Epidemiology & Management of Almond Brown Rot, Scab, and Other Diseases in CA

Project No.: **10-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. Continue evaluations of new products against brown rot, jacket rot, and shot hole in experimental orchards at UC Davis and KAC (as well as rust if the disease occurs during the season).
   - Evaluate new fungicides, fungicide pre-mixtures, and adjuvants - Adament, Luna Sensation, Quadris Top, QuiltXcel, Inspire Super, Inspire XT, Ph-D, Quash, Syllit
   - Evaluate persistence and post-infection activity of selected fungicides in laboratory studies for management of brown rot.
   - Evaluate the efficacy of natural products (Actinovate, Cerebrocide, and Regalia) against selected diseases.

b. For scab management, evaluate the effect of dormant applications (new formulations of copper or Bravo used with oil) on sporulation of infected twig lesions, as well as registered (Bravo, Mancozeb, Ziram) and new fungicides (Inspire, Syllit, Quash, Ph-D, and pre-mixtures described above) for in-season use. (Focus on Bravo for extended spring time usage for disease control - i.e., 60 day PHI).

c. For hull rot management, evaluate timing and new fungicides
   - Susceptibility of different stages of hull split (i.e., early hull split vs. late hull split)
   - QoIs, DMIs, and experimental fungicides, as well as selected pre-mixtures and adjuvants.

II. Develop baseline sensitivities of fungal pathogen populations against new fungicides and determine shifts in fungicide sensitivity.

a. Characterize baseline sensitivities of *Monilinia, Fusicladium,* and other fungal species

against DMI, SDHI, and other fungicides
   b. Determine fungicide sensitivities in locations where disease was not satisfactorily managed after fungicide treatments
   c. Evaluate almond genotype susceptibility to foliar diseases including brown rot and other diseases that develop naturally in the almond variety orchard at UC Davis under simulated rainfall as part of an ongoing collaboration with T. Gradziel.

III. Study the etiology of powdery mildew-like symptoms on almond using powdery-mildew-specific DNA primers.

Interpretive Summary:

In 2010-11, we continued our field and laboratory studies on the evaluation of new treatments against major foliar and fruit diseases of almond in California. Highly effective single-fungicides and pre-mixtures were identified for the management of brown rot blossom blight, gray mold, shot hole, scab, and rust. Pre-mixtures consistently provided high efficacy and a broad spectrum of activity, while reducing the risk for selection of resistant populations for *Monilinia* spp. and most blossom pathogens of almond. We also evaluated biocontrols as an alternative to synthetic fungicides, with Actinovate providing some activity against brown rot and gray mold.

For scab, chlorothalonil is providing excellent control when applied as a dormant treatment with oil, as petal fall applications, or within a 90 to 60-day PHI interval. The latter timing will require residue studies to be done to change the label, and this is an ongoing project with the Federal IR-4 program. For rust, new fungicides include DMIs, QoIs, chlorinated hydrocarbons, and polyoxins with excellent performance using applications timed at the first detection of symptoms (i.e., May/June).

In addition, we conducted studies on the management of hull rot, a disease with an increased occurrence in recent years due to changes in horticultural practices. We identified several fungicide classes that have activity against the pathogen *Rhizopus stolonifer.* A single application of these treatments at the beginning of hull split (20%) can reduce the disease by 55-70% (in the last two years) and this application may be combined with insecticide treatments. A second application at 50-70% hull split did not improve the efficacy of the fungicides.

With awareness and fungicide stewardship, this arsenal of treatments will help prevent the selection and build-up of resistant pathogen populations when applied in rotation or mixture programs. Resistance to date has not been found in almond populations of *Monilinia laxa* (brown rot), *Botrytis cinerea* (gray mold), *Wilsonomyces carpophilus* (shot hole), or *Rhizopus stolonifer* (hull rot), but is common in *Fusicladium* (old name: *Cladosporium*) *carpophilum* (scab) and *Alternaria* spp. against the QoI fungicides and in *Alternaria* spp. against SDHI fungicides. Additionally, we continued research on the baseline sensitivity of these organisms to newly introduced DMI and polyoxin fungicides. We found numerous insensitive outliers to DMI fungicides in *F. carpophilum* populations but not in other foliar fungal pathogen populations of almond. We also initiated research on the molecular mechanism of *F. carpophilum* resistance to QoI fungicides. We are characterizing the type of resistance as compared to other fungi where resistance has been reported.

At the time of preparing this annual report, we can only include 2011 data for the springtime diseases brown rot, shot hole, and gray mold. Trials on summer diseases including scab, rust, and hull rot are ongoing, and thus, we are presenting our 2010 data for these objectives. Research on Alternaria leaf spot is presented in a separate report.

Materials and Methods:

***Fungicide evaluations for management of brown rot, gray mold, and shot hole in experimental orchards – 2011 Research*.** Field trials were conducted at UC Davis on cvs. Drake, Butte, and Sonora and at the Kearney AgCenter on cvs. Wood Colony and Sonora. Treatments were done as single-fungicide, pre-mixture, or rotation programs. In timing trials, the efficacy of selected fungicides was compared using early-bloom or full-bloom treatments and using single-spray full-bloom treatments or two-spray programs. Among the biologicals and natural products currently available, only Actinovate was evaluated again because these materials were tested by us previously and were found not to be very effective. Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. For brown rot evaluation, the number of brown rot strikes per tree was counted for each of four or five single-tree replications. All fungicides were also evaluated in additional laboratory studies on detached blossoms that were inoculated with conidia of *M. laxa* (20,000 conidia/ml) either before or 24 h after treatment. The incidence of stamen infections was then determined after 5 days of incubation at 20C. Field-treated flower petals were collected and incubated on moist vermiculite for 5 days at 20C for the development of natural incidence of gray mold. Incidence and severity (based on a rating scale from 0 to 4) of shot hole were evaluated in a random sample of approximately 100 leaves from each single-tree replication from each treatment that was collected in late March.

***Fungicide evaluations for management of scab in commercial orchards – 2010 and 2011 research*.** In 2010, in a field trial in Butte Co. on cv. Peerless under low disease pressure, treatments were applied using an air-blast sprayer at a rate of 100 gal/A at 3 and 5 weeks after petal fall and evaluation was done in mid-July. Late-season treatments were evaluated in a trial in Kern Co. where disease pressure was moderate. Applications were done on 5-19, 6-9, and 6-30-10 and disease was evaluated in late August 2010. Incidence of disease based on 50 fruit from each of four single-tree replications from each treatment.

Large-scale field trials in 2010 and 2011 under high disease pressure were conducted in Butte Co. using a split-plot design. The main plots consisted of rows treated or not treated with dormant applications. In 2011, these were Kocide 3000-oil, Badge-oil, Bravo WeatherStik, or Bravo WeatherStik-oil. The incidence and severity of sporulating scab lesions on twigs was evaluated on 4-14, 5-3, and 5-24-11 and these data are presented. Subplots were established that were not treated or treated with selected fungicides between early petal fall (beginning of sporulation of twig lesions) and mid-spring (early May). Results for 2011 on scab evaluation from this plot are pending. A trial with a similar split-plot design was conducted in 2010. Results on the efficacy of the dormant treatments on scab sporulation were reported previously, and in this report we will present results for the petal fall and springtime applications that were done between late March and mid-May 2010. For this, the incidence (percent diseased fruit) and severity (number of lesions/fruit) of scab was evaluated on 50 fruit for each of the single-tree replications in early July.

***In vitro sensitivity of* Fusicladium carpophilum *to selected fungicides - 2010 Research*.** Isolates were collected from six orchards in Butte, Colusa, and Stanislaus Co. Using the spiral gradient dilution method, the inhibition of conidial germination on azoxystrobin-amended agar media was evaluated after ca. 20 h of incubation. For polyoxin-D, difenoconazole, metconazole, and propiconazole, we determined EC_{50} values for inhibition of mycelial growth after 4 days of incubation.

***Field evaluation of almond cultivar susceptibility to brown rot, shot hole, and bacterial blast - 2011 Research*.** Almond cultivars grown in the UC Davis almond variety plot were evaluated for disease in the springtime. 32 varieties are grown on the same rootstock and under the same conditions, thus, making comparisons meaningful.

***Fungicide efficacy in the management of hull rot - 2010 Research*.** Two field trials were conducted in Colusa Co. For this, fungicides were applied at early and late hull split. Hull rot was evaluated at the time of harvest by counting the number of shoot infections per tree.

***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. Data for the large scab field trial were analyzed using split plot procedures.

Results and Discussion:

***A. Brown rot blossom blight and gray mold management– 2011 Research**.* In the UCD trial on cv. Drake under extremely high disease pressure with high rainfall in the spring of 2011, we evaluated single treatments, new pre-mixtures, and several rotation programs. All registered and experimental pre-mixtures significantly reduced the incidence of brown rot as compared to the control (**Table 1**). Disease was reduced from 131.3 shoot infections/tree in the control to between 15.5 and 91.3 infections among the treatments. Most efficacious numerically were the new pre-mixtures Q8Y78 (FRAC 7/11), Merivon (FRAC 7/11), and the QoI YT669 (FRAC 11) that is contained in Q8Y78. Still, Pristine and Adament also performed very well with less than 30 infections per tree. In the cv. Sonora trial where disease pressure was lower (i.e., 34 infections per tree in the control) treatments that included a DMI (i.e., Quash, Indar, Bumper – FRAC 3) reduced the disease to the lowest levels (**Table 2**). In the trial at Kearney Ag Center with low disease pressure (i.e., 4.2 to 6.6 infections per tree on cvs. Sonora and Wood Colony, respectively), all treatments evaluated performed similarly well and significantly reduced the amount of disease to less than 1 infection/tree for most treatments (data not presented). In the laboratory studies on detached blossoms, experimental materials and the registered fungicides Adament (FRAC 3/11), Bumper, Indar, Inspire Super (FRAC 3/9), Pristine (FRAC 7/11),

Table 1: Efficacy of fungicide programs for management of brown rot, shot hole, and gray mold of Drake almonds at UC Davis 2011.

			Application													
			2-15	2-23	3-2	3-9	Brown rot**		Gray mold***				Shot hole on leaves***			
Program	Fungicide*	Rate	PB	FB	PF	PF	Inc. (%)	LSD^	Inc. (%)	LSD	Severity	LSD	Inc. (%)	LSD	Severity	LSD
	Control	---	---	---	---	---	131.3	a	71.7	abc	1.8	cd	73.1	a	2.3	a
Single	Syllit 65WP	20 oz	@	@	@	@	91.3	b	79.9	abc	1.9	bc	48.9	b	1.2	bc
	Syllit 65WP	31 oz	@	@	@	@	75.8	bc	91.9	a	2.6	a	53.3	b	1.1	bc
	Fontelis 1.67SC + Breakthru	14 fl oz	@	@	@	@	46.8	de	Not done				58.6	ab	1.5	bc
	Fontelis 1.67SC + Breakthru	20 fl oz	@	@	@	@	35.8	defgh	68.9	bcd	1.3	def	54.5	b	1.3	bc
	YT669 2.08SC	8 fl oz	@	@	@	@	19.5	gh	Not done				44.2	b	0.9	bc
	YT669 2.08SC + Breakthru	12 fl oz	@	@	@	@	26.3	efgh	89.5	a	2.5	ab	59.2	ab	1.5	b
	Adament 50WG	6 oz	@	@	@	@	26.3	efgh	45.7	ef	0.9	fgh	44.5	b	1.0	bc
Pre-mix	Luna Sensation SC	5 fl oz	@	@	@	@	40.5	defg	49.1	def	0.9	fgh	44.3	b	1.0	bc
	Luna Experience SC	6 fl oz	@	@	@	@	35.5	defgh	59.4	cde	1.2	efg	40.3	b	0.8	c
	Merivon (BAS703)	6.8 fl oz	@	@	@	@	16.0	h	23.6	g	0.4	h	41.3	b	0.9	bc
	Pristine 68WG	14 oz	@	@	@	@	22.0	fgh	37.5	fg	0.8	fgh	52.9	b	1.4	bc
	Inspire Super	20 fl oz	@	@	@	@	39.8	defg	44.5	ef	0.7	gh	46.2	b	1.2	bc
	Quadris Top	14 fl oz	@	@	@	@	42.0	defg	84.4	ab	2.1	abc	46.3	b	1.2	bc
	Q8Y78 240SC	24 fl oz	@	@	@	@	15.5	h	72.8	abc	1.7	cde	56.0	ab	1.5	b
Rotations	Scala 600SC	9 fl oz	@	-	-	-	56.0	cd	35.2	fg	0.6	gh	48.3	b	1.1	bc
	Rovral 4F	16 fl oz	-	@	-	-										
	Luna Experience	6 fl oz	-	-	@	@										
	Scala 600SC	9 fl oz	@	-	-	-	44.5	def	Not done				55.0	b	1.4	bc
	Luna Sensation	5 fl oz	-	@	-	-										
	Quash 50WDG	3.5 oz	-	-	@	@										

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

** - For brown rot evalution, the number of brown rot strikes per tree was counted on 4-15-11 for each of five single-tree replications.

***- Gray mold was evaluated on flower petals that were collected on 2-28-11 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.

***- Shot hole was evaluated on 3-24-11. Disease incidence was based on the number of leaves with shot hole lesions of a total of 100-120 leaves evaluated for each of five single-tree replications. Disease severity is the number of shot hole lesions per leaf.

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

Table 2: Efficacy of fungicide programs for management of brown rot, gray mold, and shot hole of Sonora almonds at UC Davis 2011

			Application			Brown rot**		Gray mold***				Shot hole on leaves***			
			2-13	2-22											
Program	Fungicide*	Rate	PB	FB	PF	Inc. (%)	LSD^	Inc. (%)	LSD	Severity	LSD	Inc. (%)	LSD	Severity	LSD
	Control	---	---	---	---	34.0	a	77.4	a	2.6	a	94.5	a	2.5	abc
Single	Actinovate	14 oz	@	@	@	25.5	b	32.8	cd	0.7	b	88.1	abcd	2.0	cde
	S-2200 4SC	2 fl oz	@	@	@	9.5	cde	not done				70.4	ef	1.6	efg
	S-2200	3 fl oz	@	@	@	6.0	def	32.5	cd	0.5	b	82.1	bcd	2.2	bcd
	IKF-5411 400SC	10.5 fl oz	@	@	@	11.9	cd	not done				80.1	cde	2.1	cd
	IKF-5411 400SC	17 fl oz	@	@	@	5.0	ef	21.4	d	0.3	b	56.3	fg	1.2	gh
	V-10135 4SC	12 fl oz	@	@	@	13.3	c	33.2	bcd	0.5	b	88.6	abc	2.2	bcd
	Indar 2F+NIS	4 fl oz	@	@	@	3.3	ef	36.4	bcd	0.6	b	91.5	ab	2.8	a
	Indar 2F+NIS	6 fl oz	@	@	@	6.3	def	38.1	bcd	0.6	b	86.6	abcd	2.7	ab
	Bumper 41.8EC	4 fl oz	@	@	@	2.5	f	52.4	b	0.7	b	78.2	de	1.8	def
	Quash	3 oz	@	@	@	1.0	f	22.5	d	0.2	b	68.4	ef	1.5	fg
Mixtures	Quash + V-10135	2.5 oz + 12 fl oz	@	@	@	0.8	f	21.8	d	0.2	b	78.0	de	1.8	def
	S-2200 + Quash	3 fl oz + 2 oz	@	@	@	0.5	f	23.2	d	0.3	b	56.9	fg	1.2	gh
	S-2200 + Quash 50WG	2 fl oz + 2 oz	@	@	@	3.0	f	not done				62.0	f	1.4	fg
Rotations	Bumper 41.8EC	4 fl oz	@			2.8	f	41.4	bc	0.5	b	36.5	h	0.7	h
	Bumper + Nevado 4F	4 fl oz + 1 pt		@											
	Nevado	1 pt			@										
	Equus 720	4 pt													
	Indar 2F + NIS	6 fl oz + 0.125% or 0.0625%	@			6.0	def	32.6	cd	0.5	b	46.3	gh	1.1	gh
	Indar 2F + NIS + Dithane	6 fl oz + 0.125%		@	@										

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.
** - For brown rot evalution, the number of brown rot strikes per tree was counted on 4-20-11 for each of five single-tree replications.
***- Gray mold was evaluated on flower petals that were collected on 2-28-11 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.
***- Shot hole was evaluated on 3-24-11. Disease incidence was based on the number of leaves with shot hole lesions of a total of 80-100 leaves evaluated for each of five single-tree replications. Disease severity is the number of shot hole lesions per leaf.
^ - Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

Quash, and Quadris Top (FRAC 3/11) were all highly effective and protected blossoms from infections of the brown rot pathogen that occurred one day before or after treatment.

Fungicide application timing studies using selected compounds indicated that under very high disease pressure on cv. Drake two applications (pink bud and full bloom) were more effective that a single application at full bloom (**Table 3).** Under lower disease pressure on cv. Butte (**Table 4**), as well as on Wood Colony and Sonora (data not shown), a single application at 80% bloom was significantly more effective than one at 20-30% bloom and disease incidence using either application was lower than in the untreated control.

Table 3: Evaluation of application timings of selected fungicides for management of brown rot of Drake almonds at UC Davis 2011.

		Application		Brown rot**	
		2-15	2-23		
Treatment	Rate/A	PB	FB	Inc. (%)	LSD^
Control	---	---	---	131.3	a
Luna Sensation SC	5 fl oz	@	@	40.5	b
Luna Sensation SC	5 fl.oz	-	@	74.3	b
Control	---	---	---	131.3	a
Quadris Top	14 fl oz	@	@	42.0	c
Quadris Top	14 fl.oz	-	@	90.8	b
Control	---	---	---	131.3	a
Pristine 38WG	14 oz	@	@	22.0	c
Pristine 38WG	14.5 oz	-	@	73.0	b
Control	---	---	---	131.3	a
Merivon (BAS 703)	6.8 fl.oz	@	@	16.0	c
Merivon (BAS 703)	6.8 fl.oz	-	@	51.0	b

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.
** - For brown rot evaluation, the number of brown rot strikes per tree was counted on 4-15-11 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).

Table 4: Evaluation of application timings of selected fungicides for management of brown rot of Butte almonds at UC Davis 2011.

		Application		Brown rot**	
		20-30% bloom	80% bloom		
Treatment*	Rate/A	2-24		Inc. (%)	LSD
Control		-	-	46.3	a
Luna Sensation	5 fl.oz.	@	-	17.3	b
Luna Sensation	5 fl.oz.	-	@	5.3	c
Control		-	-	46.3	a
BAS 703	6.8 fl.oz.	@	-	5.8	b
BAS 703	6.8 fl.oz.	-	@	2.8	b
Control		-	-	46.3	a
Quadris Top	14 fl.oz.	@	-	25.5	b
Quadris Top	14 fl.oz.	-	@	5.0	c
Control		-	-	46.3	a
Pristine	14.5 oz	@	-	21.5	b
Pristine	14.5 oz	-	@	8.5	c

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.
** - For brown rot evaluation, the number of brown rot strikes per tree was counted on 4-20-11 for each of four 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).

The efficacy of field fungicide treatments against gray mold was evaluated in a blossom petal assay. Merivon and Pristine, as well as a rotation of Scala and Rovral resulted in the numerically lowest incidence of gray mold in the cv. Drake trial (**Table 1**), and Indar, IKF-5411, Quash, S-2200, V-10135, as well as the biocontrol Actinovate were most effective in the cv. Sonora trial (**Table 2**).

B. Shot hole management – 2011 Research. In the cv. Drake trial, the incidence of shot hole on newly developed leaves in late March was 73.1% in the untreated control. The incidence among the treatments ranged from 40.3% (i.e., Merivon) to 59.2% (i.e., YT669) **(Table 1**). In the cv. Sonora trial, 94.5% of the leaves were diseased, and the incidence among the treatments ranged from 36.5% (a rotation of Bumper, Nevado, and Equus) to 91.5% (Indar at 4 fl oz) (**Table 2**). Thus, none of the treatments was highly effective and, possibly, additional infections occurred during the rainy period after the last fungicide application or fungicide residues were removed during heavy rainfall.

C. Scab management – 2010 and 2011 Research. Dormant treatments were evaluated again in the spring of 2011 in a trial in Butte Co. to reduce the production of primary inoculum in the springtime from overwintering twig lesions. By mid-April, 70.2% of the lesions on non-treated control trees sporulated, whereas 6.9% and 11.6% of the lesions sporulated on trees treated with Bravo-Oil or Kocide 3000-Oil, respectively. By early May, 89.4% of the lesions on non-treated control trees and 29.9% and 65% of the lesions on Bravo-Oil and Kocide 3000-Oil treated trees, respectively, sporulated. In a sampling done in late May, 95.1% of lesions of the control trees and still only 42.2% of Bravo-oil-treated trees sporulated. These results indicate that the Bravo-oil treatment had an extended high efficacy into late spring. Thus, dormant applications can be highly effective inoculum reduction treatments. A reduced amount of inoculum will reduce the risk for selection of fungicide resistance, but dormant treatments are not stand-alone treatments and should be used in combination with petal fall/spring treatments.

Spring-time applications for the management of scab were evaluated at three locations in 2010 and 2011 (data not available for 2011). In **Table 5**, data are presented for the 2010 Butte Co. trial with the split-plot design. Spring-time treatments performed similarly for all dormant treatments and thus, data were combined for the dormant treatments. In this trial, all three-spray programs were effective and Syllit-Equus, Inspire Super, and Quadris Top had a significantly lower disease incidence than Luna Sensation or Ph-D/Quash.

Table 5. Efficacy of petal fall and spring-time treatments for management of scab of almond cv. Carmel - Butte Co. 2010

			Applications			Dis. Incid. on fruit**		Dis. Sev. on fruit	
No.	Treatments*	Rate (/A)	3-31	4-16	5-12	(%)	LSD^	Lesions	LSD
1	Control	---	---	---	---	89.8	a	25.3	a
2	Luna Sensation	5 fl oz	@	@	@	47.2	b	5.8	b
3	Ph-D 11.2DF + Quash 50WDG	6.2 oz - 2.5 oz	@	@	@	43.8	b	4.7	b
4	Syllit 3.4FL - Equus	32 fl oz - 64 fl oz	@	@	@	27.0	c	1.7	b
5	Inspire Super	20 fl oz	@	@	@	25.6	c	1.6	b
6	Quadris Top	14 fl oz	@	@	@	22.1	c	1.2	b

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

**- Evaluations for scab on fruit were done on 7-15-10. 25 fruit of each tree were rated for the presence and severity of disease. For severity, a scale was used from 0=no disease, 1=<10, 2=11-20, 3=21-40, 4=>40 lesions/fruit.
Dormant treatments did not significantly affect the efficacy of the subsequent petal fall treatments, and thus, dormant treatments combined for each petal fall treatment.

^ 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 6. Efficacy of fungicide programs for management of scab of cv. Peerless almonds Butte Co. 2010.

				Application		Incidence**		Severity	
				3-31	4-19				
No.	Program	Fungicide*	Rate	3 wkPF	5 wk PF	%	LSD	Lesions/fruit	LSD
1	---	Control	---	---	---	86.7	a	8.5	a
2	Single	Syllit 4FL	2 pt	@	@	26.4	cd	1.3	c
3		Syllit 4FL	3 pt	@	@	17.6	cd	0.9	c
4		Dithane 75DF	6 lb	@	@	17.2	cd	1.0	c
5		Ph-D 11.2DF	6.2 oz	@	@	21.2	cd	1.1	c
6		Quash 50WG	3.5 oz	@	@	6.2	d	0.3	c
7	Pre-mix	Adament 50WG	6 oz	@	@	57.3	b	3.9	b
8		Luna Sensation 500SC	5 fl oz	@	@	10.0	cd	0.5	c
9		Inspire Super	12 fl oz	@	@	12.0	cd	0.6	c
10		Quadris Top	14 fl oz	@	@	15.6	cd	0.9	c
11		Quilt Xcel	20 fl oz	@	@	13.0	cd	0.7	c
12	Mixture	Ph-D 11.2DF + Captan 80WP	6.2 + 3 lb	@	@	20.3	cd	1.2	c
13	Rotation	Pristine 38WG	14.5 oz	@	---	27.2	cd	1.5	c
		Indar 2F + Dithane F45	6 fl oz + 192 fl oz	---	@				

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

** - Incidence of scab was based on 100 fruit from each of four single-tree replications from each treatment on 7-15-10. Severity was based on a rating from 0 = healthy, 1 = <10 lesions, 2 = 10-25 lesions, 3 = >25 lesions/fruit

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

Similarly, at another location in Butte Co. where applications were done on March 31 and April 19, all treatments were effective and reduced the incidence and severity of scab as compared to the control (**Table 6**). Highly effective treatments included Syllit, Dithane, Ph-D, Quash, Luna Sensation, Inspire Super, Quadris Top, and Quilt Excel, as well as a rotation treatment.

When spring-time treatments were initiated later in the season at the first Butte Co. location (a two-spray program starting on April 16 as compared to the three-spray program starting on March 31), the efficacy of most treatments was much reduced, indicating that infections had already become established before April 16. Treatments with Quash were the most effective, reducing the incidence of scab from 100% in the control to approximately 40% (data not presented). Late-spring applications, however, were still mostly effective in the Kern Co. trial, where disease pressure was lower (58.5% incidence in the control) (**Table 7**). Pristine was one of the least effective treatments due to QoI resistance in the pathogen population and the low activity of boscalid against *F. carpophilum*. Activity of the pre-mixture Luna Sensation that contains the same FRAC groups as Pristine, however, was very good. This can be explained by the fact that fluopyram is a new generation of SDHI fungicides (FRAC 7) belonging to a different SDHI sub-group (pyridinyl-ethyl-benzamide) than boscalid (pyridine-carboxamide). Apparently, the new sub-group has a greater binding affinity to the target site (succinate dehydrogenase in complex II of respiration). Still, we have found that less sensitive isolates already exist in *F. carpophilum* populations at low frequencies (see below). Thus, resistance could develop rapidly with sole usage of the fungicide alone or in a premixture with a QoI because resistance to the QoI is already widespread in the pathogen population.

Our data on scab management indicate that the disease can be effectively managed with currently available fungicides. A highly effective three-spray program should include dormant applications with copper-oil or potentially chlorothalonil (e.g., Echo, Bravo, Equus) or chlorothalonil-oil and two petal-fall applications with chlorothalonil, DMI fungicides such as Quash or Inspire Super, Syllit, compounds containing SDHIs (Luna Sensation), QoIs (at locations where the pathogen population has not

Table 7: Efficacy of fungicide treatments for management of scab on almond cv. Monterey - Kern Co. 2010

				Applications			Scab eval. 8-20-10**			
							Dis. Incid. on fruit		Dis. Sev. on fruit	
No.	Program	Treatment*	Rate	5-19	6-9	6-30	(%)	LSD^	Lesions/fruit	LSD
1	---	Control	---	---	---	---	58.5	ab	0.8	ab
2	Single	Prophyt	64 fl oz	@	@	@	13.3	d	0.1	c
3		Ph-D 11.2DF	6.2 oz	@	@	@	25.7	bcd	0.3	c
4		Ph-D 11.2DF organic form.	6.2 oz	@	@	@	50.0	bcd	0.7	bc
5		Quash 50WG	3.5 oz	@	@	@	17.4	d	0.2	c
6		Bravo WS	6 pints	@	@	@	44.5	bcd	0.6	bc
7	Mixtures	Ph-D + Moisturin	6.2 oz + 0.5 L	@	@	@	12.7	d	0.1	c
8	and	Adament 50WG	6 oz	@	@	@	35.0	bcd	0.4	cd
9	Pre-mixtures	Luna Sensation	4 oz	@	@	@	17.7	cd	0.2	c
10		Inspire Super SC	20 fl oz	@	@	@	23.8	bcd	0.2	c
11		Quadris Top	14 fl oz	@	@	@	42.4	bcd	0.5	c
12		Inspire XT/Inspire EC	7 fl oz	XT	XT	I	18.4	cd	0.3	cd
13		Inspire/Bravo (A16976)	7 fl oz/4 pints	@	@	@	31.5	bcd	0.3	c
14		Pristine 38WG	14.5 oz	@	@		61.2	abc	0.8	bc
15		Ph-D + Quash/Inspire	6.2 oz + 3.5 oz/7 fl oz	Q	I	Q	12.8	d	0.1	c
16		Ph-D + Inspire Super	6.2 oz + 20 fl oz	@	@	@	33.3	bcd	0.5	cd
17		Inspire Super + Prophyt	14 fl oz + 64 fl oz	@	@	@	36.4	bcd	0.4	bc
18	Rotations	Quash 50WG	3.5 oz	@			27.3	cd	0.3	c
		Luna Sensation	4 oz		@					
		Ph-D + Inspire Super	6.2 oz + 20 fl oz			@				
19		Ph-D	6.2 oz	@			38.2	bcd	0.5	bc
		Inspire Super SC	20 fl oz		@					
		Ph-D+Bravo	6.2 oz/6 pints			@				
20		Ph-D	6.2 oz	@			87.9	a	1.7	a
		Quash 50WG	3.5 oz		@					
		Ph-D + Quash	6.2 oz + 2.5 oz			@				

* - Treatments were applied using an air-blast sprayer at 100 gal/A and there were 3 single-tree replications for each treatment.
For severity, a scale was used from 0=no disease, 1=1-2, 2=3-9, and 3=>10 lesions/fruit.

^ - 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.

** - Evaluations for disease were done on 8-20-10. 10 fruit of each tree were rated for the presence and severity of disease.

developed resistance), or Ph-D. Treatments containing a DMI compound were very effective, although the incidence of natural resistance against DMIs in *F. carpophilum* was found to be high at some locations (see below). Thus, this class of chemicals can be effectively used, but should be rotated with other classes to prevent further selection of insensitivity. Because maneb fungicides have been voluntarily canceled (2008/2009), mancozeb (e.g., Dithane) fungicides are being tested and are planned for registration in 2011. The single-site mode of action fungicides Indar, Ph-D (polyoxin-D), Syllit (dodine), and Quash (metconazole), as well as the pre-mixtures Inspire Super, Quilt Xcel, and Luna Sensation, all represent new almond scab fungicides.

D. In vitro sensitivity of* Fusicladium carpophilum *to selected fungicides - 2010 and 2011 Research. A wide, continuous range of susceptibility against DMI fungicides was found among 72 isolates of *F. carpophilum* collected from 6 locations in 2010. EC_{50} values for mycelial growth ranged from 0.007 to 1.86 mg/L for difenoconazole, from 0.013 to 2.23 mg/L for metconazole, and from 0.039 to 6.70 mg/L for propiconazole. Isolates less sensitive to one DMI generally were also less sensitive to the other two DMIs. Less sensitive isolates were present in all but one location. A continuous sensitivity range was also found for polyoxin-D and was 0.041 to 9.67 mg/L. All except two isolates were resistant to QoIs. Thus, natural and induced insensitivity was again found to be widespread and this mandates the implementation of fungicide stewardship.

The mechanism of QoI resistance in *F. carpophilum* was initiated in 2011. In isolates highly resistant to azoxystrobin (EC_{50} >40 ppm), a mutation in the cytochrome b gene at position 143 (i.e., G143A) was detected in DNA sequence analyses. This mutation also confers high resistance in numerous other plant pathogens as demonstrated by others. The mechanism of resistance in isolates of *F. carpophilum* with a lower level of resistance (EC_{50} <10 ppm) could not be identified in the target gene and further studies need to be done.

***E. Hull rot management – 2010 Research*.** Two field studies were conducted in Colusa Co. on cvs. Nonpareil and Winters where *Rhizopus stolonifer* was found to be the main cause of hull rot. Based on 2009 and 2010 laboratory studies, the hull is most susceptible to infection by *R. stolonifer* during the early hull split stages of nut development). Thus, a fungicide with activity against *R. stolonifer* could be applied most effectively during the stages of high susceptibility. The incidence of hull rot was high in 2010 due to early fall rains. In both trials, the disease was significantly reduced from that in the control and there was no significant difference in efficacy among fungicides evaluated including Adament, Inspire, Luna Sensation, Ph-D, Pristine, Quadris Top, Quash, and Scholar. Disease incidence ranged from 44.8 to 53.8% in the controls to between 18.5 and 23.0% among treatments. Thus, disease was only reduced by approximately 55% to 60% even though a rain occurred in the test plot in late August. In 2009, 70% control was obtained with only a single application. Still, other parameters need to be evaluated to improve efficacy.

In 2010, Plant Growth Regulators (PGRs) were also evaluated. Ethephon increased and giberellin delayed the rate of hull split. Ethephon caused leaf yellowing and the extent of defoliation was based on the rate used. Fungicide efficacy was not affected by PGR treatments. Current recommendations for the most effective integrated management of hull rot are that hull split should be induced simultaneously with proper water management (i.e., deficit irrigation) and should proceed as quickly as possible to shorten the highly susceptible period.

F. Field evaluation of almond cultivar susceptibility to brown rot, shot hole, and bacterial blast - 2011 Research. Natural host resistance was evaluated in the UC Davis variety plot. Evaluations for brown rot were done in previous years. Due to highly conducive environmental conditions in the spring of 2011, data could also be obtained for shot hole and bacterial blast for the first time. Results are presented in **Table 8**. There was a wide range of susceptibility among early-, mid-, and late-blooming accessions. Ratings for brown rot susceptibility for most varieties were consistent with previous data, but some cultivars performed differently from previous years. This emphasizes the importance of multi-year evaluations under different environmental conditions that influence host-pathogen interactions and disease development. All cultivars were very susceptible to shot hole, whereas a wider range of susceptibility was observed for bacterial blast. These ongoing studies on natural host resistance will help growers to select cultivars and breeders to design new selections for different growing areas with different micro- or regional climates.

Table 8. Almond cultivar susceptibility to brown rot, shot hole, and bacterial blast in the UC Davis almond variety orchard in 2011.

A. Early blooming cultivars

		Brown rot		Shot hole				Bacterial blast	
No.	Variety	Inc. (%)	LSD	Inc. (%)	LSD	Lesions/leaf	LSD	Inc. (%)	LSD^
1	Winters	42.8	a	90.4	abc	3.0	ab	27.5	a
2	Aldrich	22.3	a	75.7	d	2.0	b	20.5	ab
3	NePlus Ultra	35.3	a	79.7	d	2.3	b	11.3	b
4	Peerless	29.3	a	92.3	ab	2.8	b	17.6	ab
5	Rosetta	32.0	a	96.1	a	3.8	a	23.0	ab
6	Sonora	28.5	a	82.6	cd	2.8	b	32.5	a
7	1-87	26.5	a	85.8	bcd	2.4	b	10.5	b

B. Mid blooming cultivars

		Brown rot		Shot hole				Bacterial blast	
No.	Variety	Inc. (%)	LSD	Inc. (%)	LSD	Lesions/leaf	LSD	Inc. (%)	LSD^
1	Chips	49.8	a	69.5	c	2.6	a	35.5	a
2	Jenette	40.0	ab	82.6	b	2.4	b	25.8	abc
3	Johlyn	51.5	a	93.6	a	4.7	b	22.5	abcd
4	Nonpareil	20.3	cd	85.6	ab	2.2	b	15.0	bcde
5	Price	27.8	bc	84.2	ab	2.3	b	22.5	abcd
6	Sauret No. 1	25.3	bcd	85.4	ab	2.6	b	27.8	ab
7	Wood Colony	43.6	a	75.8	bc	2.1	b	8.3	e
8	F10D, 3+4-25	14.4	cd	81.6	bc	2.7	b	19.5	bcde
9	F7, 1-1	8.5	d	77.3	bc	2.0	b	11.3	de
10	Alamo	22.0	bcd	84.1	b	2.2	b	13.0	cde

C. Late blooming cultivars

		Brown rot		Shot hole				Bacterial blast	
No.	Variety	Inc. (%)	LSD	Inc. (%)	LSD	Lesions/leaf	LSD	Inc. (%)	LSD^
	Ferragnes F7,4-7	20.5	cde	77.9	a	2.0	bcd	21.5	abcd
2	2-19E	45.0	abc	84.5	a	3.1	a	26.3	abc
3	25-75	45.8	ab	79.0	a	2.5	ab	29.8	a
4	Butte	26.0	bcde	81.3	a	2.2	bc	7.5	ef
5	Carmel	14.3	e	70.9	a	1.5	cd	14.1	bcdef
6	Fritz	15.8	e	67.4	a	1.4	d	6.8	ef
7	LeGrand	17.4	cde	76.9	a	2.0	bcd	16.0	bcde
8	Livingston	52.0	a	79.6	a	2.3	b	25.8	abcd
9	Merced	39.0	abcd	77.4	a	1.9	bcd	6.5	ef
10	Mission	14.8	e	76.6	a	1.9	bcd	4.3	f
11	Monterey	20.5	de	64.1	a	1.4	d	14.1	cdef
12	Padre	24.0	bcde	78.8	a	1.8	bcd	12.5	def
13	Plateau	42.8	abc	79.1	a	2.3	b	27.8	ab
14	Ruby	16.8	e	77.0	a	1.9	bcd	5.8	ef

Trees were evaluated on 4-29-11 for brown rot and on 4-25-11 for bacterial blast. For shot hole, leaves were collected on 4-25-11 and evaluated for incidence and severity of disease.