Project Name: Epidemiology and management of almond anthracnose and brown rot in California –
I. Pre- and postharvest studies on ecology and epidemiology of almond anthracnose;
II. New cultural and fungicide management practices for brown rot and anthracnose.

Project Number: 05-JA-02

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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.
      a. 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 2005 focused on the evaluation of new fungicides against major foliar and fruit diseases of almond in California, i.e. brown rot blossom blight, anthracnose, shot hole, and scab. Alternaria leaf spot is discussed in a separate report. Due to high rainfall disease incidence throughout the state was generally higher in the spring of 2005 than in previous years. Still, no major outbreaks were reported except in orchards that were less well maintained and where inoculum was allowed to built up in previous years. 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. In a Solano Co. field trial with a high disease pressure of brown rot blossom blight all single-fungicide programs evaluated were highly effective, including the sterol biosynthesis inhibitor V-10116 (SBI), the hydroxyanilide Elevate, and two pre-mixtures of different classes of fungicides, e.g., Pristine and USF2010 (SBI+strobilurin). Rotation programs with strobilurins (Flint, Abound), anilinopyrimidines (Vangard, Scala) and the dimethyl-dithiocarbamate (DMDC) ziram were also very effective. The incidence of shot hole was high in this trial, and was most effectively controlled by V-10116, USF2010, Pristine, and all the rotation programs. Thus, effective anti-resistance management programs can be designed using new fungicides and older, multi-site materials. Selected fungicides were also evaluated for their pre- and post-infection ("kick-back action") activity. In a field trial in Butte Co., Echo Ultimate most effectively reduced the incidence of both anthracnose and scab. Pristine and some of the rotation programs were also very effective. The natural host resistance against brown rot blossom blight was evaluated among 31 almond varieties in the newly established variety trial at UC Davis. No significant differences were found among the six early-blooming varieties evaluated where disease incidence ranged from 3.2 to 10.5%. There was, however, a wide range of susceptibility among the mid- and late-blooming varieties with 1.5 to 42.5% and 1.3 to 31.9% blight incidence, respectively. Overall, the semi-late blooming cv. Ferragnes had the lowest incidence of blossom blight (0.3%). With future evaluations, including those for other diseases of almond, data from this variety orchard will provide important information on the suitability of selected varieties in high-disease growing locations and will also help to direct breeding programs.

Fungicide evaluations for management of brown rot and shot hole. For blossom blight control, field trials were conducted in Solano and Fresno Co. Treatments were done as single-fungicide, mixture, and rotation programs. In mixtures treatments, fungicides were used at the lower label rates. Blossom blight in the Solano Co. trial at UC Davis, as evaluated by the number of infected spurs (twig strikes) per tree, was very effectively reduced under high disease pressure conditions by all treatments (Table 1). Disease was reduced from 65 strikes per tree in the control to 1.2 to 15.8 strikes in the treatments. All single-fungicide programs evaluated were highly effective, including the sterol biosynthesis inhibitor V-10116, the hydroxyanilide Elevate, and two pre-mixtures of different classes of fungicides, e.g., Pristine (pyraclostrobin/boscalid) and USF2010 (SBI/strobilurin). These repeated application trials of the same fungicide were done to determine the efficacy of these products but are not recommended for practical programs. Thus, for growers interested in how to use these new fungicides, rotation programs were also evaluated as 'real world' fungicide programs. In these trials, rotational programs with strobilurins (Flint, Abound), anilinopyrimidines (Vangard, Scala), and the DMDC ziram were very effective. Again, this trial shows that growers can effectively rotate fungicides for resistance management and not sacrifice performance of the fungicide program.

Table 1: Efficacy of fungicide programs for management of brown rot and shot hole of Drake almonds at the UC Davis experimental orchard 2005.

			Product Rate	2-17	2-23	3-16	Brown rot Strikes/tree		Shot hole Incidence		Shot hole Severity	
Programs		Treatments	(100 gal/A)	PB	FB	SS	No.	LSD	(%)	LSD	Lesions /fruit	LSD
	1	Control	---	---	---	---	65	a	70	a	3.5	a
Single fungicides	2	V-10116 50WD	1.75 oz	@	@	@	2.2	d	12.8	b	0.3	c
	3	V-10116 50WD	2.5 oz	@	@	@	1.2	d	3.2	c	0.1	c
	4	V-10135 50DF	0.3 lb	@	@	@	15.6	b	55.7	a	2.1	b
	5	V-10135 50DF	0.5 lb	@	@	@	7	bcd	70.7	a	3.2	a
	6	Elevate 50WG	1.5 lb	@	@	@	7	bcd	62.4	a	2.6	ab
Pre-mixes	7	Pristine 38WG	0.68 lb	@	@	@	1.8	d	4	c	0.1	c
	8	Pristine 38WG	0.92 lb	@	@	@	3.2	cd	0.8	c	0.01	c
	9	USF2010 500SC	6 fl oz	@	@	@	1.6	d	6.4	bc	0.2	c
Rotations +	10	Laredo EW	15.3 / 12.8 fl oz	@ 15.3 fl oz	@ 12.8 fl oz	---	15.8	b	7.3	bc	0.1	c
mixtures		Ziram 75WSP	8 lb	---	@	@						
	11	Laredo EW	12.8 / 10 fl oz	@ 12.8 fl oz	@ 10 fl oz	---	12.6	bc	2.5	c	0.04	c
		Ziram 75WSP	8 lb	---	@	@						
	12	Scala 600SC	9 fl oz	@	@	---	4.4	cd	7.2	bc	0.1	c
		USF2004 500SC	3 fl oz	---	---	@						
	13	Scala 600SC	12.8 fl oz	@	@	---	1.8	d	10.4	bc	0.4	c
		USF2004 500SC	3 fl oz	---	---	@						
	14	Vangard 75WG	5 oz	@	@	---	5.6	cd	4	c	0.1	c
		Ziram 75WSP	8 lb	---	@	---						
		Abound 2F	12.8 fl oz	---	---	@						
	15	Vangard 75WG	5 oz	@	@	---	6.6	bcd	2.4	c	0.04	c
		Abound 2F	12.8 fl oz	---	---	@						
	16	Vangard 75WG	5 oz	@	---	---	6.4	bcd	2.4	c	0.04	c
		Abound 2F	12.8 fl oz	---	@	---						
		Bravo 720F	4 pts.	---	---	@						

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. Induce was added to the V-10116 50WD treatment.

** -For brown rot evaluation, the number of brown rot strikes per tree was counted on 3-30-05 for each of five single-tree replications. Incidence and severity of shot hole on 5-4-05 are based on 25 fruit from each of five single-tree replications from each treatment.

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

The pre- and post-infection activity of selected fungicides was evaluated using field- or laboratory-treated, *Monilinia laxa*-inoculated blossoms. Two trials were done in Fresno (not shown) and Solano Co. In the Solano Co. trial on cv. Drake, post-infection treatments (applied 2

Table 2. Evaluation of the pre- and post-infection activity of selected fungicides against brown rot blossom blight on cv. Drake almond in Solano Co.

			Full bloom application, Inoculated after 1 day		Full bloom application in lab, 2 days after inoculation	
No.	Treatments	Product Rate (100 gal/A)	(%)	LSD	(%)	LSD
1	Control	---	83.4	a	94.3	a
2	V-10116 50WD + Induce	2.5 oz	30.9	b	8.4	bc
3	V-10135 50DF	0.5 lb	30.7	b	2.3	d
4	Elevate 50WG	1.5 lb	39.1	b	4.2	d
5	Pristine 38WG	0.92 lb	31.1	b	6.8	bcd
6	Laredo EW	15.3 fl oz	45.5	b	9.6	bc
7	Scala 600SC	9 fl oz	32.9	b	12.3	b
8	Vangard 75WG	5 oz	48.9	b	13	b

* - For evaluation of the pre-infection activity blossoms were treated in the field on 2-17-05 using an air-blast sprayer at a rate of 100 gal/A. Blossoms treated full bloom stage were collected after 1 day and inoculated in the laboratory with conidia of *Monilinia laxa*. For the evaluation of the post-infection activity, newly opened blossoms were collected, inoculated, and then treated in the laboratory after 2 days using a hand sprayer.

** - Blossoms were evaluated for stamen infections after 4-5 days of incubation at 20C. The incidence of stamen infections is based on the number of infected stamens of the total number of stamens. Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

days after inoculation) were more effective than pre-inoculation treatments (applied 1 day before inoculation) (Table 2). Because blossoms were of different age in the full-bloom, field application, disease was naturally higher than when blossoms were opened in the lab under controlled conditions. These data indicate that the majority of fungicides currently registered for blossom blight control on almond have pre- and post-infection activity. Thus, 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. Still, under more conducive wet conditions, a guideline for two applications at pink bud (5% open bloom) and full bloom (80% open flowers) should provide maximum benefits.

The incidence of shot hole disease was high in 2005 in our Solano Co. trial with 70% of the untreated control fruit infected. The most effective treatments after a three-spray program included V-10116 (3.2% disease) among the single-fungicide programs and Pristine (0.8% disease) and USF2010 (6.4% disease) among the pre-mixes (Table 1). All rotation-mixture programs were also highly effective, reducing the incidence of shot hole to between 2.4 and 10.4%.

Fungicide evaluations for management of anthracnose and scab. In our field trial in Butte Co., 5.4% of the developing nuts of untreated trees had anthracnose symptoms, whereas on treated trees, disease incidence was 1.25% or less (Table 3). No disease was found after treatment with Pristine or Echo Ultimate. Scab was also most effectively managed with these latter two fungicides and disease incidence on fruit was reduced from 91.2% in the untreated

Table 3. Efficacy of a bloom fungicide program for management of anthracnose and scab of Peerless almonds in Butte Co. 2005

			Application Dates and Timings				Anthracnose		Scab			
			2-16	2-22	3-2	3-30	Incidence		Incidence		Severity	
No.	Product	Rate	PB	FB	PF	4 wk -PF	(%)**	LSD	(%)**	LSD	Lesions	LSD
1	Control	---	---	---	---	---	5.4	a	91.2	a	13.8	a
2	Echo 720	4 pts	@	@	@	@	1.25	b	27.6	bc	1.7	b
3	Echo Ultimate	3.6 lb	@	@	@	@	0	b	6	c	0.2	b
4	Pristine 38WG	0.92 lb	@	@	@	@	0	b	20	bc	0.8	b
5	USF2010 500SC	6 fl oz	@	@	@	@	0.25	b	38	b	1.7	b
6	Vangard 75WG	5 oz	@	@	---	---	0.5	b	34.5	b	1.3	b
	Abound 2F	12.8 fl oz	---	@	@	@						
7	Vangard 75WG	5 oz	@	@	---	---	0.25	b	12	bc	0.3	b
	Ziram 75WSP	8 lb	---	@	---	---						
	Bravo 720F	4 pts.	---	---	@	@						
8	Laredo EW	15.3/ 12.8 fl oz	@ 15.3 fl oz	@ 12.8 fl oz	---	---	0.75	b	22	bc	1	b
	Ziram 75WSP	8 lb	---	@	@	@						
9	Scala 600SC	9 fl oz	@	@	---	---	1	b	12	bc	0.4	b
	USF2004 500SC	3 fl oz	---	@	@	@						
10	Scala 600SC	12.8 fl oz	@	@	---	---	0.75	b	46.2	b	3.7	b
	USF2004 500SC	3 fl oz	---	@	@	@						

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. Phenology: PB - Pink Bud; FB - Full Bloom; PF = petal fall.

** - Incidence of disease based on 200 (anthracnose) or 25 (scab) fruit from each of five single-tree replications from each treatment.

*** - Disease severity of scab is expressed as the number of lesions per fruit.

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

control to 6 and 20%, respectively. In addition, rotation programs with Vangard, Ziram, and Bravo or with Scala and USF2004 (strobilurin liquid formulation) were very effective and disease incidence was reduced to 12% with both programs.

Evaluation of almond varieties for their natural host resistance against brown rot blossom blight. The natural host resistance against brown rot blossom blight was evaluated among 31 almond varieties replicated 4 times (4 trees per replication) in a randomized block design in the newly established variety trial at UC Davis. After four seasons, brown rot was observed uniformly across the orchard by variety and there was no difference in disease level within varieties following prevailing wind patterns. Statistical comparisons were done among early-, mid-, and late-blooming varieties. No significant differences were found among the six early-

Table 4. Evaluation of almond varieties for their natural host resistance against brown rot blossom blight - UC Davis variety trial 2005

		Incidence				Incidence	
Bloom	Variety	%	LSD	Bloom	Variety	%	LSD
Early-	Aldrich	10.5	a	**Semi-late**	Ferragnes	0.3	NA
	NePlus Ultra	8.5	a				
	Rosetta	5.6	a	**Late-**	25-75	31.9	a
	1-87	5.2	a		Butte	24.0	ab
	Peerless	5.2	a		LeGrand	21.8	abc
	Sonora	3.2	a		Carmel	19.0	abcd
					Padre	14.0	bcde
Mid-	Wood Colony	42.5	a		Winters	8.5	cdef
	F10D	15.6	b		Merced	8.1	cdef
	Jenette	13.3	bc		Mission	7.9	def
	Price	6.4	bcd		Plateau	5.0	ef
	F7	5.8	bcd		Monterey	4.2	ef
	Alamo	5.2	bcd		Fritz	4.1	ef
	Johlyn	4.3	bcd		Livingston	3.7	f
	Sauret No. 1	3.2	cd		Ruby	1.8	f
	Chips	3.0	d		2-19E	1.3	f
	Nonpareil	1.5	d				

*- Disease was evaluated in March of 2005. The incidence of blossom blight is based on the number of blighted blossoms per 600 blossoms evaluated for each of three replications of four trees (150 blossoms evaluated for each of the four trees).

**- Disease incidence was statistically compared within each bloom group. Values followed by the same letter are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

blooming varieties evaluated where disease incidence ranged from 3.2 to 10.5% (Table 4). There was, however, a wide range of susceptibility among the mid- and late-blooming varieties. Blossom blight incidence ranged from 1.5 % (cv. Nonpareil) to 42.5% (cv. Wood Colony) among the mid-blooming varieties and from 1.3% (cv. 2-19E) to 31.9% (cv. 25-75) for the late-blooming varieties. Overall, the semi-late blooming cv. Ferragnes had the lowest incidence of blossom blight (0.3%). We will continue these evaluations in future seasons. With different environmental conditions occurring each year, data from this variety orchard will provide important information on the suitability of selected varieties in high-disease growing locations and will also help to direct breeding programs.