least significant difference (LSD) mean separation procedures ($P > 0.05$) of SAS version 9.4. Percent data was arcsin-transformed, whereas $\log_{10}$ transformation was used for count data.

Results and Discussion:

Brown rot blossom blight and gray mold management - 2018 Research. Environmental conditions were not favorable for brown rot in the spring of 2018. Due to cold weather during the bloom period, no disease developed in trials at KARE and on cv. Sonora at UC Davis.

Brown rot incidence on the highly susceptible cv. Drake at UC Davis was also low with an average of 16.4 strikes per tree in the untreated control.

On cv. Drake, all treatments significantly reduced the incidence of disease to an average of 1.6 to 6.2 strikes per tree (**Table 1**). Treatments with numerically the lowest amount of brown rot included the new F 4406-3, GWN 10320, the FRAC 7 pyraziflumid (at 4.7 fl oz), as well as the pre-mixtures Helmstar (FRAC 3/11), Luna Sensation (FRAC 7/11), and EXP-AD.

Many of the field treatments were also evaluated in laboratory pre- and post-infection studies on detached flowers. Among the 14 treatments evaluated, the new biocontrol Stargus reduced the incidence of stamen infection by approximately 60% from that of the control, but only when applied as a pre-infection treatment. The other new material, GWN 10320, that showed good efficacy in the Drake field study was not effective, possibly because infection pressure in the laboratory study was much higher. In contrast, synthetic fungicides worked well as pre- and post-infection treatments. Among new compounds, pyraziflumid, F4406-3, UC-1, UC-2, and EXP-AD reduced stamen infections to 4% or less compared to nearly 100% in the controls. Thus, some biologicals (e.g., Stargus) offer some protection and are options for organic almond producers, but the conventional fungicides provide the highest level of protection.

Table 1. Efficacy of fungicide programs for management of brown rot and shot hole of cv. Drake almonds at UC Davis 2018

				Brown rot**		Shot hole on fruit			
No.	Program	Treatment*	Rate/A	Strikes /tree	LSD ^	Incid. (%)	LSD	Lesions / fruit	LSD
1	---	Control	---	16.4	a	75.3	a	5.1	a
2	Single	Rhyme	7 fl oz	3.4	bc	3.9	fg	0.1	c
3		Pyraziflumid	3.1 fl oz	2.8	c	39.4	b	1.8	b
4		Pyraziflumid	4.7 fl oz	1.6	c	27.8	bc	0.7	bc
5		F4406-3	5 fl oz	2	c	7.3	defg	0.1	c
6		F4406-3	6 fl oz	2.2	c	25.1	bcd	0.7	c
7		UC-1	4 fl oz	4.2	bc	8.0	defg	0.2	c
8		GWN 10320	24 fl oz	2.2	c	9.1	defg	0.2	c
9		GWN 10320	32 fl oz	2.6	c	18.4	bcde	0.4	c
10	Pre-mixtures	Merivon	5.5 fl oz	6.2	b	4.0	fg	0.1	c
11		Luna Sensation	7.8 fl oz	1.6	c	10.9	bcdef	0.2	c
12		Luna Experience	8 fl oz	3.6	bc	8.7	defg	0.4	c
13		Helmstar	14.5 fl oz	2	c	9.4	defg	0.2	c
14		UC-2	7 fl oz	2.2	c	2.0	g	0.0	c
15		EXP-AD	13.7 fl oz	3.4	bc	4.7	efg	0.1	c
16	Rotation	Vangard + Tilt Quadris Top	5 + 4 oz 14 fl oz	3.4	bc	14.5	bcde	0.3	c

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A on 2-13 (80% bloom) and 3-9 (3 weeks after petal fall).

** - For brown rot evaluation in mid-May, the number of strikes per tree was counted for each of four single-tree replications. For shot hole, 25 fruit were collected from each tree and evaluated using a rating scale of 0, 1-3, 4-6, 7-10, or >10 lesions per fruit.

^ - Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

The efficacy of fungicides against gray mold was evaluated in laboratory flower petal assays on cv. Drake (**Table 2**). The lowest levels of disease developed using Rhyme, Luna Experience, F4406-3, and EXP-AD, but other treatments also significantly reduced gray mold incidence and severity.

<u>Shot hole management – 2018 Research.</u> Incidence and severity of shot hole were high in the untreated controls in 2018 on cvs. Drake and Sonora at UC Davis. On both cultivars, UC-1 and UC-2 reduced the incidence to less than 10% as compared to the controls with 73-75% incidence. On cv. Drake, Rhyme, F4406-3, GWN 10320, Luna Experience, Merivon, Helmstar, and EXP-AD were also highly effective (**Table 1**). Most other treatments evaluated also significantly reduced disease incidence from the control, except Stargus and the conventional fungicide IKF-5412 that were evaluated on cv. Sonora. Still, disease severity was significantly reduced by all treatments evaluated.

Table 2. Efficacy of fungicide treatments for management of gray mold of cv. Drake almonds in the laboratory.

No.	Program	Treatment*	Rate/A	Gray mold*** Inc. (%)	LSD^	Severity	LSD
1	---	Control	---	90.3	a	2.9	a
2	Single	Rhyme	7 fl oz	35.7	fg	1.0	ef
3		Pyraziflumid	4.7 fl oz	74.1	bc	1.9	bc
4		Pyraziflumid	3.1 fl oz	74.8	b	2.2	b
5		GWN 10320	32 fl oz	87.6	a	2.7	a
6		UC-1	3 fl oz	58.3	de	1.5	cd
7		F4406-3	5 fl oz	24.2	hi	0.5	gh
8		F4406-3	6 fl oz	24.8	ghi	0.7	fgh
9	Pre-mixtures	Merivon	5.5 fl oz	68.7	bcd	2.1	b
10		Luna Sensation	7.8 fl oz	62.3	cd	1.7	cd
11		Luna Experience	8 fl oz	22.0	i	0.3	h
12		Quadris Top	14 fl oz	61.9	d	1.4	de
13		Helmstar	14.5 fl oz	46.4	ef	0.8	fg
14		UC-2	5 fl oz	34.5	fgh	0.8	fg
15		EXP-AD	13.7 fl oz	28.4	ghi	0.6	fgh

* Flower petals were collected in the field, placed onto moist vermiculite, and treated in the laboratory using a hand sprayer.

*** Gray mold was evaluated for ca. 50 petals for each of three replications per treatment using a scale: 0=0, 1=<25%, 2=26-50%, 3= 51-75%, 4=76-100% petal area diseased.

^ Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation (*P* > 0.05).

<u>Hull rot management – 2017 Research.</u> The incidence of hull rot was low to moderate at our orchard northern California sites; whereas at the Fresno Co. site (UC KARE) it was high due to our intentional over-head irrigation application. Incubation of diseased fruit indicated that *Rhizopus stolonifer* was the main pathogen at our trial locations. Over the years, this fungus has been the primary pathogen; the occurrence of *Monilinia fructicola* has been much more variable. *Aspergillus niger* is only occasionally found in our surveys of central and northern California Nonpareil orchards. Possibly, microclimatic conditions (temperature) could be responsible for differences in occurrence of hull rot pathogens (e.g., *A. niger* in Kern Co. because it may be more heat-tolerant).

Treatments for the management of hull rot included foliar applications of fungicides and alkaline fertilizers at pre- and early hull split. Timings of foliar applications were targeting the main infection periods of the hull rot pathogens *M. fructicola* (pre-hull split) and *R. stolonifer* (early to mid-hull split) applied with the navel orange worm treatment. These are currently the suggested timings in a two-spray program for hull rot management.

Di-KPO_4 alone or mixed with calcium hydroxide performed well in our Colusa Co. trial, significantly reducing the disease to less than 6.8 spur infections per tree as compared to 19.3 infections per tree in the control (**Table 3**). The natural product GA-143 also reduced the disease to less than 6.5 infections per tree. The efficacy of GA-143 and di-KPO_4 was similar to the fungicide treatments. Still, Fontelis mixed with Ph-D reduced the disease to the lowest level

Table 3. Effect di-potassium phosphate, GA-142, and fungicide treatments on the incidence of hull rot on cv. Nonpareil almond - Colusa Co. 2017

				Application date		Strikes/tree**	
No.	Program	Treatment*	Rate (/A)	7-18-17	8-3-17	No.	LSD^
1	---	Control	---	---	---	19.3	a
2	Fertilizers	di-KPO_4	48 oz	---	@	6.3	b
3		di-KPO_4	48 oz	@	@	3.8	b
4		di-KPO_4 + $Ca(OH)_2$	48+ 320 oz	---	@	6.8	b
5		di-KPO_4 + $Ca(OH)_2$	48 + 320 oz	@	@	5.8	b
6		$Ca(OH)_2$	320 oz	---	@	6.0	b
7	Biological	GA-142	24 fl oz	@	@	5.8	b
8		GA-142	24 fl oz	---	@	6.5	b
9	Mixtures	Fontelis + Tebucon	20 fl oz + 8 oz	---	@	5.0	b
10		Fontelis + Inspire	20 + 7 fl oz	---	@	7.0	b
11		Fontelis + Abound	20 + 15.5 fl oz	---	@	6.0	b
12		Fontelis + Ph-D	20 fl oz + 6.2 oz	---	@	3.3	b

* Treatments were applied using an air-blast sprayer at 100 gal/A. The first application on 7-18-17 was at early suture. opening. The second application was at 5% hull split. All treatments included Breakthru at 8 fl oz/A.

** Disease was evaluated on 8-15-17.

^ Values followed by the same letter are not significantly different based on an analysis of variance and least significant difference (LSD) mean separation (P > 0.05) procedures.

with 3.3 strikes per tree (**Table 3**). In the Fresno Co. trial, disease on untreated controls was low on cv. Padre and moderate on cv. Wood Colony with 12.0 and 30.5 strikes per tree, respectively (**Table 4**). All fungicides significantly reduced the disease from the control on cvs. Padre and Wood Colony. The disease was significantly reduced to a range of 2-5% on cv. Padre for all fungicides evaluated; whereas Inspire EC, Inspire EC + pyraziflumid, Luna Experience, EXP-AD, UC-2, and IKF-5412 reduced the disease to <9% on cv. Wood Colony. In the second Colusa Co. trial on Nonpareil, all fungicides significantly reduced the disease to less than 4.3 infections/tree from 9.3 infections/tree in the untreated control (**Table 5**). In this latter trial, the top treatments were UC-1, IKF-5412, IKF-5414, and the Quash and Quash-Intuity rotation with less than 2 infections/tree.

In the third Colusa trial, the disease was significantly reduced to less than 3.6 strikes/tree by all fungicide treatments as compared to 11.7 strikes/tree in the control. The lowest values for Ph-D and Quadris Top were obtained when they were applied only once on 7-18-2017; whereas the lowest disease level for Luna Experience was when the fungicide was applied only once on 7-8-2017 (**Table 6**). The different timings of the three fungicides resulted in statistically similar levels of disease control.

In summary, we demonstrated that several fungicides containing FRAC Groups 3, 7, 11, or 19, the natural product GA-142, as well as the alkalizing foliar fertilizer di-KPO_4 reduced the incidence of hull rot in several trials over the last two years. Alkalizing treatments and natural products could possibly be used in organic almond production and may have other benefits in balancing the nutritional content of the hulls especially regarding nitrogen. This strategy is being evaluated again in 2018. Reduction in disease with the most efficacious fungicides is

Table 4. Efficacy of fungicide treatments for management of hull rot of almond - Fresno Co. 2017.

No.	Program	Treatment*	Rate (/A)	Padre Strikes/tree No.	Padre Strikes/tree LSD^	Wood colony Strikes/tree No.	Wood colony Strikes/tree LSD^
1	---	Control	---	12.0	a	30.5	a
2	Single	Inspire EC	7 fl oz	5.3	b	8.3	b
3		Pyraziflumid	5.08 fl oz	5.3	b	11.3	b
4		UC-1	7 fl oz	4.3	b	14.3	b
5	Mixtures	Quash + Ph-D	3 + 6.2 oz	4.8	b	11.3	b
6		Inspire EC + Ph-D	7 fl oz + 6.2 oz	not done		not done	
7		Inspire EC + Pyraziflumid	7 + 6.2 fl oz	4.8	b	6.5	b
8	Pre-mixtures	Luna Sensation	7 fl oz	not done		not done	
9		Luna Experience	8 fl oz	3.0	b	9.0	b
10		Merivon	6.5 fl oz	4.3	b	12.3	b
11		Quadris Top + DyneAmic	14 + 16 fl oz	3.0	b	13.8	b
12		EXP-AD	14.1 fl oz	3.8	b	8.3	b
13		UC-2	7 fl oz	4.3	b	8.0	b
14		IKF-5412	12.5 fl oz	2.0	b	8.8	b

* Treatments were applied using an air-blast sprayer at 100 gal/A on 7-31-17 to cvs. Padre (5% hull split) and Wood Colony (10% hull split). Overhead irrigation was applied for 8 h one day after each application.

** Disease was evaluated in mid-August 2017.

^ Values followed by the same letter are not significantly different based on an analysis of variance and least significant difference (LSD) mean separation ($P > 0.05$) procedures.

generally between 60-80%. Higher levels of control have not been realized even with additional applications. This is probably due to long infection periods (hull split may take 4 to 6 weeks to complete) and the problem of residues getting into newly splitting hulls. Thus, hull rot is difficult to reduce to very low levels based on any one management method. For hull rot caused by *Monilinia* species, applications should be done before hull split and before rains that may occur in early to mid-June. This is because *Monilinia* species can invade healthy tissues and do not require injuries. In contrast, for hull rot caused by *R. stolonifer* (or by Aspergillus, Botrytis, and other species), fungicide timings at the beginning of hull split are optimal because infections generally depend on injuries including the splitting of the hull. Therefore, we suggest a two-spray program to effectively manage hull rot caused by *Monilina* <u>and</u> *Rhizopus* species. This is also because the pathogen population causing hull rot generally is not known for a given orchard site and the pathogen species are usually present at varying frequencies among locations and years. Still, if no rain occurs and humidity remains low without dew formation in the weeks before hull split, the emphasis is placed on the early hull split timing.

For the best integrated management of hull rot, fungicides should be used together with proper water management (i.e., deficit irrigation) and nitrogen fertilization. Excessive nitrogen applications and nitrogen applications made late into the spring season are more conducive for hull rot. Additionally, dust control and air movement are critical to reduce nut contamination with soil-borne spores and humidity, respectively. Thus, pruning or hedging should still be practiced.

Table 5. Efficacy of fungicide treatments for management of hull rot of cv. Nonpareil almond - Colusa Co. 2017.

No.	Program	Treatment*	Rate (/A)	Application 5-31	Application 7-13	Strikes/tree** No.	Strikes/tree** LSD^
1	---	Control	---	---	---	9.3	a
2	Single	Ph-D	6.2	@	@	2.8	b
3		UC1 + Sylcoat	4 + 8 fl oz	@	@	1.5	b
4		Pyraziflumid + NIS	5.08 + 8 fl oz	@	@	2.3	b
5	Mixture	Ph-D + Tebucon	6.2 + 4 oz	@	@	2.8	b
6	Pre-mixtures	Luna Experience + NIS	8 fl oz	@	@	3.5	b
7		UC2B = BAS752 + Sylcoat	6 oz + 8 fl oz	@	@	3.0	b
8		IKF-5412 + NIS	15 + 8 fl oz	@	@	2.0	b
9		IKF-5413 + NIS	15.5 + 8 fl oz	@	@	2.8	b
10		IKF-5414 + NIS	15.5 + 8 fl oz	@	@	1.8	b
11		Merivon + Sylcoat	6.5 + 6 fl oz	@	@	4.3	b
12	Rotations	Fontelis + Tebucon + NIS	20 fl oz + 8 oz + 8 fl oz	@	---	3.8	b
		Fontelis + Abound + NIS	20 + 15 + 8 fl oz	---	@		
13		Fontelis + Tebucon + NIS	20 fl oz + 8 oz + 8 fl oz	@	---	2.7	b
		Fontelis + Ph-D + NIS	20 fl oz + 15 oz + 8 fl oz	---	@		
14		Quash	3.36 oz	@	---	1.8	b
		Quash + Intuity	3.36 oz + 3.36 fl oz	---	@		

* Treatments were applied using an air-blast sprayer at 100 gal/A. The first application on 5-31-17 was targeted against the *Monilinia* pathogen. The application on 7-13-17 was at an advanced suture opening stage and was targeted against the *Rhizopus* pathogen. NIS = non-ionic surfactant. The grower indicated that watering was cut back by 50% 1 month before harvest and no fertilizer was applied since May.

** Disease was evaluated on 8-15-17.

^ Values followed by the same letter are not significantly different based on an analysis of variance and least significant difference (LSD) mean separation ($P > 0.05$) procedures.

<u>Develop baseline sensitivities of fungal pathogens of almond against new fungicides - 2017-18 Research.</u> The new SDHI fungicides pyraziflumid, pydiflumetofen, and isofetamid (each belonging to a different SDHI sub-group) were all highly toxic to isolates of *M. laxa* and EC_{50} values were similar to the previously evaluated fluxapyroxad and fluopyram (**Figure 1**). In contrast, a much wider range of sensitivities was determined for *B. cinerea* (**Figure. 2**). Although the majority of isolates was highly sensitive, several isolates had EC_{50} values between 1 and 5.6 ppm. Interestingly, sensitivity characteristics of isolates were similar for pydiflumetofen and pyraziflumid. One isolate was found to be highly resistant against the three

SDHI compounds. This indicates that *B. cinerea* is at risk to develop resistance. Furthermore, cross resistance is present among SDHI sub-groups and SDHI fungicides should always be rotated with different FRAC codes.

Table 6. Efficacy of fungicide treatments for management of hull rot of cv. Nonpareil almond - Colusa Co. 2017.

				Application dates			Strikes/tree**	
No.	Program	Treatment*	Rate (/A)	6-7	7-6	7-18	No.	LSD^
1	---	Control	---	---	---	---	11.7	a
2	Single	Ph-D + Breakthru	6.2 oz + 8 fl oz	---	---	@	2.0	b
3		Ph-D + Breakthru	6.2 oz + 8 fl oz	---	@	---	4.3	b
4	Pre-mixtures	Quadris top + DynAmic	14 fl oz + 14 fl oz	@	---	@	3.8	b
5		Quadris top + DynAmic	14 fl oz + 14 fl oz	@	---	---	3.5	b
6		Quadris top + DynAmic	14 fl oz + 14 fl oz	---	@	---	3.8	b
7		Quadris top + DynAmic	14 fl oz + 14 fl oz	---	---	@	3.3	b
8		Luna Experience + Breakthru	7 fl oz + 8 fl oz	@	---	@	4.0	b
9		Luna Experience + Breakthru	7 fl oz + 8 fl oz	@	---	---	4.3	b
10		Luna Experience + Breakthru	7 fl oz + 8 fl oz	---	@	---	3.5	b

* Treatments were applied using an air-blast sprayer at 100 gal/A. The first application on 6-7-17 was targeted against the *Monilinia* pathogen, and the others against the *Rhizopus* pathogen. The application on 7-6-17 was at early suture opening stage, the one on 7-18-17 at 1% hull split. The grower indicated that watering was cut back by 50% 1 month before harvest and no fertilizer was applied since May.

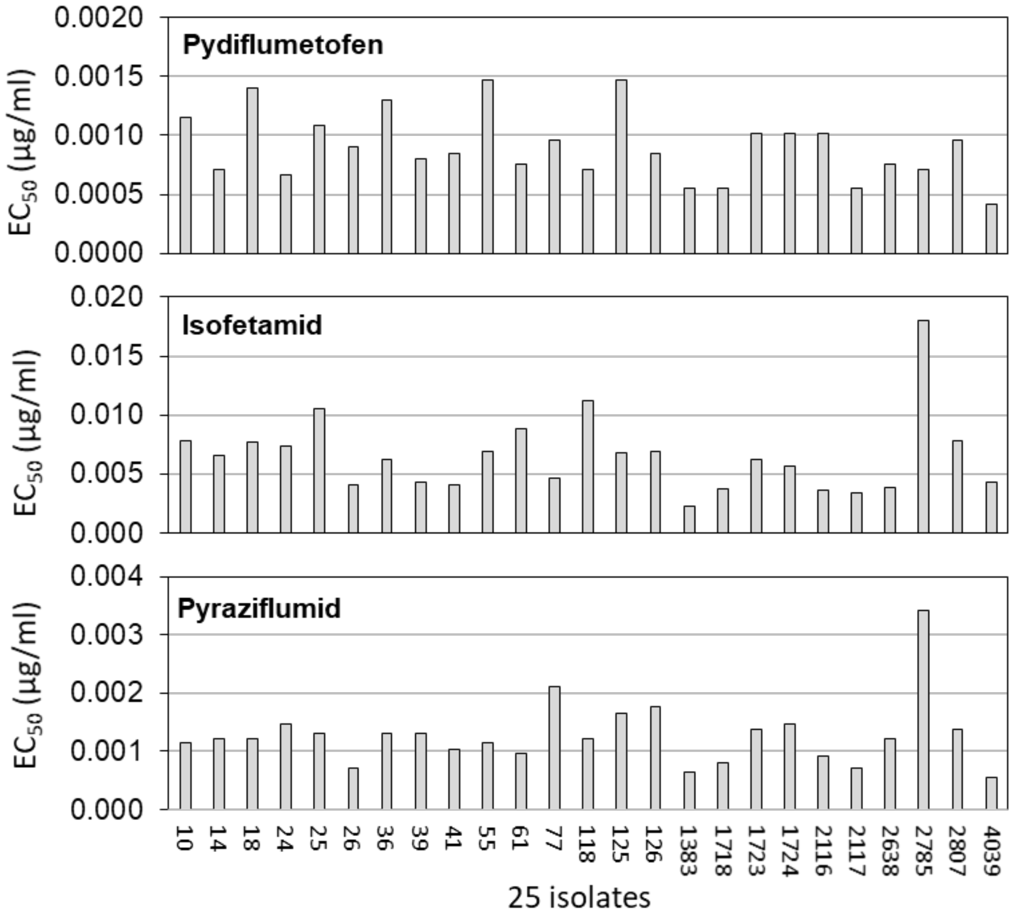
** Disease was evaluated on 8-15-17.

^ Values followed by the same letter are not significantly different based on an analysis of variance and least significant difference (LSD) mean separation ($P > 0.05$) procedures.

<u>Evaluation of natural host susceptibility against diseases in a new variety orchard - 2017 and 2018 Research.</u> In an orchard at UC Davis, 23 almond varieties and genotypes, including numbered accessions and standard cultivars (e.g., Nonpareil, Winters, Wood Colony) on two rootstocks (Krymsk 86 and Nemaguard) were evaluated for brown rot and shot hole in the spring of 2017 and 2018. There was no significant difference between the two rootstocks, and thus, data were combined. Data in **Tables 7 to 8** are ranked from low to high susceptibility based on 2017 evaluations.

In both years, Wood Colony and genotype p16.013 were the most susceptible to brown rot, whereas all others had much lower levels of disease (**Table 7**). Significant differences in susceptibility were also found for shot hole that was evaluated on leaves and fruit (data in **Table 8** are for fruit). Evaluations for the two years showed some similar trends. Thus, Aldrich Jenette, Winters, and UCD 3-40 were among the most, whereas Folsom and Supareil were among the least susceptible. In an evaluation of scab on fruit in 2017, Winters and p13.019 had the highest, whereas genotypes Y117-91-03 and UCD 8-27 had the lowest incidence of disease.

These results characterize almond cultivars and genotypes for their susceptibility to selected diseases. Less susceptible cultivars eventually can be recommended for cultivation in areas where these diseases prevail, especially when chemical control measures have to be limited (e.g., organic production). Genotypes that are more resistant could be used for further breeding if other horticultural characteristics still need to be improved. Our evaluations need to be continued, and also should be done in other growing areas. For the three diseases evaluated, Nonpareil scored at the lower level of susceptibility and the goal is to obtain other cultivars with disease resistance and with other favorable horticultural characteristics, similar to Nonpareil.



SDHI Subgroup	Fungicide	Range (µg/ml)	Average (µg/ml)
Pyridinyl-ethylbenzamide	Fluopyram	0.004 – 0.019	0.010
Pyrazole-4-carboxamides	Fluxapyroxad	0.001 – 0.007	0.004
Phenyl-oxo-ethyl thiophene amide	Isofetamid	0.002 – 0.016	0.007
N-methoxy-phenylethyl)-pyrazolecarboxamides	Pydiflumetofen	0.0004 – 0.0015	0.001
Pyrazinecarboxamide	Pyraziflumid	0.0006 – 0.0034	0.001

Figure 1. Baseline sensitivities of 25 isolates of *Monilinia laxa* to SDHI fungicides. Sensitivities were determined using the spiral gradient dilution method. In the histograms, isolates are in the same order for each of the three fungicides

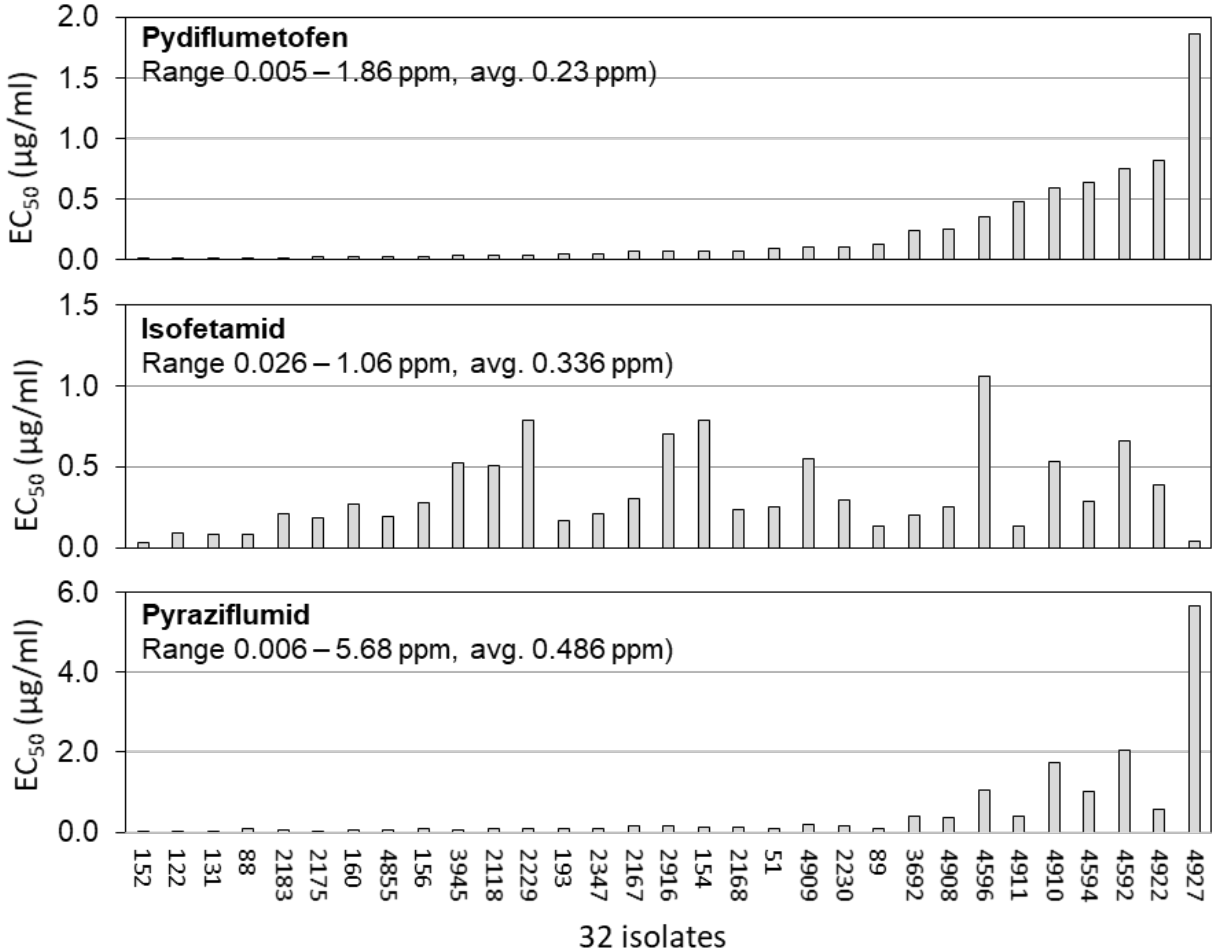


Figure 2. Baseline sensitivities of 32 isolates of *Botrytis cinerea* from tree fruit crops in California to SDHI fungicides. Sensitivities were determined using the spiral gradient dilution method. In the histograms, isolates are in the same order for each of the three fungicides. An additional isolate (from plum) was highly resistant to the three SDHIs (not shown in the figure).

Table 7. Susceptibility of current and new almond cultivars and genotypes to brown rot at UC Davis 2017 and 2018.

	Brown rot			
	2017		2018	
Cultivar/Genotype	Strikes/tree	LSD	Strikes/tree	LSD
Jenette	0.0	d	0.8	cd
UCD 8-27	0.0	d	0.0	d
p13.019	0.1	d	0.1	d
Capitola	0.3	cd	0.0	d
Nonpareil	0.3	cd	0.0	d
y121-42-99	0.3	cd	0.3	cd
Aldrich	0.4	cd	0.1	d
UCD 116	0.4	cd	0.1	d
UCD 3-40	0.4	cd	0.5	cd
Folsom	0.5	cd	0.3	cd
Sterling	0.5	cd	0.0	d
Supareil	0.6	cd	0.3	cd
Kester	0.6	cd	0.1	d
7-159 UCD	0.6	cd	0.0	d
Y117-91-03	0.7	cd	0.3	cd
1-271 UCD	1.0	cd	0.3	cd
97-1-232	1.3	cd	0.0	d
Winters	1.3	cd	0.1	d
Durango	1.5	cd	0.5	cd
UCD 8-160	1.5	cd	1.3	c
8-201 UCD	1.8	c	0.9	cd
p16.013	6.6	b	3.9	b
Wood Colony	10.4	a	8.1	a

*-The orchard was not treated with fungicides.

Table 8. Susceptibility of current and new almond cultivars and genotypes to shot hole at UC Davis 2017 and 2018.

	Shot hole on fruit			
	2017		2018	
Cultivar/Genotype	Inc. (%)	LSD	Inc. (%)	LSD
Folsom	22.5	gh	19.8	f
UCD 116	23.4	h	39.5	cdef
Supareil	27.1	fgh	18.4	ef
Y117-91-03	27.3	efgh	56.8	abcd
UCD 8-160	32.2	defgh	46.2	cdef
Sterling	33.2	defgh	26.0	def
Kester	37.0	efgh	32.5	def
Nonpareil	37.5	cdefgh	44.6	bcdef
8-201 UCD	38.7	cdefgh	56.6	abcd
Capitola	39.6	cdefgh	36.5	def
7-159 UCD	40.0	cdefgh	29.0	def
Durango	40.9	cdefg	68.1	abc
y121-42-99	40.9	cdefg	53.6	abcd
Wood Colony	44.2	bcdef	55.8	abcd
p16.013	45.0	bcdef	50.5	abcd
p13.019	46.4	bcdef	53.7	abcd
UCD 8-27	46.8	bcdef	47.0	abcd
97,10-232	48.0	bcd	30.8	def
1-271 UCD	49.7	bcd	68.8	ab
Aldrich	55.8	abc	68.0	a
Jenette	61.1	ab	73.6	a
Winters	63.6	ab	41.9	bcdef
UCD 3-40	70.7	a	43.8	bcdef

*-The orchard was not treated with fungicides.