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

Project No.: **09-PATH4-Adaskaveg**

Project Leader: J. E. Adaskaveg
Department of Plant Pathology
UC Riverside
Riverside, CA 92521
(951) 827-7577
E-mail: jim.adaskaveg@ucr.edu

Project Cooperators and Personnel:
D. Thompson and J. Enns, UC Riverside
H. Förster and T. Gradziel, UC Davis
J. Connell, UCCE - Butte County
R. Duncan, UCCE - Stanislaus County
J. Edstrom, UCCE - Colusa County
B. Holtz, UCCE - Madera County
L. Wade, Arysta Life Science

Objectives:

I. **Disease management strategies**

A. Evaluate new fungicides and develop efficacy data based on spectrum of activity, systemic action, and persistence.
  a. Continue evaluations on brown rot, jacket rot, shot hole, and scab.
  b. Evaluate selected fungicides (e.g., Pristine) and fungicide additives such as BioForge for their effectiveness against diseases, as well as plant growth regulation effects as compared to the use of fungicides alone.
  c. Evaluate persistence and post-infection activity of selected fungicides in field/laboratory studies for management of foliar diseases.
  d. For scab management, evaluate the effect of dormant applications (liquid lime sulfur, copper-oil) on sporulation of infected twig lesions, as well as the fungicides dodine and difenoconazole for in-season use.
  e. Use information on the characteristics of fungicides to develop effective rotation programs for disease management of almond.

B. Develop baseline sensitivities of fungal pathogen populations against new fungicides and determine shifts in fungicide sensitivity.
  a. Characterize baseline sensitivities of *Monilinia, Cladosporium,* and other fungal species against SBI and other fungicides
  b. Determine extent of strobilurin resistance in populations of *C. carpophilum* and AP (e.g., cyprodinil – Vangard) resistance in *Monilinia* spp. in CA.

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 (UCD) under simulated rainfall (ongoing collaboration with T. Gradziel).

II. **Epidemiology and management of hull rot**

A. Cultural practices and fungicide treatments for reducing hull rot.
B. Evaluate end dates for weed and dust control prior to hull split to prevent hull contamination.
C. Evaluate the toxicity of fungicides against *Rhizopus stolonifer* and *Monilinia fructicola*.
D. Evaluate hull split fungicide treatments with different spray volumes.

Interpretive Summary:

In 2009 - 2010 we conducted 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, rust, and hull rot. We also evaluated several natural products and a biocontrol as alternatives to synthetic fungicides. This arsenal of treatments will help to 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 *Cladosporium carpophilum* (scab) and *Alternaria* spp. against the QoI fungicides and in *Alternaria* spp. against SDHI fungicides. In addition, we initiated studies on the management of hull rot, a disease with an increased occurrence in recent years. At the time of preparing this annual report in mid-July, many of our projects on summer diseases are ongoing and thus, this report summarizes only some of the research conducted in 2010. Specifically, research on scab, rust, and hull rot are ongoing and this report focuses on 2010 brown rot and some of our scab research; whereas for hull rot 2009 data are presented.

Materials and Methods:

***Fungicide evaluations for management of brown rot, shot hole, and gray mold in an experimental orchard*.** Field trials were conducted at UCD on cvs. Drake and Sonora and at the Kearny AgCenter on cv. Wood Colony. Treatments were done as single-fungicide, pre-mixture, or rotation programs as shown in **Table 1**. Biologicals and natural products as compared to a fungicide treatment are shown in **Table 2**. 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 single-tree replications. Incidence and severity of shot hole were based on a random sample of 25 fruit from each of five single-tree replications from each treatment. In additional studies, field-treated blossoms were taken to the laboratory, placed on moist vermiculite, and inoculated with conidia of *M. fructicola* (10,000 conidia/ml). The incidence of stamen infections was determined after 5 days of incubation at 20C. Treated flower petals were also collected and incubated on moist vermiculite for 5 days at 20C for the development of natural incidence of gray mold. Data were evaluated using an analysis of variance and LSD mean separation ($P > 0.05$).

***Fungicide evaluations for management of scab in commercial orchards*.** In a field trial in Butte Co. on cv. Peerless, treatments were done as rotation programs as shown in **Table 4**. Treatments were applied using an air-blast sprayer at a rate of 100 gal/A at full bloom (grower applied), 3-wk petal fall/shuck split, and 5-wk after petal fall. Incidence of disease based on 50 fruit from each of four single-tree replications from each treatment. Data were evaluated using an analysis of variance and LSD mean separation ($P > 0.05$).

Additionally, for scab management, two large-scale field trials were conducted in Butte County using a split-split plot design. The main plots consisted of rows treated or not treated with: Plot 1 - copper-oil (Badge SC 1.7 gal-4% oil), an experimental copper (GWN426-1 gal/A), or untreated; Plot 2 - copper (Kocide 2000 6 lb/A)-surfactant, or copper-oil (Kocide 2000 6 lb-4% oil, or untreated) in early February of 2010. Sub-plots were established that were not treated or treated in late March to mid-May (petal fall and spring applications) with Luna Sensation, PhD/Quash, Syllit/Equus, Inspire Super, or Quadris Top. The effect of copper treatments on sporulation of scab lesions was evaluated in May. 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. Data were evaluated using an analysis of variance and LSD mean separation ($P > 0.05$) using split plot procedures.

***In vitro sensitivity of Cladosporium carpophilum or Monilinia laxa isolates to selected fungicides*.** Isolates were collected from seven orchards in Butte and Kern Counties. Using the spiral gradient dilution method, the inhibition of conidial germination on azoxystrobin-amended agar media was evaluated after ca. 20 h of incubation. Boscalid, polyoxin-D, difenoconazole, and metconazole were also evaluated in assays. A baseline sensitivity range study was initiated for polyoxin-D, metconazole, and difenoconazole using selected populations of *C. carpophilum*.

***Field evaluation of almond cultivar susceptibility to brown rot*.** Almond cultivars grown in the UCD almond variety plot were not sprinkler irrigated as in previous years due to the high spring rainfall that to create favorable conditions for the occurrence of brown rot. Trees were evaluated for brown rot that occurs naturally in this orchard including anthracnose, rust, shot hole, and scab. The goal is to have a standardized field study for comparing disease susceptibility among many almond cultivars to foliar diseases, unlike what can be done in commercial orchards where only a limited number of cultivars is grown. All 32 varieties are on the same rootstock and grow in the same soil type. All data were analyzed using analysis of variance and least significant difference (LSD) mean separation procedures of SAS.

***Fungicide efficacy in the management of hull rot*.** Two large-scale field trials were conducted in Colusa County. For this, fungicides were applied at different stages of hull split (b1, b3, and c stages as outlined in the IPM Manual for almonds) and using different application volumes. Hull rot was evaluated at the time of harvest by counting the number of shoot/fruit infections per tree. In laboratory studies, fruit were collected from Nonpareil and Winters varieties at different stages of development (as described above) and inoculated with a spore suspension of *R. stolonifer*. Disease incidence was determined after 5 days of incubation at >95% RH, 20C. All data were analyzed using analysis of variance and least significant difference (LSD) mean separation procedures of SAS. Data for 2009 are shown but trials are ongoing for 2010.

Results and Discussion:

A. Brown rot blossom blight management and gray mold assays*.* In the UCD trial on cv. Drake, we evaluated single treatments, new pre-mixtures, and several rotation programs. All registered and experimental pre-mixtures were effective against brown rot (**Table 1**) under extremely high disease pressure in this experimental orchard. Disease was reduced from ca. 100 shoot infections/tree in the control to less than 30 by most treatments with the best treatments (e.g., Adament, Luna Sensation, and Quash) reducing disease to less than 5 infections/tree. Inspire Super, Quilt Xcel, and Quadris Top were used at ca. half rates as compared to our previous years' trials and still significantly reduced disease to moderate levels. Under lower disease pressure, low rates were sufficient in managing the disease (data not shown from the KAC trial on cv. Wood Colony). Higher labeled rates should be used under high disease pressure. The efficacy of field fungicide treatments against gray mold was evaluated in a laboratory blossom petal assay. Flowers that were treated with selected materials at full bloom in the field were collected and their petals were evaluated after incubation at 20 C, 100% RH. All fungicide treatments evaluated significantly reduced the incidence and severity of gray mold. Adament, Luna Sensation, Inspire Super, Quilt Xcel, as well as rotations with Syllit, Vangard, or Scala reduced the disease to the lowest levels (**Table 1**).

In laboratory tests on the evaluation of the pre- and post-infection activity of selected treatments, Syllit and Ph-D (Polyoxin-D) were the least effective among the fungicides (data not presented). Adamant, Luna Privilege, Quash, Inspire Super, Quadris Top, Inspire XT, Luna Sensation, and Quilt Xcel were all highly effective and protected blossoms from infections of the brown rot pathogen that occurred one day before or after treatment. The biocontrol/natural products were not very effective in these laboratory studies under high disease pressure conditions.

B. Shot hole management. Treatments of Syllit, Pristine, and Quadris Top were highly effective against shot hole and reduced the incidence and severity of the disease to the lowest ratings among all treatments (**Table 1**). Other very efficacious treatments included Quilt Xcel, as well as the programs that included rotations with Equus, Dithane, and Abound.

Table 1: Efficacy of fungicide programs for management of brown rot, shot hole, and gray mold of Drake almonds at UC Davis 2010.

			Application				Brown rot**		Shot hole***				Gray mold***			
			2-18	2-22	3-4	3-24										
Program	Fungicide*	Rate	PB	FB	PF	PF	Inc. (%)	LSD	Inc. (%)	LSD	Sev	LSD	Inc. (%)	LSD	Sev.	LSD
Single	Control	---	---	---	---	---	99.8	a	98.0	a	11.3	a	97.2	a	3.3	a
	Quash 50WG	2.5 oz	@	@	@	@	8.0	gh	53.0	cd	2.6	de	73.1	bcdef	1.1	bcd
	Quash 50WG	3.5 oz	@	@	@	@	4.0	h	31.5	def	1.4	defg	73.3	bcdef	1	cde
	Indar 2F + Breakthru	6 - 6 fl oz	@	@	@	@	17.3	efg	75.0	b	5.8	b	83	b	1.6	b
Pre-Mixtures	Inspire Super	10 fl oz	@	@	@	@	33.7	cde	47.0	cd	2.3	def	67.9	cdef	1.1	bcd
	Inspire Super	12 fl oz	@	@	@	@	27.5	cde	34.0	de	1.2	defg	78.3	bcd	1.3	bcd
	Quadris Top	8 fl oz	@	@	@	@	36.7	cd	10.0	gh	0.3	fg	79.7	bc	1.4	bc
	Quilt Xcel	12 fl oz	@	@	@	@	25.3	def	14.0	ef	0.4	fg	58.9	ef	0.8	de
	Adament 50WG	6 oz	@	@	@	@	5.3	h	51.0	cd	2.6	de	60.8	def	0.9	cde
	Luna Sensation 500SC	5 fl oz	@	@	@	@	3.5	h	36.0	de	1.5	defg	67.1	cdef	0.9	de
	Pristine 38WG	14.5 oz	@	@	@	@	18.0	efg	0.0	h	0.0	g	69.5	cdef	1.2	bcd
Rotations	Vangard 75WG	5 oz	@	@	---	---	38.8	cd	15.0	fg	0.4	fg	53.5	fg	0.9	cde
	Syllit 4FL	2 pt	---	@	@	@										
	Vangard 75WG	5 oz	@	@	---	---	27.0	cde	5.0	gh	0.1	g	36.5	g	0.5	e
	Syllit 4FL	3 pt	---	@	@	@										
	Bumper 41.8EC	4 fl oz	@	---	---	---	61.3	b	3.0	gh	0.1	g	69.4	cdef	1.1	cd
	Nevado 4F	16 fl oz	---	@	---	---										
	Equus 720SC	4 pts	---	---	@	@										
	Scala 600SC	9 fl oz	@	---	---	---	24.3	def	54.0	cd	3.3	cd	58.7	ef	1	cd
	Adament 50WG	4 oz	---	@	@	---										
	Syllit 4FL	48 fl oz	---	@	@	---										
	Rovral 4F	16 fl oz	---	---	---	@										
	Scala 600SC	9 fl oz	@	---	---	---	11.8	fgh	63.6	bc	4.8	bc	ND			

Luna Sensation 500SC	5 fl oz	---	@	---	---									
Rovral 4F	16 fl oz	---	---	@	@									
Inspire Super	12 fl oz	@	---	---	---	41.7	c	17.0	efg	0.6	efg	ND		
Quadris Top	8 fl oz	---	@	---	---									
Abound 2F	12.3 fl oz	---	---	@	@									
Indar 2F + Breakthru	6 fl oz - 6 fl oz	@	@	@	@	28.3	cde	12.0	fg	0.4	fg	75.8	bcdef	1.1	bcd
Dithane 75DF	6 lb	---	@	@	@									

* - 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 5-7-10 for each of five single-tree replications.
***- Shot hole was evaluated on 5-20-10. Disease incidence was based on the number of fruit with shot hole lesions of a total of 25 fruit evaluated for each five single-tree replications. Disease severity is the number of shot hole lesions per fruit.
***- Gray mold was evaluated on flower petals that were collected on 2-24-10 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.
Note: Rain occurred between the second application and petal collection two days later.
^ - Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

In a trial to evaluate biologicals and natural products on cv. Sonora, the biocontrol/natural products Actinovate, Ph-D, and Cerebrocide significantly reduced brown rot and gray mold as compared to the control (**Table 2**). Regalia was less effective against brown rot and ineffective against gray mold. All treatments were compared to Vangard which had the lowest levels of both brown rot and gray mold among treatments evaluated (**Table 2**).

Table 2: Efficacy of treatment programs with fungicides, natural products, and biocontrols for management of brown rot and gray mold of cv. Sonora almonds at UC Davis 2010

		2/17	2/22	3/1	3/11	Brown rot**		Gray mold***			
Fungicide*	Rate	PB	FB	PF	PF	Inc. (%)	LSD^	Inc. (%)	LSD	Severity	LSD
Control	---	---	---	---	---	72.3	a	93.8	a	3	a
Actinovate	12 oz	@	@	@	@	31.0	b	49.8	bc	1.2	de
Regalia C 20%	0.50%	@	@	@	@	43.3	ab	80.9	a	2.4	abc
Regalia C 20%	1%	@	@	@	@	43.8	ab	86.3	a	2.6	ab
Regalia B 5%	0.50%	@	@	@	@	46.3	ab	74.8	ab	2	bcd
Cerebrocide	0.50%	@	@	@	@	42.5	ab	51.7	bc	1.5	cde
Polyoxin-D	6 oz	@	@	@	@	38.8	b	46.9	c	1.2	de
Vangard	5 oz	@	@	@	@	1.8	c	37.1	c	0.6	e

* 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 4-15-10 for each of four single-tree replications.

*** Gray mold was evaluated on flower petals that were collected on 2-25-10 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 ($P > 0.05$).

C. Scab management. Three trials were conducted on the management of scab. Two studies in Butte Co. also included the evaluation of dormant treatments to reduce the production of primary inoculum in the springtime from overwintering twig lesions on previous year's growth. Sporulation was first observed on lesions occurring on shoots from previous year's late summer/fall growth, as opposed to lesions on spring/summer growth, indicating that vigorous tree growth in late summer/fall before dormancy can lead to the production of highly susceptible host tissue and thus, should be avoided. Delayed-dormant (early February, 2010) applications with copper-oil or an experimental copper were most effective in delaying twig lesion sporulation. In a mid-spring evaluation in May, incidence/severity of sporulation was 85%/1.3, 66.9%/1.1, and 43.0%/0.5 for the untreated control, copper-surfactant (Kocide 3000-5 lb/A–Cohere 1 pt/A), and copper-oil (Kocide 3000 5 lb- 4% Oil/100 gal/A) treatments, respectively. In the second plot, incidence/severity was 88.7%/1.4, 62.3%/0.6, and 60.7%/0.9 for the untreated control, an experimental liquid copper (GWN426 1 gal/A), and copper-oil (Badge SC 1.7 gal/A- 4% Oil/100 gal/A) treatments, respectively (**Table 3**). Thus, dormant applications can be highly effective inoculum reduction treatments. A reduced amount of inoculum will reduce the risk for selection for fungicide resistance but dormant treatments are not stand-alone treatments and should be used in combination with petal fall/spring treatments.

Table 3. Efficacy of fungicide treatments for management of scab on almond cv. Carmel – Butte Co. 2010

A. Evaluation of dormant treatments plot A

			Applic.	Sporulation twig lesions**		Dis. Incid. On fruit***		Dis. Sev. On fruit	
No.	Treatments*	Rate (/A)	Feb. 3	Severity	LSD^	(%)	LSD	Lesions	LSD
1	Control	---	---	1.4	a	42.7	ab	6.7	A
2	Badge SC- Oil	1.7 gal – 4 gal	@	0.9	ab	39.3	b	6.9	A
3	GWN426	4 qt	@	0.6	b	45.7	a	6.6	A

* Treatments were applied using an air-blast sprayer at a rate of 1(

** Twig lesions were evaluated for sporulation on 5-5-10 using a rating scale from 0=no sporulation, 1=sporulation very low, to 3=>70% of the lesion dark or intense sporulation around the margin of the lesion.

*** 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. Petal fall treatments did not significantly affect the efficacy of the dormant treatments, and thus, all petal fall treatments were combined for each dormant 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.

B. Evaluation of petal fall and spring-time treatments

			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 + Quash	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.

Dormant treatments were also evaluated as part of fungicide management programs for scab that included treatments after petal fall. Dormant treatments and petal fall treatments did not interact and significantly reduced disease incidence when all treatments were combined (**Table 3 A, B**). Petal fall/spring treatments also significantly reduced disease severity (**Table 3B**). Note that disease evaluations were all done in July 2010 and disease can quickly build up in orchards over time when high inoculum levels are present in untreated control treatments.

Chlorothalonil (Echo 720, Equus, and Bravo Weather Stik) alone (data not shown) and incombination with other fungicides (**Table 3B**) were highly effective in reducing the incidence and severity of scab. Inspire Super, Quadris Top, and Quash were also very effective. Syllit and Dithane also performed very well, whereas Ziram had an intermediate efficacy (data not shown). Luna Sensation and Ph-D/Quash (low rate) were intermediate in their effectiveness against scab. The reduced effectiveness of Luna Sensation was potentially due to cross resistance to known SDHI resistance in *Cladosporium carpophilum* populations in this orchard. Thus, where both boscalid/QoI resistance has developed after extensive use of Pristine, other SDHI or QoI fungicides such as fluopyram (SDHI) and trifloxystrobin (QoI), respectively, are less effective. This has also been validated in laboratory studies.

In another field trial in Butte County with a much lower disease pressure and no known SDHI-resistance, all single-fungicides, mixtures and pre-mixtures, as well as rotation programs reduced disease incidence to significantly lower levels than the control, although differences among treatments were observed (**Table 4**).

Table 4. Efficacy of fungicide programs for management of scab of cv. Peerless almonds Butte County 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		@	---	27.2	cd	1.5	c
		Indar 2F + Dithane F45	6 fl oz + 192 fl oz	---	@				

* Treatments were applied using an air-blast

** 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,

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

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 and two petal-fall applications with chlorothalonil (e.g., Echo, Bravo, Equus) or DMI fungicides such as Quash or Inspire Super. Multi-site mode of action fungicides has a low potential of resistance development. Because maneb fungicides have been voluntarily canceled (2008/2009), mancozeb (e.g., Dithane) fungicides are being tested and are planned for future registrations. 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. Hull rot management with fungicides**.** Results obtained from laboratory and field experiments are from 2009. Studies in 2010 are ongoing. This research is providing new insights for the management of hull rot caused by *Rhizopus stolonifer*, the main cause of hull rot. In three field studies, the efficacy of six fungicides was evaluated. In all three trials, there was no significant difference in efficacy among timings, number of applications, and application volumes used (**see footnote of Table 5**). Thus, for each trial, data were combined for these parameters. All compounds, including Abound, Gem, Quash, Scholar, Quadris Top, and Luna Privilege, significantly reduced the incidence of hull rot and there was no consistent ranking in efficacy among the fungicides tested (**Table 5**). Grower trials where applications of Gem and wettable sulfur were evaluated demonstrated a similar level of efficacy for Gem but not wettable sulfur.

Laboratory studies indicated that almond hulls are susceptible to infection by *R. stolonifer* only during a brief period of nut development. As a wound pathogen the pathogen requires injuries (i.e., splitting of the hull) but additionally, we found that the physiological state of the tissue is critical. The highest incidence of infection of detached almond fruit was observed at hull split stage b2 (*see* IPM for almonds Page 7) when only a very small crack of the hull is present. Later stages resulted in significantly fewer infected fruit, no infections occurred at stage f, when the hull is completely split and partially rolled up. These differences in susceptibility of the hull to infection by *R. stolonifer* are likely due to differences in the moisture content of the hull.

Table 5. Efficacy of fungicide treatments for management of hull rot on cv. Winters – Colusa Co. 2009 using applications done at different timings and application volumes**.**

				Orchard 1		Orchard 2		Orchard 3	
				Total disease**					
No.	Program	Treatments*	Rates (/A)	Strikes/tree	LSD***	Strikes/tree	LSD	Strikes/tree	LSD
1	---	Control	---	60.9	a	75.9	a	15.0	a
2	Single	Abound 2F	12.5 fl oz	38.3	b	44.2	b	5.1	c
3	fungicides	Gem 500SC	3 fl oz	30.2	bcd	32.7	c	5.2	c
4		Quash 50WG	3.5 oz	29.9	bcd	26.4	bc	4.3	c
7		Scholar 50WP	6 oz	26.8	cd	36.8	bc	4.5	c
5	Pre-mixtures	Quadris Top SC	14 fl oz	37.1	bc	33.5	bc	6.0	bc
6		USF2016 SC	4 fl oz	24.8	d	34.4	bc	8.2	b

* In orchard 1, single treatments were applied using an air-blast sprayer on 7-20-09 at 100 or 200 gal/A, or 2 applications were done on 7-20 and 8-11 at 100 gal/A. In orchard 2 single treatments were done on 7-20, 8-11, or 8-28-09 at 100 gal/A. In orchard 3, treatments were done on 7-20 or 8-13-09 at 150 gal/A. Hull split stages were b1 on 7-20, b3 on 8-11, and c on 8-28-09.

** Evaluations for disease were done on 9-11-09 and the number of hull rot twig strikes was counted on each of the 4 single-tree replications.

*** There were no significant differences in treatment efficacies among timings, number of applications, and application volumes for each orchard. Thus, data for each fungicide treatment were combined for these parameters. 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.

Based on these laboratory studies, the most important timing of a hull rot fungicide application would be during the early stages of hull split. Possibly, we did not see differences in application timings in our field trials because of the long hull split duration within an orchard where a similar number of nuts was in the susceptible stage at each of the fungicide timings. Consequently, for the most effective integrated management of hull rot, 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. A fungicide could then be applied most effectively during the stages when susceptibility is high.

E. Susceptibility of almond varieties against brown rot blossom blight. The natural host resistance was again evaluated in the UCD variety plot. There was a wide range of susceptibilities among early-, mid-, and late-blooming accessions. Whereas observations for some varieties were consistent with previous data, others performed differently from previous evaluations (**Table 6**). In 2010, more rainfall occurred during bloom than in 2008 or 2009. This emphasizes the importance of doing multi-year evaluations with different environmental conditions that influence host-pathogen interactions and disease development. 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 6: Susceptibility of almond varieties against brown rot blossom blight - UCD 2010.

A. Early-blooming varieties

No.	Variety	No. strikes*	LSD**
1	Aldrich	7.6	c
2	Sonora	11.3	bc
3	Winters	13.8	bc
4	NePlus Ultra	14.3	bc
5	Peerless	17.5	b
6	1-87	20.3	ab
7	Rosetta	28.3	a

B. Mid-blooming varieties

No.	Variety	No. strikes	LSD
1	F7, 1-1	6.5	c
2	Jenette	6.8	c
3	Nonpareil	9.6	c
4	Chips	10.5	bc
5	Sauret No. 1	11.3	bc
6	Price	12.3	bc
7	Johlyn	14.0	bc
8	Alamo	14.9	bc
9	F10D, 3+4-25	21.0	b
10	Wood Colony	58.0	a

C. Late-blooming varieties

No.	Variety	No. strikes	LSD
1	Monterey	2.3	e
2	Ruby	6.0	e
3	Carmel	6.8	e
4	Plateau	7.8	e
5	2-19E	9.4	de
6	Ferragnes F7,4-7	16.8	cde
7	Merced	18.5	cde
8	Livingston	19.3	cde
9	Fritz	20.8	cde
10	Mission	21.6	cde
11	LeGrand	26.4	bcd
12	Butte	34.5	bc
13	Padre	56.3	b
14	25-75	106.5	a

* - For evaluation, the number of brown rot strikes per tree was counted in April 2010.

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