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

Project No.: **15-PATH4-Adaskaveg**

Project Leader: J. E. Adaskaveg
Department of Plant Pathology and Microbiology
2317 Webber Hall
200 Office University Building
University of California, Riverside
Riverside, CA 92521
951.827.7577
jim.adaskaveg@ucr.edu

Project Cooperators: D. Thompson, H. Förster, D. Cary, and S. Haack, UC Riverside
T. Gradziel, UC Davis
R. Duncan, UCCE - Stanislaus County
B. Holtz, UCCE - San Joaquin County

Objectives:

I. Disease management strategies: Evaluate new fungicides and develop efficacy data based on spectrum of activity, systemic action, and persistence.
   a. Continue evaluations of new products against brown rot, jacket rot, and shot hole, in experimental orchards at UC Davis and UC Kearney Agricultural Research and Extension (KARE) center (as well as rust if the disease occurs during the season).
      - Evaluate new fungicides, fungicide pre-mixtures, and adjuvants - Aproach 2.08SC, A120259E, IL-54111, R-106506 SC, UC-1, UC-2, UC-2B, penthiopyrad (Fontelis), metconazole - Quash, dodine - Syllit, Luna Experience, Luna Sensation, Quadris Top, Quilt Xcel, Inspire Super, Merivon, as well as biologicals (Fracture, Serenade Optiva, Botector, MBI-2016 and WXF-160001).
      - Evaluate persistence and post-infection activity of selected fungicides in laboratory studies for management of brown rot.
   b. For hull rot management, evaluate application timing and new fungicides. Groups and materials include:
      - QoIs, DMIs, SDHIs, polyoxin-D, and experimental fungicides, as well as selected pre-mixtures as above.
      - Alkaline treatments by themselves or in combination with fungicides (foliar alkaline fertilizers)
      - “Cut-off” dates for applying nitrogen before hull split

II. Develop baseline sensitivities of fungal pathogen populations against new fungicides and determine potential shifts in fungicide sensitivity.
   a. Characterize baseline sensitivities of *Monilinia* species against SDHIs (penthiopyrad, fluxapyroxad, fluopyram).
   b. Determine fungicide sensitivities in 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 against brown rot blossom blight, shot hole, and other diseases that develop naturally in the springtime.

In this annual report, we can only include 2016 data for the springtime diseases brown rot, shot hole, and gray mold. Trials on summer diseases including hull rot are ongoing, and thus, 2015 data are presented for these objectives.

Interpretive Summary:

In 2015-16, we again evaluated new treatments against major foliar and fruit diseases of almond in California in field and laboratory studies. New fungicides evaluated included two new QoI - FRAC 11 compounds (i.e., Intuity - mandestrobin and Aproach - picoxystrobin) and the experimental (FRAC groups not disclosed) single-active ingredient treatments R106506, UC-1, and EXP-A and pre-mixtures UC-2, UC-2B, EXP-AD, EXP-AF, and IL-54111. The new experimental natural product WXF-16001 was also evaluated. These new treatments were compared to registered single-active-ingredient and pre-mixture compounds belonging to the DMIs – FRAC group 3, SDHIs – FRAC group 7, anilinopyrimidines – FRAC group 9, QoIs – FRAC group 11, polyoxins – FRAC group19, phosphonates – FRAC group 33, isophthalonitriles – FRAC M5, and guanidines – U12. With awareness and fungicide stewardship, the increasing arsenal of available fungicide treatments will help prevent the selection and build-up of resistant pathogen populations when applied in rotation or mixture programs. The use of pre-mixtures is a resistance management strategy, and additionally, the spectrum of activity is generally expanded so that several diseases can be targeted by a single treatment. Incidence of brown rot and gray mold at our trial sites in the spring of 2016 was low to moderate, and shot hole occurred at very low incidence. For brown rot management, most of the single- and pre-mixture-fungicides and rotation programs provided excellent disease control. Aproach, a mixture of Aproach with Fontelis (FRAC 7), the FRAC 7/11 pre-mixture Merivon, and the experimentals R-106506 and UC-2B were among the best treatments. For gray mold, the lowest levels of disease on cultivar (cv.) Drake were obtained using the experimentals EXP-A, EXP-AF, and UC-2B; and on cv. Sonora, Serenade Opti and the Ph-D/Tebucon mixture were most effective. Studies on the management of hull rot were conducted in orchards with *Rhizopus stolonifer* as the main pathogen. Soil applications with calcium sulfate or liquid lime sulfur that were intended to reduce soil inoculum levels did not significantly reduce hull rot. This indicates that populations of the omnipresent *R. stolonifer* that has a high reproduction potential and is readily wind-disseminated from nearby fields cannot be easily reduced. In our trials, we demonstrated, as in the previous season, that alkalizing treatments can be as effective as fungicides in reducing hull rot, but there was no additive effect when applied together with a fungicide. Alkalizing treatments were applied to possibly neutralize fumaric acid that is produced by *R. stolonifer* and is considered to be responsible for the dieback symptoms on almond spurs. Phytotoxicity was observed with some of the alkalizing treatments, but the fertilizer Di-K phosphate did not cause leaf burning after two applications. 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). In baseline sensitivity studies with *R. stolonifer*, EC_{50} values for two QoI - FRAC 11 compounds were much lower than for two DMI - FRAC 3 or two SDHI - FRAC 7 compounds. In addition, a wider range of sensitivities was found for the SDHIs. Lastly, for evaluation of natural host resistance to diseases in our new almond variety block at UC Davis, first data were obtained with rust evaluations in the fall of 2015.

Materials and Methods:

***Fungicide evaluations for management of brown rot, gray mold, and shot hole in experimental orchards – 2016 Research*.** Field trials were conducted at UC Davis on cv. Drake, Butte, and Sonora, and at the Kearney Agricultural Research and Extension (KARE) Center on cv. Wood Colony. Treatments were done as single-fungicide, mixture, pre-mixture, or rotation programs. Four applications were done at UC Davis from pink bud to petal fall. A single application was done at KARE. This was followed by two 6- to 8-h simulated rain applications. For brown rot evaluation, the number of strikes per tree was counted for each of four or six single-tree replications. All fungicides were also evaluated in laboratory studies on detached blossoms 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 cvs. Drake and Sonora. For this, flower petals were collected after the full bloom field spray and incubated on moist vermiculite for 5-6 days at 20C for the development of natural incidence of the disease.

***Fungicide evaluations for management of hull rot - 2015 Research*.** Field trials were conducted in cv. Nonpareil orchards in Colusa, San Joaquin, and Fresno Co. where hull rot was mostly caused by *R. stolonifer*. Treatments to evaluate fungicide efficacy were mostly done as a two-spray program with applications at pre- and mid-hull split. In addition to fungicides, alkaline fertilizers or sodium bicarbonate were used in an effort to neutralize fumaric acid secretion of *R. stolonifer* that is responsible for causing dieback symptoms of hull rot. Furthermore, soil applications of liquid lime sulfur or calcium sulfate (in early May and June) were evaluated to potentially inactivate inoculum populations of *R. stolonifer* on the orchard floor. Liquid lime sulfur treatments were done in a split plot trial with foliar fungicide applications. Hull rot was evaluated by counting the number of shoot infections in a 30-sec evaluation per tree.

Develop baseline sensitivities of fungal pathogens from hull rot-infected fruit against different fungicide classes – 2015-16 Research. Additional isolates of *R. stolonifer* were obtained from almond fruit with hull rot symptoms in the summer of 2015. In vitro fungicide sensitivities were determined for two DMIs (difenoconazole, metconazole), two SDHIs (fluopyram, fluxapyroxad), and two QoIs (trifloxystrobin, pyraclostrobin) using the spiral gradient dilution method as described previously (Forster et al., Phytopathology 94:163-170). For the DMIs and SDHIs, sensitivities were tested for mycelial growth inhibition, and for the QoIs, inhibition of conidial germination was evaluated.

Evaluation of natural host susceptibility against diseases in a new variety orchard – 2015 Research. A new variety block was established at UC Davis in the spring of 2014 for evaluation of disease susceptibility of new varieties and genotypes. Twenty-eight varieties on two rootstocks were planted in a randomized block design. Leaf rust developed late in the season of 2015 and severity of disease was evaluated in October 2015. Severity ratings were based on a scale from 0 = healthy, 1 = 1-5 lesions, 2 = 6-14 lesions, 3 = 15-25 lesions, to 4 = >25 lesions/leaf.

***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. For the hull rot trial with liquid lime sulfur, a split-plot analysis was performed with liquid lime sulfur treatments or no treatments as the main plots and foliar fungicide applications as the sub-plots.

Results and Discussion:

***Brown rot blossom blight and gray mold management – 2016 Research**.* Although more rainfall occurred in the spring of 2016 than 2015, brown rot incidence at UC Davis was low to moderate (average of 19 brown rot strikes per tree) on the highly susceptible cv. Drake, and no disease was observed on cvs. Sonora and Butte. On cv. Drake, all treatments significantly reduced the incidence of disease to an average of 4.4 strikes per tree or less (**Table 1**).

Table 1. Efficacy of fungicide programs for management of brown rot and gray mold of cv. Drake almonds at UC Davis 2016.

				Application				Brown rot**		Gray mold***			
					2-16	2-23	3-8	Strikes/					
No.	Program	Treatment*	Rate/A	PB	FB	PF	PF	tree	LSD^	Inc. (%)	LSD	Severity	LSD
1	---	Control	---	---	---	---	---	19.0	a	71.3	b	2.0	b
2	Single	EXP-A	5.13 fl oz	@	@	@	@	2.0	cde	20.2	efg	0.5	fg
3		R-106506 SC + NIS	3.38 fl oz	@	@	@	@	1.0	de	37.1	cdef	0.7	efg
4		R-106506 SC + NIS	5.08 fl oz	@	@	@	@	0.2	e	54.7	bcd	1.3	bcdef
5		UC-1	4 fl oz	@	@	@	@	4.4	b	39.1	cde	1.0	defg
6		Aproach 2.08SC + NIS	8 fl oz	@	@	@	@	0.0	e	60.0	bc	1.4	bcde
7		Aproach 2.08SC + NIS	12 fl oz	@	@	@	@	1.0	de	90.0	a	2.9	a
8	Mixtures	Aproach 2.08SC + Fontelis + NIS	8 + 14 fl oz	@	@	@	@	0.6	de	66.4	b	1.7	bcd
9		Aproach 2.08SC + Fontelis + NIS	8 + 16 fl oz	@	@	@	@	1.0	de	73.7	ab	1.9	bc
10	Pre-	Quadris Top + Dyne-Amic	14 + 16 fl oz	@	@	@	@	2.6	bcd	69.4	b	1.7	bcd
11	mixtures	Merivon	6.5 fl oz	@	@	@	@	0.6	de	36.9	cdef	1.1	cdefg
12		EXP-AD	13.7 fl oz	@	@	@	@	2.8	bcd	25.5	efg	0.4	g
13		EXP-AF	6.84 fl oz	@	@	@	@	3.4	bc	14.3	g	0.3	g
14		IL-54111	12.5 fl oz	@	@	@	@	2.8	bcd	22.2	efg	0.4	g
15		IL-54111	15 fl oz	@	@	@	@	1.6	cde	31.0	defg	0.9	efg
16		UC-2B	6 fl oz	@	@	@	@	0.8	de	16.6	fg	0.4	g

* Treatments were applied using an air-blast sprayer at a rate of 100 gal/A and there were 6 single-tree replications for each treatment.

** For brown rot evaluation, the number of brown rot strikes per tree was counted for each of six single-tree replications.

*** Gray mold was evaluated on flower petals that were collected after the full bloom spray and incubated on moist vermiculite in the laboratory. Incidence of gray mold was based on ca. 50 petals for each treatment replication. Severity was evaluated using a rating scale: 0=0, 1=<25%, 3=51-75%, 4=76-100% petal area diseased.

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

Treatments that reduced brown rot incidence to an average of 1 or fewer strikes per tree included the FRAC group 11 Aproach, a mixture of Aproach with Fontelis (FRAC 7), the FRAC 7/11 pre-mixture Merivon, and the experimentals R-106506 and UC-2B. In the KARE trial, where trees received two overhead irrigations for 6 to 8 h after the single application, an average of 28.2 strikes developed on control trees (**Table 2**). The natural product WXF-16001 did not significantly reduce the disease from the control, but the biocontrol Botector showed moderate efficacy with 15.4 strikes per tree. Fungicide treatments reduced the disease to between 3.8 strikes (i.e., Luna Experience) and 9.8 strikes (i.e., the experimental UC-1), and there was no significant difference among fungicides used.

Most of the field treatments were also evaluated in laboratory pre- and post-infection studies on detached cvs. Butte and Wood Colony blossoms. All eleven fungicide treatments performed very well and reduced the incidence of brown rot by >90% from that of the control. The biological treatments Fracture and WXF-16001 were not effective, however, Botector, as in previous years, significantly reduced the incidence of stamen infections (35% or 67.6% reduction from the control for cvs. Wood Colony and Butte, respectively) as a pre-infection treatment.

The efficacy of field fungicide treatments against gray mold was evaluated in blossom petal assays on cvs. Drake (**Table 1**) and Sonora (**Table 3**). The lowest levels of disease on cv. Drake occurred using the experimentals EXP-A, EXP-AF, and UC-2B. On cv. Sonora, Serenade Opti and the Ph-D/Tebucon mixture resulted in the lowest disease incidence (**Table 3**). A pink bud application of Rovral/Oil followed by a full bloom application with Pristine was the least effective treatment.

Table 2. Efficacy of fungicides for management of brown rot of cv. Wood Colony almonds at KARE, Fresno Co. 2016.

				Brown rot strikes**	
No.	Program	Treatment	Rate/A	No./tree	LSD^
1	---	Control	---	28.2	a
2	Biologicals	WXF-16001	0.35%	18.4	ab
3		WXF-16001	0.70%	19.2	ab
4		Botector	10 oz	15.4	bc
5	Single	Fontelis + Breakthru	20 + 6 fl oz	7	d
6		Aproach 2.08SC +Breakthru	8 fl oz + 6 fl oz	7.4	cd
7		Aproach 2.08SC +Breakthru	12 fl oz + 6 fl oz	8.6	cd
8		UC-1 + Induce	4 fl oz + 6 oz	9.8	cd
9	Mixtures	Fontelis + Tebucon 45DF + Breakthru	8 fl oz + 4 oz + 6 fl oz	9.4	cd
10		Aproach 2.08SC + Fontelis + Breakthru	8 + 14 + 6 fl oz	7	d
11		Aproach 2.08SC + Fontelis + Breakthru	8 + 16 + 6 fl oz	7.6	cd
12	Pre-	Luna Experience + Breakthru	8 fl oz + 4 fl oz	3.8	d
13	mixtures	Merivon	5.5 fl oz	7	d
14		Merivon	6.5 fl oz	8.6	cd
15		Quadris Top + DyneAmic	14 + 16 fl oz	7.2	d
16		UC-2B + Induce	6 fl oz + 6 fl oz	6.4	d

* Treatments were applied using an air-blast sprayer at a rate of 100 gal/A at 30% bloom (2-19-16) 6-8 h of overhead sprinkler irrigation was applied to the orchard one and two days after application.

** For brown rot evaluation on 4-13-16, the number of brown rot strikes per tree was counted for 3 min for each of five single-tree replications.

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

Shot hole management – 2016 Research. The incidence of shot hole was very low in the untreated control in 2016 on cvs. Drake, Sonora, and Butte at UC Davis and no efficacy data could be obtained.

Our field studies indicate that numerous highly effective fungicides are available for the management of brown rot blossom blight. Among new conventional compounds, Aproach, R-106506, and UC-2B (FRAC groups not disclosed) are promising treatments with high efficacy against brown rot. UC-2B was also among the most effective treatments against gray mold.

Our data also indicate that some biologicals such as Botector and Serenade Opti can have a role in the management of springtime diseases for organic and possibly conventional farmers where low disease pressure occurs because moderate reductions in brown rot and gray mold were observed with these treatments.

Table 3. Efficacy of biological and fungicide treatments for management of gray mold of cv. Sonora almonds at UC Davis 2015.

				Applications			**Gray mold*** **	
				2-10	2-17	3-3		
No.		Treatment*	Rate	PB	FB	PF	Inc. (%)	LSD
1	---	Control	---	---	---	---	43.9	a
2	Biologicals	Fracture + Breathru	30 fl oz + 0.25%	@	@	@	19.1	bc
3		Botector	8 oz	@	@	@	8.9	def
4		Serenade Opti + NIS	16 oz	@	@	@	3.5	g
5	Single	Quash	3.5 oz	@	@	@	7.7	f
6		Rovral+NIS	1 pints	@	@	@	12.1	def
7		Rovral + Omni Oil	1 pt + 1.5% oil	@	@	@	10.6	def
8	Pre-mixture	Viathon	2 pt	@	@	@	10.0	def
9		Viathon	3 pt	@	@	@	8.8	def
10	Rotations	Rovral + NIS	1 pints	---	@	---	8.6	ef
		Serenade Opti + NIS	16 oz	---	---	@		
11		Serenade Opti + NIS	16 oz	---	@	---	13.7	cd
		Rovral + NIS	1 pints	---	---	@		
12		Rovral + Omni Oil	1 pt + 1.5% oil	@	---	---	12.4	de
		Tebuconazole	4 oz	---	@	---		
		Luna Sensation + NIS	5 oz	---	---	@		
13		Rovral + Omni Oil	1 pt + 1.5% oil	@	---	---	23.1	b
		Pristine	14.5 oz	---	@	---		
		Merivon	5.5 fl oz	---	---	@		
14		Ph-D	6 oz	@	@	@	3.0	g
		Tebuconazole	4 oz	@	@	---		
15		Oso	13 fl oz	@	@	@	8.4	ef
		Tebuconazole	4 oz	@	@	---		

* Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. NIS = Non-ionic surfactant.

*** Gray mold was evaluated on flower petals that were collected after the full bloom spray and incubated on moist vermiculite in the laboratory. Incidence of gray mold was based on ca. 50 petals for each treatment replication. Severity was evaluated using a rating 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).

Note: No brown rot developed in this trial

Table 4. Efficacy of fungicide treatments for management of hull rot of cv. Nonpareil almond - Colusa Co. 2015.

				Applications			Incidence of hull rot			
							No LLS*		LLS	
No.	Program	Treatment	Rate (/A)	5/12	6/11	7/20	%	LSD^	%	LSD
1	---	Control	-----	---	---	---	15.9	a	13.3	a
2	Single	Calcium sulfate*	45 lb	@	@	---	10.3	ab	not done	
3		Inspire	7 fl oz	---	@	@	12.3	ab	10.3	ab
4	Mixture	Quash + mandestrobin	3.36 oz + 3.36 fl oz	---	@	@	6.5	b	not done	
5	Pre-	Quadris Top + DyneAmic	14 fl oz + 16 fl oz	---	@	@	9.8	ab	8.8	b
6	mixtures	Luna Experience	6 fl oz	---	@	@	8.0	b	Not done	
7		EXP-2	7 fl oz	---	@	@	8.5	b	Not done	
8		EXP2B	7 fl oz	---	@	@	9.3	b	Not done	
9		Merivon	6.5 fl oz	---	@	@	7.8	b	6.8	b
10		Viathon	64 fl oz	---	@	@	8.5	b	Not done	
11	Rotations	Ph-D + Quash + Nufilm P	6.2 + 3 oz + 8 fl oz	---	@	---	7.0	b	Not done	
		Ph-D + Abound + Nufilm P	6.2+ 12 fl oz + 8 fl oz	---	---	@				
12		Luna Experience	6 fl oz	---	@	---	10.5	ab	7.5	b
		Luna Sensation	5 fl oz	---	---	@				
13		Luna Sensation	5 fl oz	---	@	---	7.8	b	Not done	
		Luna Experience	6 fl oz	---	---	@				

* Calcium sulfate was applied to the soil under the tree canopy by spraying (1 gal/tree). Liquid lime sulfur (LLS) was applied commercially to the soil on 5-8-15 and 6-4-15 at 15 gal/A. Foliar treatments were applied using an airblast sprayer at 100 gal/A.

** The number of hull rot strikes/tree was determined on 8-20-15.

^ 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.

Table 5. Effect of liquid lime sulfur and fungicide treatments on the incidence of hull rot of cv. Nonpareil almond in San Joaquin Co. 2015

Sub-plot appl.	6/12	Control		Luna Experience		Qu. Top + DyneAmic		Merivon		Inspire		Main plot	
	7/14	Control		Luna Sensation		Qu. Top + DyneAmic		Merivon		Inspire		Treatment Avg	
Main Plot	Appl. Date	Dis. Inc.^	LSD^^	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD	Dis. Inc.	LSD
Control	---	22.6	A a	12.0	AB a	8.3	B a	12.5	AB a	7.8	B a	15.4	a
LLS 15 gal/A	5-7/6-3	23.5	A a	9.3	B a	6.8	B a	9.7	B a	9.7	B a	14.3	a
Sub-plot trt avg		23.1	A	10.4	B	7.4	B	10.8	B	8.9	B		

^ Trees were evaluated for the presence of hull rot on 8-10-15. Disease values are the number of hull rot strikes/per tree.

^^ Values followed by the same number are not significantly different based on an analysis of variance and LSD mean separation (*P* > 0.05). Statistical comparisons for values in the shaded area by column are with lower case letters. Main plot treatment averages are values for treatments over all sub-plots and are statistically compared by column. Sub-plot averages are values for each of the main plots and are statistically compared within the row.

***Hull rot management – 2015 Research*.** The incidence of hull rot was low to moderate at our orchard sites likely due to the statewide drought and reduced orchard watering. Incubation of diseased fruit indicated that *Rhizopus stolonifer* was the main pathogen at our trial locations.

Table 6. Efficacy of fungicide treatments for management of hull rot of cv. Nonpareil almond - San Joaquin Co. 2015.

				Applications		Hull rot**	
No.	Program	Treatment*	Rate (/A)	6/12/2015	7/14/15	strikes/tree	LSD^
1	---	Control	-----	---	---	29.7	a
2	Single	Double OK 0-0-30	3 gal / 64 fl oz***	@	@	12.8	b
3		Di-potassium phosphate	32 oz / 48 oz****	@	@	9.8	b
4		Inspire	7 fl oz	@	@	7.8	b
5	Mixtures	Quash + mandestrobin	3.36 oz + 3.36 fl oz	@	@	13.0	b
6		Double OK 0-0-30 + Qu Top + Dyn.	3 gal / 64 fl oz*** + 14 + 16 fl oz	@	@	16.3	b
7		Di-K phosphate + Qu Top + Dyn.	32 / 48 oz**** + 14 + 16 fl oz	@	@	10.0	b
8	Pre-mixtures	Quadris Top + DyneAmic	14 + 16 fl oz	@	@	8.3	b
9		Merivon	6.5 fl oz	@	@	12.5	b
10		EXP-2	7 fl oz	@	@	10.3	b
11		EXP-2B	7 fl oz	@	@	9.5	b
12	Rotations	Ph-D + Quash + Nufilm P	6.2 + 3 oz + 8 fl oz	@	---	10.0	b
		Ph-D + Abound + Nufilm P	6.2 oz + 12 + 8 fl oz	---	@		
13		Luna Experience	6 fl oz	@	---	12.0	b
		Luna Sensation	5 fl oz	---	@		
14		Luna Sensation	5 fl oz	@	---	11.5	b
		Luna Experience	6 fl oz	---	@		

* Treatments were applied using an airblast sprayer at 100 gal/A at early hull split and mid-hull split.
** Disease was evaluated on 8-10-15.
*** Used 3 gal in the first and 64 fl oz in the second application.
**** Used 32 fl oz in the first and 48 oz in the second application.
^ 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.

Over the years, this fungus has been the primary pathogen; the occurrence of *Monilinia fructicola* has been much more variable. Possibly, microclimatic conditions (temperature) could be responsible for this (e.g., *R. stolonifer* is more heat-tolerant). Treatments for the management of hull rot included foliar applications of fungicides or alkaline fertilizers at pre- and mid-hull split and of soil applications with liquid lime sulfur or calcium sulfate in early May to mid-June. Timings of foliar applications were targeting the main infection periods of the hull rot pathogens *M. fructicola* (pre-hull split) and *R. stolonifer* (mid-hull split). These are currently the recommended timings in a two-spray program for hull rot management.

Fungicide treatments in a trial in Colusa Co. were only moderately effective, reducing the number of strikes per tree from an average of 15.9 in the control to between 6.5 (Quash + Intuity - mandestrobin) and 12.3 (Inspire) (**Table 4**). More importantly, soil applications with calcium sulfate or liquid lime sulfur did not significantly reduce hull rot levels in this trial. Liquid lime sulfur also was not effective in another trial (**Table 5**). On average in the main plot, there were 15.4 strikes/tree on control trees and 14.3 strikes/tree on trees that had received a liquid lime sulfur treatment to the soil. Therefore, inoculum levels of *R. stolonifer* in an orchard cannot be easily reduced. This is because this fungus produces abundant spores that are readily wind-dispersed over a larger area (several fields). Although a reduction of soil populations may be achieved with these treatments, new inoculum is quickly re-introduced into an orchard. Two applications (one in early June and the other in July at early hull split) of Luna Experience/Luna Sensation, Quadris Top, Inspire, or Merivon significantly reduced the disease from that of the control.

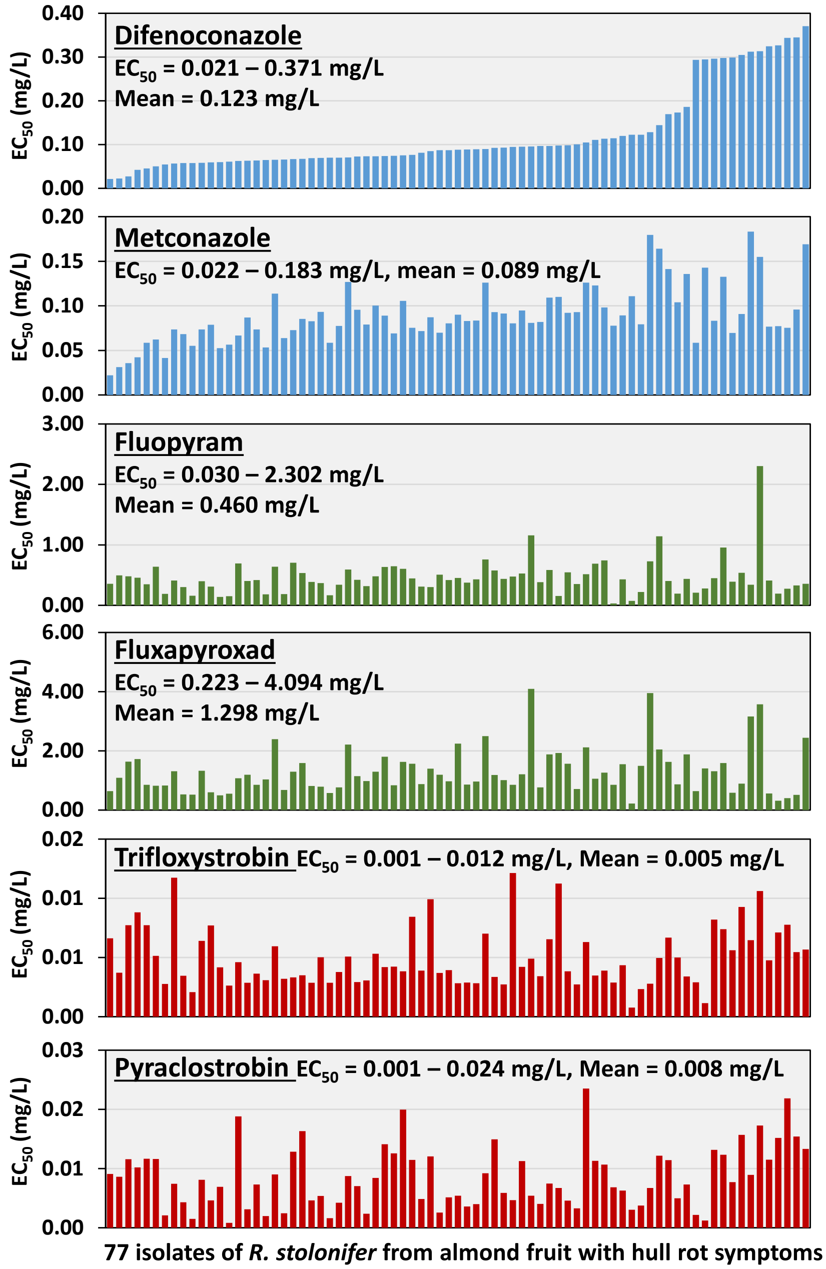

Figure 1. Sensitivity of isolates of *Rhizopus stolonifer* to two DMI, two SDHI, and two QoI fungicides. Isolates are arranged from sensitive to less sensitive in the histogram for difenoconazole and are in the same order for the other fungicides.

In another trial in San Joaquin Co., all treatments evaluated, including alkaline fertilizers and fungicides, significantly reduced the amount of hull rot from an average of 29.7 strikes/tree in the control to between 7.8 strikes (i.e., Inspire) and 16.3 strikes/tree (Double OK 0-0-30 mixed with Quadris Top) (**Table 6**). There was no significant difference among all treatments, thus, they all performed similarly statistically. Alkalizing treatments in combination with Quadris Top did not result in improved efficacy as compared to either treatment alone, perhaps due to pH inactivation of the fungicide. Alkalizing treatments were applied to possibly neutralize fumaric acid that is produced by *R. stolonifer* and is considered to be responsible for the dieback symptoms on almond spurs with hull rot-affected fruit. This strategy was successful, similar to trials in 2014 when lime or sodium bicarbonate were used. Sodium bicarbonate at 4% was also very effective in another trial at KARE in 2015 (data not presented), however, severe phytotoxicity resulted. One of the alkaline fertilizers used in the trial of **Table 6**, Double OK 0-0-30, also resulted in phytotoxicity; therefore, the rate was reduced in the second application. Di-K phosphate, however, did not cause any leaf burning, and we increased its rate for the second application.

In summary, we demonstrated that fungicide or alkalizing treatment such as Di- K phosphate can be used to reduce the incidence of hull rot without causing phytotoxicity. Alkalizing treatments could possibly be used in organic almond production. This strategy is being evaluated again in 2016. Due to long infection periods (hull split) and the problem of obtaining residues into newly splitting hulls, hull rot is difficult to reduce to very low levels. We previously demonstrated that if *Monilinia* species are the main pathogens, applications should be done before hull split (e.g., early to mid-June) because these fungi can invade the intact, immature hull and do not require injuries. *R. stolonifer*, in contrast, depends on injuries such as hull splits for infection. Therefore, at this time, we still recommend a two-spray program to most effectively manage hull rot. This is also because the pathogen population causing hull rot is generally not known for a particular orchard site and both pathogens are usually present at varying frequencies among locations and years. 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 currently being evaluated to determine if a cut-off date of early May can improve disease management.

Determine baseline sensitivities of fungal pathogen populations against new fungicides and potential shifts in fungicide sensitivity - 2015/2016 Research. Baseline sensitivity studies were continued for 77 isolates of the main hull rot pathogen *R. stolonifer* for representative fungicides in FRAC groups 3, 7, and 11 (**Figure 1**). With very low EC_{50} values, the FRAC 11 QoI compounds were more active against this pathogen than FRAC 3 or 7 compounds. A wider range of sensitivities was found for the two SDHIs as compared to the QoIs and DMIs. In fact, the least sensitive isolate for fluopyram had an almost 80-fold higher EC_{50} value than the most sensitive one. This may indicate a higher risk of resistance development for FRAC group 7 that is now widely used to manage many diseases of almond.

Evaluation of natural host susceptibility against diseases in a new variety orchard- 2015 Research. In a new orchard block at UC Davis with new varieties of almond, twenty-eight varieties, including numbered accessions and standard cultivars (e.g., Nonpareil, Winters, and Wood Colony) on two rootstocks (Krymsk 86 and Nemaguard) were available. Almond leaf rust developed late in 2015 and was evaluated. There was no significant difference between the two rootstocks, and thus, data were combined for the analysis (**Table 7**). Overall, cv. Marcona was the most, and cv. Jennette the least susceptible cultivar evaluated. Still, there was only an approximately 3-fold difference in severity levels between these extremes. Over the coming years, we will continue to evaluate naturally occurring diseases in this orchard. Additionally, we will distribute inoculum of selected diseases by air-blast spraying during susceptible host stages to maximize our gain from this planting.

Table 7. Natural host susceptibility among cultivars and genotypes to leaf rust in a variety block at UC Davis 2015.

Cultivar/genotype*	Rust severity**	LSD^
Marcona	2.9	abcdef
UCD3-40	2.8	a
UCD-116	2.8	a
Nonpareil	2.6	abcdef
WoodColony	2.6	abc
8-201ucd	2.3	abcdef
7-159ucd	2.2	abcdef
1-271ucd	2.1	abcdef
p16.013	2.0	abcdefg
2-19eTotal	1.7	bcdefgh
p13.019	1.6	cdefgh
Durango	1.5	defgh
Supareil	1.5	defgh
97-1-232	1.4	defgh
Folsom	1.4	defgh
Sterling	1.4	defgh
UCD8-160	1.3	efgh
UCD8-27	1.3	efgh
Aldrich	1.3	efgh
Capitola	1.2	fgh
Winters	1.2	fgh
y121-42-99	1.2	fgh
Y117-91-03	1.1	gh
Jenette	0.8	h

* Trees were planted in 2014. Scions were grafted to Nemaguard and Krymsk rootstocks.

** Disease was evaluated in October 2015. Severity ratings were based on a scale from 0 = healthy, 1 = 1-5 lesions, 2 = 6-14 lesions, 3 = 15-25 lesions, to 4 = >25 lesions/leaf.

^ 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.