

# Epidemiology and Management of Almond Anthracnose and Brown Rot in California

---

**Project No.:** 04-JA-02

**Project Leader:** James E. Adaskaveg, Dept. of Plant Pathology, UC Riverside

**Cooperating Personnel:** H. Förster, D. Thompson, G. Driever, J. Connell (Butte Co.), J. Edstrom (Colusa Co.), R. Duncan (Stanislaus Co.), M. Freeman (Fresno Co.), and P. Verdegaal (San Joaquin Co.).

- I. Pre- and post-harvest studies on ecology and epidemiology of almond anthracnose;
- II. New cultural and fungicide management practices for brown rot and anthracnose.

## Objectives

### I. **Epidemiology**

- A. Determine factors that may induce the biotrophic phase of the pathogen to shift to the necrotrophic or disease phase.
  - 1) Evaluation of the effects of plant stresses such as inoculum density on anthracnose disease development under conducive or less conducive leaf wetness and temperature conditions.
  - 2) Studies on pH modulation of the almond host by the pathogen.
- B. Continue to develop a wetness-temperature model for predicting disease on susceptible cultivars.
  - 1) Evaluation of the effects of interrupted wetness periods and of multiple inoculations on disease incidence and severity.
  - 2) Evaluation of microclimatic factors in field studies.
- C. Field evaluation of host susceptibility to blossom, leaf, fruit, and kernel diseases among almond cultivars.
  - 1) Varieties planted in the variety block at UC Davis will be sprinkler-irrigated during bloom and evaluated for brown rot, shot hole, and other diseases.
  - 2) As part of collaboration with Dr. T. Gradziel, we will continue to evaluate almond genotype susceptibility to anthracnose and evaluate fungi associated with kernel discolorations.

## II. Disease Management Strategies

- A. Continue to determine the potential for resistant populations of target organisms to develop by establishing  $EC_{50}$  and baseline sensitivity values and monitoring field populations.
- B. Continue fungicide efficacy studies and evaluation of rotation programs for anthracnose management, as well as evaluations of new fungicides for brown rot and other diseases of almond.
  - Evaluate persistence and post-infection activity of selected fungicides in field inoculation studies for management of brown rot and anthracnose.
- C. Continue to develop a minimum application fungicide program for maximum disease control of major foliar diseases.

## Summary

Our research in 2004 focused on the evaluation of new fungicides against major foliar and fruit diseases of almond in California, i.e. brown rot and Botrytis blossom blights, Colletotrichum disease, shot hole, and scab. Alternaria leaf spot is discussed in a separate report. Disease incidence was generally low throughout the state, except in orchards that were less well maintained and where inoculum was allowed to build up in previous years. Fungicide efficacy trials were initiated in these orchards and late spring rains increased levels of disease to high proportions. Highly effective fungicides were identified that were also applied in rotation and mixture programs. The use of these programs will help to prevent the selection and build-up of resistant pathogen populations. Pristine and mixtures and rotations of Vanguard and Abound effectively reduced the incidence of brown rot, Colletotrichum disease, and scab in a field trial in Butte Co. In the Solano Co. field trial with a high disease pressure of brown rot blossom blight all fungicides evaluated were highly effective, including sterol biosynthesis inhibitors (Elite, V-10116, Systhane), anilinopyrimidines (Vanguard, Scala), strobilurins (Flint, USF 2004), pre-mixtures of different classes of fungicides (Pristine, USF2010) and mixture and rotation programs with new and older, multi-site materials. Selected fungicides were also evaluated for their pre- and postinfection ("kick-back action") activity. Basic studies on the epidemiology of anthracnose were also continued with research focusing on a unified model that integrates environmental (i.e., wetness and temperature), as well as host susceptibility parameters. Studies on the effect of fungal modulated pH shifts in plant tissue were also continued.

**Fungicide evaluations for management of brown rot, shot hole, and Botrytis petal blight.** For blossom blight control, field trials were conducted in Butte, Fresno, and Solano Co. Treatments were done as single-fungicide, mixture, and rotation programs. In treatments that were mixtures, fungicides were used at the lower label rates. Blossom blight, as evaluated by the number of infected spurs (twig strikes) per tree, was very effectively reduced under high disease pressure conditions by all treatments in the Solano Co. trial at UC Davis (Table 1). Disease was reduced from 62.6 strikes per tree in the control to 0.6 to 11.2 strikes in the treatments. Among the single-fungicide

treatments Flint and USF2004 numerically were the least effective, whereas the most effective were the experimental sterol biosynthesis inhibitors Elite, Systhane, and V-10116, as well as the anilinopyrimidines Scala and Vanguard. In addition, all mixtures including Vanguard/Abound, Pristine, Scala/Rovral, and USF2010 performed very well. Similarly, most rotational programs performed well in this study. The high efficacy of the recently registered Pristine against brown rot blossom blight was also demonstrated in the Butte Co. trial where it was compared to rotation programs that included Abound, Vanguard, Bravo, Systhane, and Ziram (Table 4).

**Table 1.** Efficacy of fungicide programs for management of brown rot blossom blight and shot hole of Drake almonds at the UC Davis experimental orchard 2004.

No.	Treatments	Product Rate (100 gal/A)	Application dates			Brown rot		Shot hole	
			2-22	2-27	3-18	Strikes/tree	LSD	Incidence	LSD
			PB	FB	SS			e	
1	Control	---	---	---	---	62.6	a	31.2	a
2	Scala 600SC	18 fl oz	@	@	@	1.8	e	6.2	bcde
3	Flint 50WDG	3 oz	@	@	@	11.2	bc	8.4	bcd
4	USF 2010 500SC	6 fl. oz	@	@	@	1.6	e	6.4	bcde
5	Elite 45WP (+Induce)	6 oz	@	@	@	1	e	10.4	b
6	USF 2004 500SC	3 fl. oz	@	@	@	8.8	bcd	10.2	bc
7	Systhane 20EW	15.3 fl oz	@	@	@	5.8	cde	3.6	e
8	V-10116 1.25FL (+Induce)	5.67 fl.oz.	@	@	@	0.6	e	5.4	cde
9	Pristine 38WG	0.92 lb	@	@	@	3.4	de	5	de
10	Scala 600SC	9 fl oz	@	@	@	1.8	e	6.2	bcde
	Rovral 4F	11 fl. oz	@	@	@				
11	Vanguard 75WG	10/5 oz	@	@	---	4.4	de	7.2	bcd
	Abound 2F	9/11.5 fl oz	---	@	---				
	Bravo 720F	4 pts	---	---	@				
12	Vanguard 75WG	10 oz	@	@	---	1.8	e	9.4	bcd
	Abound 2F	11.5 fl oz	---	---	@				
13	Vanguard 75WG	10/5 oz	@	@	---	1.8	e	8.8	bcd
	Abound 2F	11.5 fl oz	---	@	---				
	Ziram 75DG	8 lbs	---	---	@				
14	Systhane 20EW	15.3/12 fl oz	@	@	---	12.6	b	5	de
	Ziram 75DG	8 lbs	---	@	@				
15	Pristine 38WG	0.68 lb	@	@	---	1.6	e	8.4	bcd
	Echo 720	4 pts	---	---	@				

\* - Treatments were applied to 5 single-tree replications for each treatment using an air-blast sprayer at a rate of 100 gal/A. Brown rot was evaluated on 4-20-04 and the number of strikes per trees was counted. Shot hole was evaluated on 4-28-04 and incidence of disease was based on 300 leaves from each replication per treatment. Disease incidence on fruit was very low (<1%).

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

Due to very low natural disease incidence of brown rot blossom blight in the Fresno Co. trial, treated blossoms were collected from the field and then inoculated in the laboratory with conidia of *Monilinia laxa*. In this trial, pink bud applications with Pristine, a mixture

of Vanguard and Abound (high rate), and a rotation with Scala and Flint were more effective than rotations with Eagle and Echo or Vanguard and Abound and significantly reduced the incidence of stamen infections as compared to the control. To evaluate the protective action of the fungicides, trees were treated in the field at full bloom using an air-blast sprayer and blossoms were then collected and inoculated in the laboratory. Blossoms that were collected one day after application generally were better protected against subsequent infection as compared to blossoms collected after two days. Still most treatments, with the exception of the Scala-Flint rotation, significantly reduced the incidence of infected stamens as compared to the untreated control.

**Table 2.** Two-day post-infection activity of selected fungicides and mixtures for control of brown rot blossom blight of cv. Mission almonds in a laboratory experiment.

Treatments	Rate (400 gal/A)	Inc. of stamen infections	
		(%)	LSD
Control		72.2	a
Scala 600SC	18 fl oz	7.3	b
Pristine 38WG	0.68 lb	7.7	b
Pristine 38WG	0.92 lb	4.8	b
Eagle 20W	15.3 fl oz	13.8	b
Vanguard 75WG	5 oz	11.4	b
Vanguard 75WG Abound	5 oz 11.5 fl oz	14.4	b
Vanguard 75WG Abound 2F	5 oz 9 fl oz	13.4	b

\* - Newly opened blossoms were collected in the field, placed into plastic boxes with moist vermiculite, and inoculated with *Monilinia laxa* ( $1.5 \times 10^4$  conidia/ml) in the laboratory. After 2 days blossoms were sprayed to run-off using a hand sprayer by and incubated at 20C for 3-4 days.

\*\* - Numbers followed by the same letter are not significantly different from each other.

All fungicides and mixtures tested also were highly effective in post-infection (“kick-back action”) studies in the laboratory where blossoms were first inoculated and then treated after 2 days (Table 2). Thus, the majority of fungicides currently registered for blossom blight control on almond have pre- and post-infection activity. This indicates that under less conducive disease conditions (little rainfall) a delayed bloom application with one late pink bud or full bloom spray will be sufficient to protect the flowers from blossom blight.

Shot hole disease pressure was low in 2004 in our Solano Co. trial. Few fruit were diseased and fungicide efficacy could only be evaluated on leaves. All treatments significantly reduced the disease as compared to the control, where 31.2% of the leaves were diseased (Table 1). Numerically, single-fungicide applications with Systhane (3.6%) had the lowest incidence of disease, followed by Pristine (5%) and V-10116 (5.4%). The rotational programs were also highly effective with disease incidence in the Systhane and ziram program similar to those previously mentioned.

Botrytis blossom blight was evaluated on blossom material from the Sloan and Fresno Co. orchard locations using a newly developed method where petals from field-treated blossoms are incubated in the laboratory and evaluated for natural incidence of disease. Most of the decay was caused by *B. cinerea* but *Monilinia* spp. and *Sclerotinia sclerotiorum* were also detected at low levels. All three of these organisms are known to be jacket rot and green fruit rot pathogens of almond. In both trials, Vanguard/Abound in mixtures or in rotations and Pristine were among the best treatments, reducing both the incidence and severity of disease from the non-treated control and some of the other treatments. An Eagle/Echo rotation was the least effective in this trial. Data from the Fresno trial is shown in Table 3. In the Solano trial, sterol biosynthesis inhibitors generally were less effective except Elite and USF2010.

**Table 3.** Evaluation of single-fungicide and fungicide rotation and mixture programs for management of Botrytis petal blight of cv. Mission almond in a field trial in Fresno Co. 2004

Treatments	Product Rate (100 gal/A)	Application date		Incidence of petal blight		Severity of petal blight	
		Feb 24 50% FB	Mar 8 PF/SS	(%)	LSD	(%)	LSD
Control				87.0	a	2.3	A
Pristine 38WG	0.68 lb	@	@	31.7	b	0.8	Bc
Pristine 38WG	0.92 lb	@	@	26.7	b	0.5	C
Scala 600SC	18 fl oz	@	---	41.1	b	0.9	Bc
Flint 50WDG	3 oz	---	@				
Eagle 20W	15.3 fl oz	@	---	70.2	a	1.8	A
Echo 720F	4 pts	---	@				
Vanguard 75WG	5 oz	@	@	41.4	b	0.7	Bc
Abound 2F	11.5 fl oz	@	@				
Vanguard 75WG	5 oz	@	@	47.5	b	0.9	B
Abound 2F	9 fl oz	@	@				
Vanguard 75WG	5 oz	@	---	37.2	b	0.6	Bc
Abound 2F	11.5 fl oz	---	@				

\* - Trees were treated at a rate of 100 gal/A using a backback air-blast sprayer. Blossom petals were collected after 2 days, placed into plastic boxes with moist vermiculite, and incubated at 20C for 3-4 days. Disease incidence was based on the number of diseased petals of the total number of petals. For disease severity a rating scale was used with 0 = healthy, 1 = <25% of petal area diseased, 2 = 26-50% of petal area diseased, and 3 = > 50% of petal area diseased.

\*\* - Numbers within a column that are followed by the same letter are not significantly different from each other.

**Fungicide evaluations for management of anthracnose and scab diseases.** The incidence of anthracnose (*Colletotrichum* disease) was low in most locations in the epidemic centers of Butte and Stanislaus-Merced Co. in 2004. Disease was mainly found in orchards that were less well maintained. Here, inoculum had been allowed to build up in previous years and late spring rains created favorable conditions for the disease. In our field trial in Butte Co. 11% of the developing nuts of untreated trees were diseased whereas on treated trees, disease incidence was 2.3% or less. A high rate (10 oz) of Vanguard was more effective than a low rate (5 oz) for managing

anthracnose. Mixtures of fungicides that were highly effective treatments included Pristine, Vangard/Abound, and Systhane/Ziram (Table 4).

Scab was also effectively managed with treatments containing Abound or Pristine in the Butte Co. trial (Table 4). In the control 85.4% of the fruit had scab lesions, whereas in the treatments it was between 4.6% and 26.9%. Treatments containing Bravo or Ziram were less effective against scab than Abound or Pristine, but still they were significantly better than the non-treated control treatment in this trial. Overall, programs that included chlorothalonil (Bravo, Echo) were very effective against anthracnose and shot hole, but were less effective against scab.

**Table 4.** Efficacy of a bloom fungicide program for management of brown rot, anthracnose, and scab of Peerless almonds in Butte Co. 2004

No.	Treatments	Rate (100 gal/A)	Date				Disease incidence						Dis. severity*	
			2/21 PB	2/29 FB	3/23 SS	4/21 PF	Brown Rot		Anthracnose		Scab		Scab Sev.	LSD
1	Control	---	---	---	---	---	7.3	a	11.0	a	85.4	a	21.8	a
2	Vangard 75WG	5 oz	@	@	---	---	0.5	b	2.3	b	4.6	d	0.8	c
	Abound 2F	11.5 fl oz	---	---	@	@								
3	Vangard 75WG	10 oz	@	@	---	---	2.3	b	1.3	bc	15.9	bcd	2.2	c
	Abound 2F	11.5 fl oz	---	---	@	@								
4	Vangard 75WG	10/5 oz	@	@	---	---	1.3	b	0.7	bc	36.5	b	5.8	b
	Abound 2F	9/11.5 fl oz	---	@	@	---								
	Bravo 720F	4 pts	---	---	---	@								
5	Vangard 75WG	5 oz	@	@	@	@	2.3	b	0.8	bc	8.0	cd	1.2	c
	Abound 2F	9 fl oz	@	@	@	@								
6	Vangard 75WG	5 oz	@	@	@	@	0.8	b	0.8	bc	12.0	bcd	1.5	c
	Abound 2F	11.5 fl oz	@	@	@	@								
7	Systhane 20EW	15.3/12 fl oz	@	@	---	---	1.8	b	0.3	c	26.9	bc	3.9	bc
	Ziram 75DG	8 lbs	---	@	@	@								
8	Pristine 38WG	0.68 lb	@	@	@	@	0.5	b	0.8	bc	9.0	cd	1.4	c
9	Pristine 38WG	0.92 lb	@	@	@	@	0.5	b	0.5	c	15.5	bcd	2.6	c

\* - Trees were treated at a rate of 100 gal/A using a backback air-blast sprayer. There were four single-tree replications per treatment. Brown rot was evaluated on March 10 and disease severity was based on the number of brown rot strikes per tree. Anthracnose and scab were evaluated on June 2, 2004. Anthracnose incidence was based on the number of diseased fruit of the total number of fruit evaluated. For scab, 25 fruit were collected from each tree and evaluated for incidence and severity of disease. Severity was rated using a scale with 0 = healthy, 1 = <25% of fruit surface diseased, 2 = 25-50% of fruit surface diseased, and 3 = >25% of fruit surface diseased. Data are expressed as the average fruit surface area affected.

\*\* - Numbers within a column that are followed by the same letter are not significantly different from each other.

**Epidemiological models for predicting anthracnose and basic studies on host-pathogen interactions.** Basic studies on the epidemiology of anthracnose were also continued with research focusing on a unified model that integrates environmental (i.e., wetness and temperature), as well as host susceptibility parameters. Statistical analyses were done on accumulated data from potted plants in the greenhouse and

from field studies obtained in the last several years. A new statistical approach using mixed models for fixed treatment and random block effects was used. This will be summarized later.

Studies on the effect of fungal modulated pH shifts in plant tissue were also continued. In 2003 and 2004 we demonstrated that *Colletotricum acutatum* induced pH shifts within almond fruit tissue with the accumulation of ammonia. Symptoms developed only after pH shifts and ammonia accumulation. These data support threshold models for predicting disease.