Annual Report 2001

Prepared for the Almond Board of California

Project No. 95-JA1:

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

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OBJECTIVES

I. **Epidemiology**
- A. Detection of fungal pathogens in plant tissue
  1. Detection of anthracnose and other diseases in almond orchards as a preharvest management tool using molecular assays.
     - a. Evaluation of the ELISA detection kit in cooperation with farm advisors as a method for rapid diagnosis of anthracnose.
     - b. Continue determining the accuracy of the ELISA detection kit as compared to DNA-PCR detection or isolation of the pathogen on agar media.
  2. Detection of postharvest anthracnose infections in whole and sliced kernels.
- B. Evaluation of the effects of microclimatic parameters such as leaf wetness and temperature on disease development in growth chamber and field studies.
- C. Histological studies on the initial infection process of *C. acutatum* on almond under different environments.
- D. Laboratory, growth chamber, and field evaluation of host susceptibility and temperature-wetness relationships for disease development on selected almond cultivars.

II. **Disease management strategies**
- A. Determination of potential development of resistant populations of target organisms by establishing EC_{50} and baseline sensitivity values and monitoring field populations.
- B. Continuation of fungicide efficacy studies and rotation programs for anthracnose management (dormant and in- season programs will be evaluated), as well as evaluations of new fungicides for brown rot, shot hole, and other diseases of almond.
- C. Orchard sanitation and irrigation practices for anthracnose management

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SUMMARY

Due to low rainfall in the spring of 2001, anthracnose incidence was low in both epidemic centers of Butte and Stanislaus-Merced Co. Disease incidence data obtained in field trials and under controlled conditions in growth chambers were correlated to environmental parameters (temperature, rainfall, and other parameters) and accumulated results of these disease progress data from several years will be the basis for the development of a disease prediction model. Disease incidences on blossoms and fruit in 2001 in the Stanislaus-Merced trial were approximately half as high as they were in 2000, which correlated with the much lower rainfall in 2001. In growth chamber studies using isolates of both *Colletotrichum* genotypes for

inoculation, leaves and blossoms were influenced differently by wetness period duration. For leaves, wetness duration was a more critical parameter for disease development than it was for blossoms. Temperature, however, was of similar importance for both tissues. Preliminary studies indicated that the effect of wetness period on fruit is similar as for leaves. When four almond cultivars were compared for their disease susceptibility in these growth chamber studies, differences in susceptibility among the cultivars were similar to previous field evaluations ranging from low to high susceptibility. Histological studies indicated that during infection the anthracnose pathogen first has a biotrophic phase (quiescent infection) and then a necrotrophic phase. This corresponds to a shift from symptomless infections to expression of disease symptoms. Factors that trigger the shift from the biotrophic into the necrotrophic phase are currently being investigated. The ELISA assay for disease detection again was found to be very accurate. Because of low disease levels in 2001, however, only few samples were evaluated. In fungicide efficacy studies, rotation programs with Abound and Captan, Flint and Captan, Laredo and Captan, Abound and Ziram, or Laredo and Ziram were all very efficacious for disease control. Comparatively, Ziram was equivalent to Captan as a broad spectrum rotational or companion fungicide with Abound. Treatments with the experimental compound BAS516 in rotation with Captan were also very effective. Continued development of new materials is essential in developing fungicide management programs that are highly effective and that prevent the development of resistance within populations of *Colletotrichum* and other foliar fungal pathogens of almond. For brown rot blossom blight control Vangard, Scala, and BAS516 were the most effective treatments, whereas for shothole control all fungicides tested showed a similar efficacy in suppressing the disease. In a study where 4 applications of Elevate were compared to a standard 2-application program with Rovral or Captan, no differences in efficacy or yield based on kernel weight were found.

INTRODUCTION

Anthracnose and brown rot are two of the major foliar diseases of almond in California. Brown rot is caused by either of the fungi *Monilinia laxa* or *M. fructicola*. *M. laxa* primarily causes blossom blight and green fruit rot, whereas *M. fructicola* primarily causes hull rot throughout the state but can also cause blossom blight and green fruit rot in the central and southern San Joaquin Valley. Both organisms can be found throughout the almond production areas of the Central Valley. Anthracnose caused by *Colletotrichum acutatum* has only more recently been described as a disease causing crop losses. Anthracnose fruit rot is the major disease of almonds. Fruit rot can occur at any stage of fruit development provided that there are conducive environments for fungal growth and infection. The pathogen can also cause a blossom blight similar in appearance to brown rot blossom blight, as well as twig and branch dieback of almond. Thus, the major emphasis of this research program is to develop effective management programs for both brown rot and anthracnose by studying: 1) the biology and ecology of the pathogen; 2) the epidemiology of the disease in growth chamber and field studies, 3) new methods for detection, and 4) development of new, effective treatments for susceptible varieties of almond.

RESULTS AND DISCUSSION

Epidemiology - Field evaluations of disease progress and relationships to environmental parameters. In two field sites in Butte and Merced Co., disease progress curves during the spring season were developed for blossoms and fruit of NePlus Ultra. At each site, dataloggers were used to record environmental parameters (leaf wetness, temperature, and relative humidity) and disease incidence was evaluated weekly on selected non-fungicide treated trees. Anthracnose blossom blight, which is easily confused with brown rot blossom blight, was positively identified in selected samples by fungal isolation or by the ELISA assay (see below). At both sites, rainfall occurred from mid-February to mid-April (bloom through petal fall). Environmental data for the Merced Co. field site are shown in Fig. 1. Incidence of anthracnose blossom blight increased from 1.5% to 10.3% (3/15-4/11); whereas fruit rot increased from 1.2% to 14.2% (3/29-5/15) at this NePlus Ultra orchard (Fig. 2). In 2000, incidence of blossom and fruit anthracnose had increased from 10.8% to 29% and 0.9% to 28.6%, respectively, in this same orchard. This difference in disease incidence correlated with the amount of rainfall in both years. Total rainfall during the

spring was 7.78 in 2000, whereas in 2001 it was 4.46 in (Fig. 1). Leaf wetness occurred throughout the evaluation period in both years. Thus, rainfall was a more critical parameter for determining disease development than leaf wetness. As in the Merced Co. trial anthracnose incidence in the Butte Co. orchard was lower for blossoms and fruit in 2001 as compared to 2000 (Fig. 3). Disease data from these and previous years' trials will be used to describe disease progress curves and to model anthracnose of almond blossoms and fruit.

Epidemiology – Field and growth chamber evaluations of disease progress after inoculation and wetness/temperature relationships. The effects of wetness duration and temperature on disease development on almond leaves and blossoms (cv. NePlus Ultra, Wood Colony, Carmel, and Nonpareil) were evaluated in growth chamber and field inoculation studies. For inoculation, conidial suspensions (10^6 conidia/ml) of an isolate of the pink phenotype of *C. acutatum,* the most predominant strain in California orchards, were prepared from 14-day-old potato dextrose agar (PDA) cultures grown at 24 C. Viability of inoculum was determined by evaluating conidial germination on PDA. Leaves (the youngest 20 leaves of each branch) and blossoms of potted trees of each cultivar were inoculated on both surfaces using an air nozzle sprayer and were then exposed to different wetness durations (3, 24, 48 and 72 h) by bagging. Plants were incubated in growth chambers at selected temperatures (4, 10, 15, 20 C) during this time. Four days after inoculation, the trees were transferred to a greenhouse adjusted to 22 ± 2 C for the rest of the incubation period. Disease incidence was evaluated 10 to 14 days after inoculation on leaves as number of necrotic spots per leaf, and 5 to 7 days after inoculation on blossoms as percentage of infected blossoms.

Leaf lesions became apparent during the post-inoculation period of 10 to 14 days on leaves, and of 5 to 7 days on blossoms. The number of lesions did not increase after these periods. Results of these studies indicated that for both, leaves and blossoms, 10 C represents a critical threshold temperature for fungal infection (Figs. 4,5). Thus, below this temperature disease was infrequent and at very low levels, regardless of wetness duration. These data from experiments done under controlled conditions correspond well with field observations on fruit and blossoms in previous years. We had determined that an average threshold temperature of 15-16 C is required for development of the disease under fluctuating day/night springtime temperatures. Leaves and blossoms were influenced differently by wetness period duration. On leaves, the wetness duration represents a critical parameter for fungal infection (Figure 4). For example, long wetness periods of ca. 3 days and temperatures over 15 C, were required for high disease incidence in all almond cultivars studied. On blossoms, however, wetness duration was not as critical as temperature for infection. Disease developed at all wetness periods evaluated (Figure 2). Thus, in general, the slope of the relief surfaces was greater with increased wetness on leaves than on blossoms. Preliminary field studies indicated that the effect of wetness period on fruit is similar as for leaves. In addition, in these controlled-environment studies we have corroborated the results of previous field observations and inoculation studies regarding disease susceptibility of almond fruit of different cultivars. The relationship of wetness duration and temperature was similar for the different almond cultivars, however, disease severity was significantly different on the four cultivars. In defined environments of growth chamber studies, NePlus Ultra was the most susceptible variety to anthracnose on leaves. The number of lesions per leaf generally was 3- to 6-times higher on NePlus Ultra than that on Nonpareil for each wetness period evaluated from 10 to 20 C (Fig. 4). Nonpareil was the most resistant variety for both leaves and blossoms (Figures 4 and 5). Carmel and Wood Colony were intermediate in disease susceptibility as compared to Nonpareil and NePlus Ultra. Experiments done with detached fruit of almond cultivars Carmel, Sonora, and Nonpareil also corroborate the higher resistance for almond anthracnose of the cultivar Nonpareil.

In summary, the data generated from controlled environment and field studies show that different disease prediction models are required for different tissues (i.e. blossoms vs. leaves and fruit). Furthermore, although the relationship of wetness duration and temperature was similar for the different almond varieties, the magnitude of the severity of disease was significantly different. Thus, a scaling factor will be required for the predictive models for each variety.

Histological studies and time sequence studies of spore germination and germ tube differentiation on leaf and blossom tissues provide an explanation for the differences in wetness/temperature relationship described above for the two tissues. The absence or low number of lesions on leaves or blossoms at temperatures of 10 C or lower could be explained by the inability of conidia to form appressoria during the

wetness period duration provided. The different responses to wetness duration in both tissues also may be related to the structure of the tissue. It was observed that infection of leaves and blossoms is initiated from appressoria, however, on blossoms hyphae are also able to penetrate directly. Thus, the delicate blossom tissues did not restrict or delay the penetration process of the fungus as did the leaf tissues studied.

Comparative studies for the two genotypes of *C. acutatum* occurring in California were done in growth chamber experiments for leaves, and in laboratory studies for fruit. In growth chamber experiments, leaves of potted small trees of almond cultivars Wood Colony, Carmel, Nonpareil and NePlus Ultra were inoculated with both *C. acutatum* genotypes and incubated by following the procedure described above. In laboratory studies, the two genotypes of *C. acutatum* were evaluated for their virulence on detached fruits of cultivars Carmel, Sonora, and Nonpareil. Two different methods of inoculation were used: (1) air nozzle inoculation: a concentration of 10^6 spores/ml of *C. acutatum* fruit was sprayed onto the fruit using an air nozzle sprayer, and (2) drop inoculation of injured fruit: fruit was punctured with a lancet in the center of its upper surface and a 10-µl drop of a spore suspension of 10^6 spores/ml was placed on it. After inoculation, fruits were placed in plastic boxes under high relative humidity (> 95%) at selected temperatures (4, 10, 15, 20, 25 and 30 C). Disease incidence was evaluated 2 weeks after inoculation. Spray-inoculated fruit was rated according to the percentage of fruit surface infected (0 = no disease fruit, 1 = 1 to 25 %, 2= 26% to 50%, 3 =51% to 75% and 4 = 75 to 100%). In wound-inoculated fruit, the disease rating was based on lesion diameter on the fruit.

Results of these studies indicated that the wetness/temperature relationships for anthracnose development on leaves were similar for both strains. The pink genotype, however, was more virulent at temperatures over 15 C and caused a higher disease severity on leaves and fruits than the gray genotype. Thus, our predictive models will be developed for the pink strain as a worst-case scenario. In addition, experiments on detached fruit of almond cultivars Carmel, Sonora, and Nonpareil also corroborate the higher resistance for almond anthracnose of the cultivar Nonpareil.

Histological studies. Studies to evaluate the initial infection process and the formation of quiescent infections by *C. acutatum* were done on attached and detached leaves and detached blossoms (petals) of cultivar Carmel. Detached blossoms and attached or detached leaves of plants grown in the greenhouse were inoculated with 10-µl droplets of a conidial suspension that was prepared as described above. Inoculum droplets were placed 5 mm apart on the upper surface of the petals and the lower surface of the leaves. Detached blossoms and leaves were incubated in a parafilm-sealed Petri dish. For inoculation of attached leaves, the Petri dishes were attached to the branch, providing closed incubation chambers. Experiments were done at selected temperatures of 10, 15, and 20 C. Samples were obtained 0.5 h, 3 h, 6 h, 12 h, 24 h, 36 h, 48 h, and 72 h after inoculation by excising 5 x 5 mm leaf pieces from the inoculated tissues. The percentage of germinating conidia, appressoria, and melanized appressoria was assessed by counting at least 300 conidia in randomly chosen objective fields (observations at 400 x). A conidium with a germ tube of at least the length of one conidium width was assessed as germinated. The percentage of germination was assessed as the percentage of germinated conidia of total conidia present in the sample. The percentage of appressoria was calculated as the percentage of appressoria of the number of germinated conidia. The percentage of melanized appressoria was assessed as the number of dark-brown, rounded appressoria of the total number of appressoria.

For direct observation of conidial germination and appressorium formation using bright field microscopy, samples were cleared in saturated chloral hydrate for at least 24 h. For microscopic observation samples were washed in distilled water, stained with 0.05 % acid fuchsin for 2 min, washed in distilled water, and mounted on glass-slides. For embedding and sectioning of tissues to evaluate fungal penetration and colonization, samples were fixed for four hours in glutaraldehyde (2.5 % v/v) in 0.05 M phosphate buffer (pH 6.8) at room temperature, rinsed (3 x 15 min) in 0.05 M phosphate buffer (pH 6.8), dehydrated in a graded ethanol series (10%, 35%, 50%, 70%, 80%, 95%) (3 x 5 min), and embedded in JB-4™ embedding medium (Polysciences, Inc.). Transverse sections ca. 3 µm thick were obtained with a rotatory microtome. The sections were stained for 2 min in 0.05 % acid fuchsin, washed in distilled water, and mounted on glass-slides for light microscopy.

The penetration process was analyzed using the program Syncroscopy-Automontage® (Microbiology International). This software combines the in-focus regions from a series of sequential images

taken of a sample, each at a different point of focus, to generate a single montage image of, for example an appressorium, which is completely in focus. Individual images at step-wise focus intervals of ca. 1 µm were captured by using a digital camera (Sony DKC-5000) and the computer grabber of the program Adobe-Photoshop®. The montage images were obtained by applying the scan-montage option of the software Syncroscopy-Automontage® to the source images. This software can also generate 3D-representations of the sample and make measurements. This allows qualitative analysis of the montage image by generating a color-relief image or a depth map, and the quantification of the depth-relief of an area of interest. We tested this image-analysis software for its application to light micrographs of the penetration process of *C. acutatum* on almond tissues.

Similar observations were made on attached and detached leaves. We observed that infection of leaves and blossoms occurs from appressoria, but on blossoms hyphae can also penetrate directly. Thus, this information provides an explanation for the differences in wetness/temperature relationships described above for blossoms and leaves. Apparently, the delicate blossom tissues do not restrict or delay the penetration process of the fungus as do leaf or fruit tissues. Our observations indicated that conidia germination of *C. acutatum* was similar on both leaves and blossom surfaces for all temperatures tested. At 20 C, conidia started germinating ca. 3 h after inoculation. Differentiation of the germ tube into appressoria began ca. 6 h after inoculation, however, the majority of appressoria do not complete melanization until ca. 12 h after inoculation. This sequence of development was drastically slowed down when tissues were incubated at 10 C. At this temperature, germination started 24 to 48 h after inoculation, and melanization of appressoria did not begin until at least 72 h after inoculation. The percentage of germ tubes differentiating into appressoria was higher on leaves than on blossoms. On leaves at 20 C, 99 % of the conidia formed appressoria 12 h after inoculation, whereas on petals, it was only 50 %. Leaf cross-sections showed that hyphal penetration and formation of an infection vesicle developed 24 h after inoculation. Penetration hyphae developing from the appressoria swelled and formed infection vesicles and broad primary hyphae, which grew intracellularly. During this stage the fungus stayed in a biotrophic stage and the protoplast of the epidermal cells did not seem to be affected. After this, the primary hyphae progressively colonized new epidermal cells. By 72 h after inoculation narrow secondary hyphae developed that reached the mesophyll cells. At this point, the biotrophic stage seemed to shift into a necrotrophic stage and some host cells were killed. By 96 h after inoculation disease symptoms became visible macroscopically as a water-soaked areas that ca. 10 days after inoculation turned necrotic. These symptoms were similar to those typically observed on leaves in the field. Microscopic observations of the lesions showed that the fungus developed profusely in this area.

In petal tissue, intracellular colonization was observed. Infection vesicles arising from appressoria could be observed directly (without tissue clearing) 24 h after inoculation. 3D-color relief image and line profile analysis of inoculated petal tissue indicated that the infection vesicles developed intracellularly within epidermal cells. In addition, intramural colonization from hyphae that directly penetrated petal tissue was observed.

Thus, a combined study using classical histological methods and a new software for image analysis, Syncroscopy®-Automontage®, has allowed us to determine that the almond anthracnose fungus colonizes its host intracellularly and undergoes a biotrophic phase, i.e. quiescent infection. The length of this phase is variable and temperature-dependent. For example, at 20 C, this stage is very short with 3-4 days on leaves, and only 1 day on blossoms. At 10 C it may last several weeks on leaves and at least one week on blossoms. Thus, certain combinations of wetness period durations and temperature appear to be conducive for infections but not for subsequent disease development. We are currently investigating the factors that determine the switch from the biotrophic (i.e., living) phase to a necrotrophic (i.e., killing) phase that eventually leads to symptom development. Preliminary studies indicate that inoculum levels, water stress, and or/and carbohydrate depletion are some factors that may be involved in this change in the plant-parasite interaction. (i.e., biotrophic to necrotrophic). For example, we have found that wetness period duration was related to an incremental increase in the number of appressoria formed. Therefore, wetness duration may be critical for disease development because it allows for a critical number of individual infections (i.e. threshold) to occur that are required for disease manifestation. This information on the developmental biology of the pathogen is valuable for developing suitable strategies of management of the disease. A model to predict infection periods and to improve timing of fungicide applications is currently being developed

based on the biology of the fungus, the disease progress curves in the field, and disease development under defined growth chamber conditions. The model focuses on leaf and fruit infections and will likely have rain, wetness period, temperature, and degree-day parameters to predict disease on one of the most susceptible varieties, NePlus Ultra.

Detection of anthracnose in almond orchards as a preharvest management tool using molecular assays. In 1999 and 2000, we reported that a protein or ELISA assay had an accuracy of 83% for correctly identifying *Colletotrichum*-infected tissues, assuming that the standard isolation method of growing the fungus from plant tissue was 100% accurate. In 2001, we continued to evaluate the ELISA system in cooperation with John Edstrom, Roger Duncan, and Joe Connell. Low levels of disease throughout the state resulted in only a few samples that were evaluated. In general, the method was accurate and correlated with isolation data. The practicality of the assay may require additional lab help for farm advisors or for private labs to be involved.

Fungicide evaluations for management of anthracnose. In 2001, fungicides registered for anthracnose control included Captan, Abound, Laredo, and Rally. Fungicides that were evaluated in field trials either alone or in mixtures or rotations were: Abound (azoxystrobin), Flint (trifloxystrobin), Rally (myclobutanil), Laredo (an EC formulation of myclobutanil), Captan (captan), Ziram (ziram), and the experimental compounds BAS500 and BAS516. In all trials, fungicides were applied using air-blast sprayer at a rate of 100 gal/A. Data were analyzed using an analysis of variance and treatment mean values were separated using least significant mean separation procedures of SAS 6.12.

In a comparative evaluation of single-fungicide treatments (5 applications for each fungicide in approximately 2-week intervals from mid-February to mid-April), all fungicides including the experimental compounds BAS500 and BAS516 significantly reduced the disease incidence as compared to the control (Table 1). Furthermore, there was no difference between the fungicides. There was also no difference for the two rates of Flint evaluated (2 oz and 3 oz). For Laredo, however, the higher rate (12.8 fl oz vs. 8 oz.) had to be used. Numerically, disease incidence after BAS516 applications was lower as compared to BAS500. In a fungicide mixture program using Laredo/Captan, Laredo/Ziram, Abound/Captan, or Abound/Ziram, disease was reduced from 4.6% in the control to 1.6-0% (Table 2). The mixtures containing Captan were more effective (Laredo/Captan significantly, Abound/Captan numerically) than those containing Ziram. In another trial, however, there was no difference between Laredo/Captan and Laredo/Ziram applications and disease was reduced from 6.2% in the control to zero levels (Table 3). Similarly, rotations between Abound and Captan or Abound and Ziram both reduced the disease to zero levels (Table 3). In another trial that included fungicide programs with mixtures and rotations of Abound and Captan, Flint and Captan, or BAS516 and Captan, all programs significantly decreased disease incidence as compared to the untreated control (Table 4). One of the programs using Flint and Captan was the most effective treatment, reducing incidence of blight from 4.7% to 0%.

Fungicide evaluations for management of brown rot blossom blight and shot hole. Fungicides evaluated in field trials using three applications (at pink bud, full bloom, and petal fall) for control of blossom blight included: Scala (pyrimethanil), Vangard (cyprodonil), Abound (azoxystrobin), Flint (trifloxystrobin), Elevate (fenhexamid), Laredo (myclobutanil), Rovral (iprodione), BAS500, and BAS516. As described above, fungicides were applied using air-blast sprayer at a rate of 100 gal/A. All treatments had five single tree replications. Data were analyzed using an analysis of variance and treatment mean values were separated using least significant mean separation procedures of SAS 6.12.

In this trial, applications of any of these fungicides were efficacious (Table 5). The most effective treatments were Vangard, Scala, and BAS516, reducing blight incidence from 13.4% in the control to 1.8% or less. For control of shothole, the same fungicides were evaluated using three applications (petal fall, shuck split, and 5 wk after petal fall. These treatments significantly reduced the incidence of disease from that of the control (Table 6) but they were more suppressive than preventative.

In a yield study on Nonpareil and Price almond, four applications of Elevate were compared to a standard two-application program with Rovral or Captan. In this study there were four replications of approximately 14 trees per replication. Gross weights and kernel weight for a 4 lb sub-sample were determined for each replication. No significant differences in yield were found based on kernel weight.

Fig. 1. Disease progress curves for anthracnose on NePlus Ultra almond blossom and fruit in Cortez, Merced Co., CA, 2000-2001

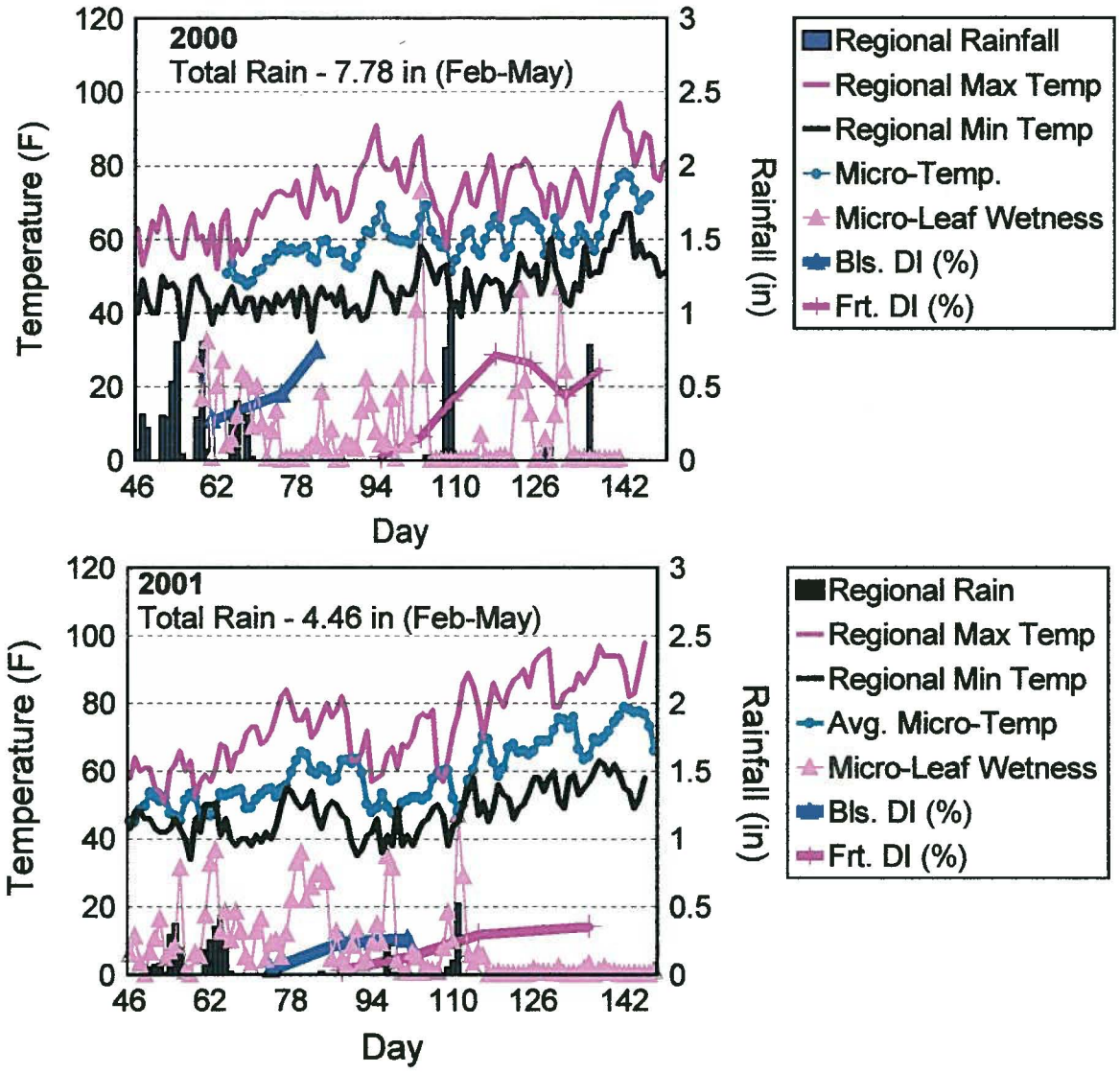


Fig. 2. Disease progress curve for anthracnose on NePlus Ultra almond fruit in Cortez, CA, 2000-2001

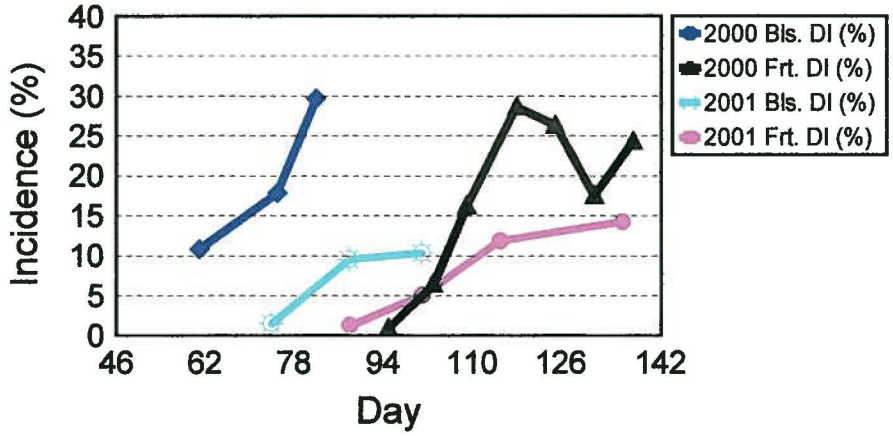


Fig. 3. Disease progress curves for anthracnose on NePlus Ultra almond fruit in Butte Co., CA, 2000-2001

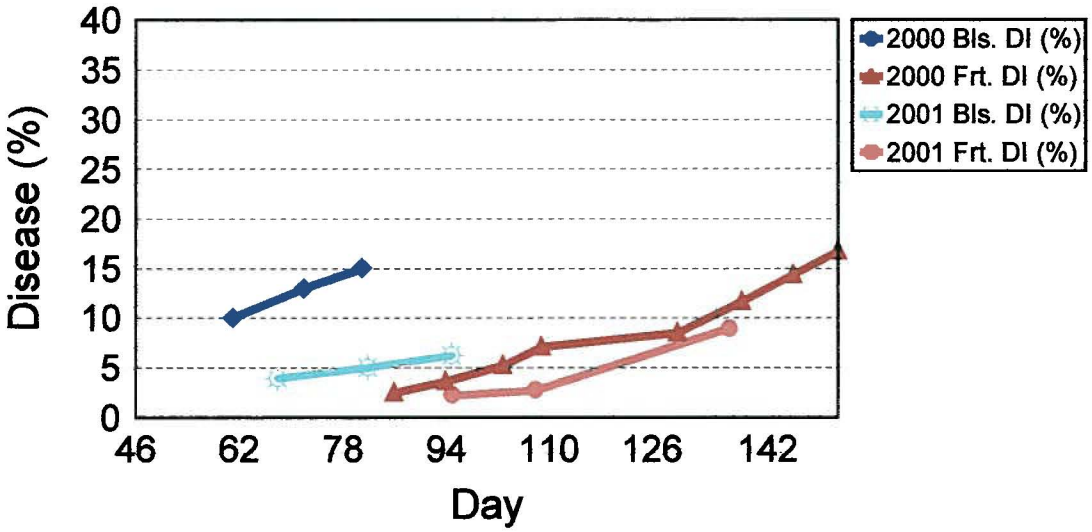


Figure 4.

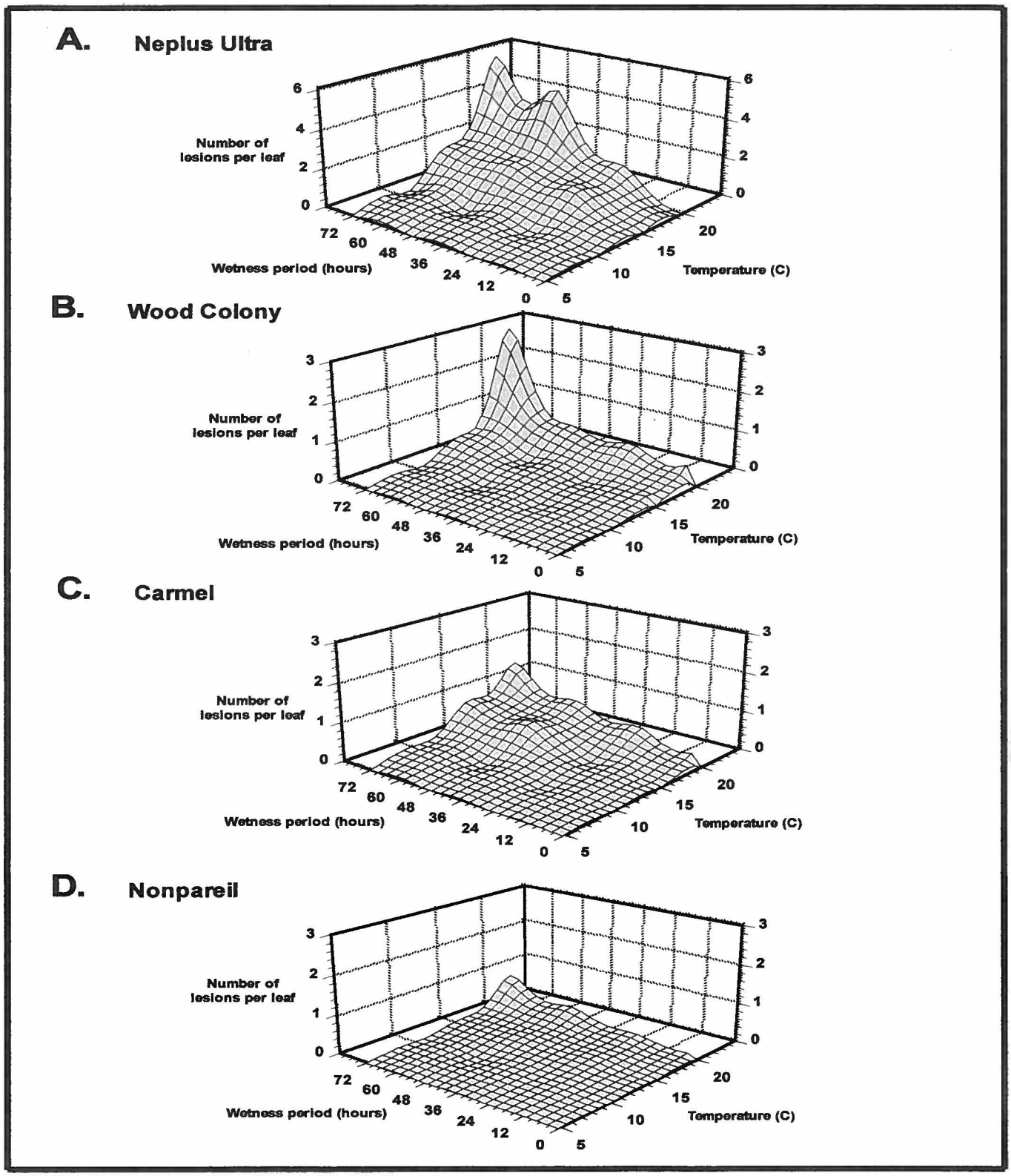


Figure 4. Response surface graphs of anthracnose disease severity on leaves of four almond cultivars under defined combinations of wetness period duration and temperature.

Figure 5.

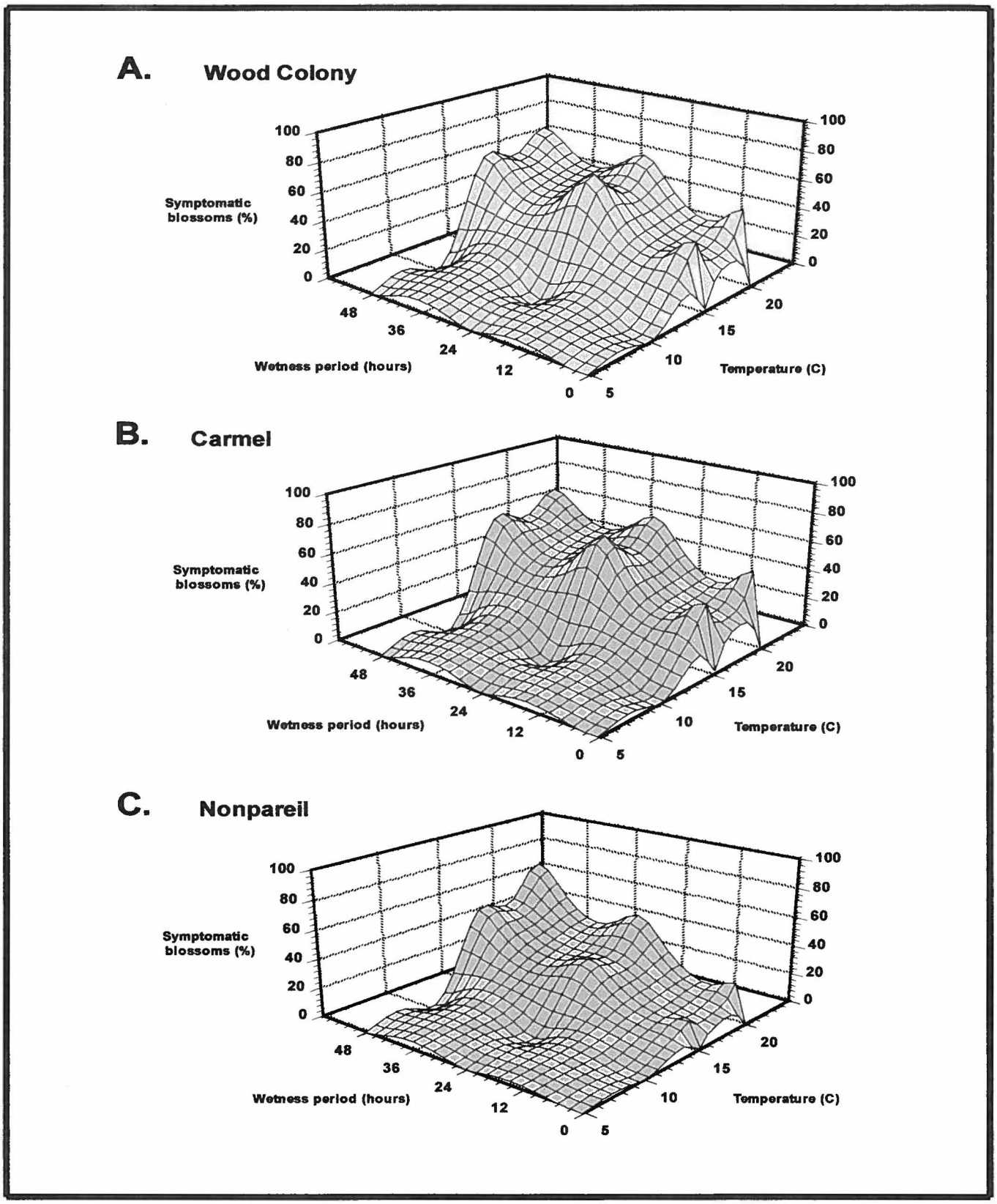


Figure 5. Response surface graphs of anthracnose disease severity on blossoms of three almond cultivars under defined combinations of wetness period duration and temperature.

Table 1. Efficacy of fungicide treatments for management of anthracnose on almond cv. Price in the spring of 2001.

No.	Treatment*	Formulation	Product Rate (/A)	Incidence** fruit anthracnose	LSD
1	Laredo	2F	12.8 oz	3.8	bc
2	Laredo	2F	8 oz	6.3	ab
3	BAS500	20%	9.5 oz	3.8	bc
4	BAS516	38%	0.658 lb	2.3	c
5	BAS516	38%	0.92 lb	2.5	bc
6	Flint	50WDG	3 oz	2.3	c
7	Flint	50WDG	2 oz	3.8	bc
8	Abound	2F	12.8 fl oz	2.5	c
9	Check	---	---	9.3	a

* - Treatments were applied using an air-blast sprayer (100gal/A) at full bloom (3/1), petal fall (3/8), shuck split (3/22), and 5 (4/5) and 7 weeks (4/18) after petal fall.
** - Evaluations on 5/3 were based on 100 fruit for each of 4 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 2. Efficacy of fungicide mixtures for management of anthracnose on almond cv. NePlus Ultra in 2001.

			Date and Stage					Incidence	
Program	Treatments*	Rate	PB	FB	3/8 PF	3/22 SS	4/5 5-wk	fruit anthracnose	LSD
1	Laredo	12.8 fl oz	Van	Van	@	@	@	0.0	d
	Captan 50WP	6 lbs			@	@	@		
2	Laredo	12.8 fl oz	Van	Van	@	@	@	1.6	b
	Ziram 75DF	8 lbs			@	@	@		
3	Abound 2F	12.8 fl oz	Van	Van	@	@	@	0.4	cd
	Captan 50WP	9 lbs			@	@	@		
4	Abound 2F	12.5 fl oz	Van	Van	@	@	@	1.2	bc
	Ziram 75DF	8 lbs			@	@	@		
5	Check	---	Van	Van	---	---	---	4.6	a

* - Aerial applications with Vangard were applied at pink bud and full bloom on all treatments by the grower. The subsequent treatments were applied using an air-blast sprayer (100gal/A) at petal fall, shuck split, and 5 weeks after petal fall.
** - Evaluations were based on 400 fruit on 4/18 for each of 4 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 3. Efficacy of fungicide rotation programs for management of anthracnose on almond cv. NePlus Ultra in 2001

			Developmental stage at treatment						Incidence** fruit	
Program	Treatments	Rate	PB	FB	PF	SS	5-wk	7-wk	anthracnose	LSD
1	Laredo +	10 fl oz	Van	Van	@	@	@	@	0	b
	Captan	6 lbs								
2	Laredo +	10 fl oz	Van	Van	@	@	@	@	0	b
	Ziram	8 lbs								
3	Abound	12.5 fl oz	Van	Van	@				0	b
	Captan	9 lbs				@				
	Abound	12.5 fl oz					@			
	Captan	9 lbs						@		
4	Abound	12.5 fl oz	Van	Van	@				0	b
	Ziram	8 lbs				@				
	Abound	12.5 fl oz					@			
	Ziram	8 lbs						@		
5	Check	---	Van	Van	---	---		---	6.2	a

* - Aerial applications with Vangard were applied at pink bud and full bloom on all treatments by the grower. Subsequent treatments were applied using an air-blast sprayer (100gal/A) at petal fall, shuck split, and 5 and 7 weeks after petal fall.

** - Evaluations were based on 400 fruit on 5/4 for each of 4 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. Efficacy of fungicide rotation programs for management of anthracnose on almond cv. NePlus Ultra in 2001

				Date						Incidence fruit	
				2/13	2/23	3/7	3/29	4/12			
Program	Treatment*	Formulation	Prod/Acre	PB	FB	PF	SS	5th	6th	anthracnose	LSD
1	Abound	2F	15 fl oz	@	@		@		@	0.25	bc
	Captan	50WP	9 lbs			@		@			
2	Abound	2F	15 oz/12.8 fl oz	@	@	@	@	@	@	0.75	bc
	Captan	50WP	9 lbs/6 lbs			@	@	@	@		
3	Flint	50WDG	3 oz	@	@		@		@	1	b
	Captan	50WP	9 lbs			@		@			
4	Flint	50WDG	3 oz/2 oz	@	@	@	@	@	@	0	c
	Captan	50WP	9 lbs/6 lbs			@	@	@	@		
5	BAS516	38%	0.92 lb	@	@		@		@	0.25	bc
	Captan	50WP	9 lbs			@		@			
6	Check	---	---	---	---	---	---	---	---	4.7	a

* - Treatments were applied using an air-blast sprayer (100gal/A) at pink bud, full bloom, petal fall, shuck split, and 5 weeks after petal fall.

** - Evaluations were based on 100 fruit on 4/25 for each of 4 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 5. Efficacy of a bloom fungicide program for management of brown rot blossom blight of Drake almonds at the UC Davis experimental orchard.

Treatment*	Formulation	Product Rate (/A)	Application Dates: Pink Bud (2/19)	Full Bloom (2/28)	Petal Fall (3/6)	Brown rot strikes: Incid. (%)	LSD
Laredo	2EC	8 oz	@	@	@	4.6	b
Laredo	2EC	12.8 oz	@	@	@	3.6	bc
Elevate	50WG	1.5 lb	@	@	@	6.4	b
Abound	2F	12.8 oz	@	@	@	3.2	bc
Scala	40F	0.54 lb ai	@	@	@	2.4	bcd
Scala	40F	0.71 lb ai	@	@	@	0	d
Flint	50WDG	3 oz	@	@	@	4.6	b
Vangard	75WG	10 oz	@	@	@	1.8	bcd
BAS500	20%	9.5 oz	@	@	@	3.6	bc
BAS516	38%	0.25 lb	@	@	@	1	cd
BAS516	38%	0.35 lb	@	@	@	2.2	bcd
Rovral	4F	16 oz	@	@	@	2.6	bcd
Check	---	---	---	---	---	13.4	a

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

** - Incidence of disease based on 100 shoot samples 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 ($P > 0.05$).
LSD mean separation ($P > 0.05$).

Table 6. Efficacy of a bloom fungicide program for management of shothole of Drake almond fruit at the UC Davis experimental orchard.

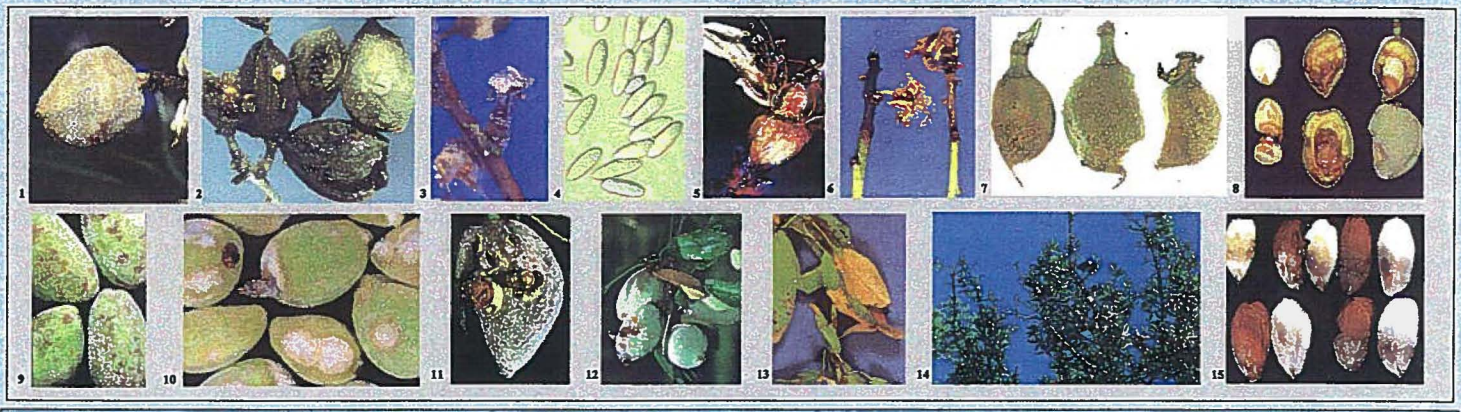
Treatment	Formulation	Prod/Acre	Application Dates: Petal Fall	Shuck Split	5-wk-after Petal Fall -	Shothole on Fruit: Incid. (%)	LSD
Laredo	2EC	8 oz	@	@	@	3.5	b
Laredo	2EC	12.8 oz	@	@	@	4.9	b
Elevate	50WG	1.5 lb	@	@	@	5.6	b
Abound	2F	12.8 oz	@	@	@	6.4	b
Scala	40F	0.54 lb ai	@	@	@	5.2	b
Scala	40F	0.71 lb ai	@	@	@	4.5	b
Flint	50WDG	3 oz	@	@	@	5.1	b
Vangard	75WG	10 oz	@	@	@	5.6	b
BAS500	20%	9.5 oz	@	@	@	4.4	b
BAS516	38%	0.66 lb	@	@	@	4.7	b
BAS516	38%	0.92 lb	@	@	@	5.5	b
Rovral	4F	16 oz	@	@	@	6.1	b
Check	---	---	---	---	---	13.9	a

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

** - Incidence of disease based on a 25-fruit sample 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 ($P > 0.05$).

Almond anthracnose and its management in California

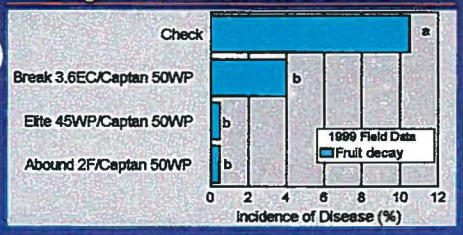
J. E. Adaskaveg, H. Förster, and D. Thompson, Department of Plant Pathology, University of California, Riverside
UCCE cooperators: J. H. Connell (Butte Co.), J. Edstrom (Colusa Co.), R. Duncan (Stanislaus Co.), and M. Freeman (Fresno Co.)



Disease symptoms: 1) Fruit mummy with dried gum drops in fall season; 2) Overwintered, mummified fruit that tested positive for the pathogen; 3) Infected peduncles with pink sporulation of the pathogen; 4) Conidia (spores) of *C. acutatum*, 5) Blighted blossom with pink sporulation on flower cup; 6) Infected blossoms and spurs; 7) Infected fruitlets with orangish sunken lesions; 8) Internal symptoms of fruit and kernels; 9 &10) Quiescent infections on detached mature almond fruit, in Fig. 10 active decay develops after incubation; 11 &12) Symptoms on mature fruit; 13) Leaf symptoms; 14) Dieback of branches; and 15) Symptoms on harvested kernels.

Fungicide trials in 1999 and 2000

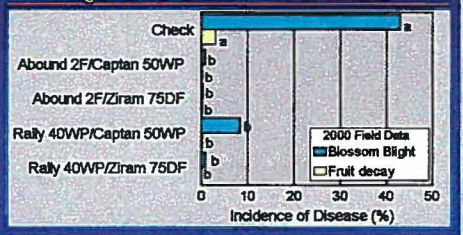
Efficacy of selected fungicide rotations for management of anthracnose of almond



Fungicides were applied using an air-blast sprayer at pink bud, full bloom, petal fall, shuck split, 5- and 8-wk after petal fall on NePlus almonds

1999

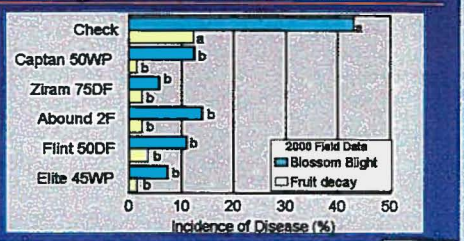
Efficacy of selected fungicide rotations for management of anthracnose of almond



Fungicides were applied using an air-blast sprayer at pink bud, full bloom, petal fall, shuck split, 5- and 8-wk after petal fall on NePlus almonds

2000

Efficacy of selected new fungicides for management of anthracnose of almond



Fungicides were applied using an air-blast sprayer at pink bud, full bloom, petal fall, shuck split, and 5-wk after petal fall on Price almonds

2000

Fungicide trials in 2001

Eficacy of fungicide rotations for management of anthracnose on almond cv. NePlus Ultra in 2001

Treatment	PB	FB	PF	SS	5 wk	Disease Incidence (%)
Abound 2F 15 fl oz	@	@				
Captan 50WP 9 lb			@		@	bc
Abound 2F 15 oz/12.8 fl oz	@	@	@	@	@	
Captan 50WP 9 lb/6 lb			@	@	@	bc
Flint 50WDG 3 oz	@	@		@		
Captan 50WP 9 lb			@		@	b
Flint 50WDG 3 oz/2 oz	@	@	@	@	@	
Captan 50WP 9 lb/6 lb			@	@	@	c
BAS516 38% 0.92 lb	@	@		@		
Captan 50WP 9 lb			@		@	bc
Control	—	—	—	—	—	a

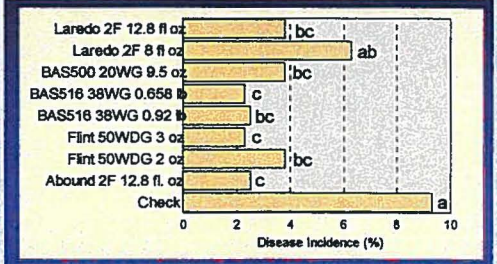
PB = pink bud; FB = full bloom; SS = shuck split; 5-wk = 5 weeks after petal fall

Eficacy of fungicide mixtures for management of anthracnose on almond cv. NePlus Ultra in 2001

Treatments*	EPB	PB	FB	PF	SS	5-wk	Disease Incidence (%)
Laredo EC 12. 8 fl oz	Van	Van	@	@	@	@	
Captan 50WP 6 lb			@	@	@	@	d
Laredo EC 12. 8 fl oz	Van	Van	@	@	@	@	
Ziram 75DF 8 lb			@	@	@	@	b
Abound 2F 12.8 fl oz	Van	Van	@	@	@	@	
Captan 50WP 9 lb			@	@	@	@	cd
Abound 2F 12.8 fl oz	Van	Van	@	@	@	@	
Ziram 75DF 8 lb			@	@	@	@	bc
Check	Van	Van	—	—	—	—	a

Acronyms: EPB = early pink bud; PB = pink bud; FB = full bloom; SS = shuck split; 5-wk = 5 weeks after petal fall.

Eficacy of new and registered fungicides for manageme of anthracnose on almond cv. Price in 2001

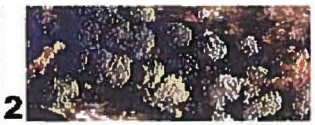
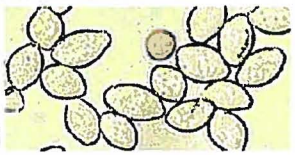


Fungicides were applied at full bloom, petal fall, shuck split, and 5 and 7 weeks after petal fall.

Management of brown rot blossom blight of almond in California

J.E. Adaskaveg, H. Forster, and D. Thompson, University of California, Riverside
Cooperating: J. H. Connell, J. Edstrom, and M. Freeman, UCCE, Butte, Colusa, and Fresno Co., respectively.

Brown rot blossom blight is caused by the fungi *Monilinia laxa* and *M. fructicola* and is one of the most important diseases of almond in California. We continued our research by evaluating the newest fungicides available including those considered "reduced risk" by the US-EPA. "Reduced risk" fungicides increase the adoption of IPM practices or show: 1) Reduced toxicity to non-target organisms; 2) Have low environmental persistence; or 3) Are safer to consumers and workers. Currently, Abound, Vangard, Flint, Elevate, BAS500, and BAS516 are reduced risk fungicides.

1 2 3 4 5

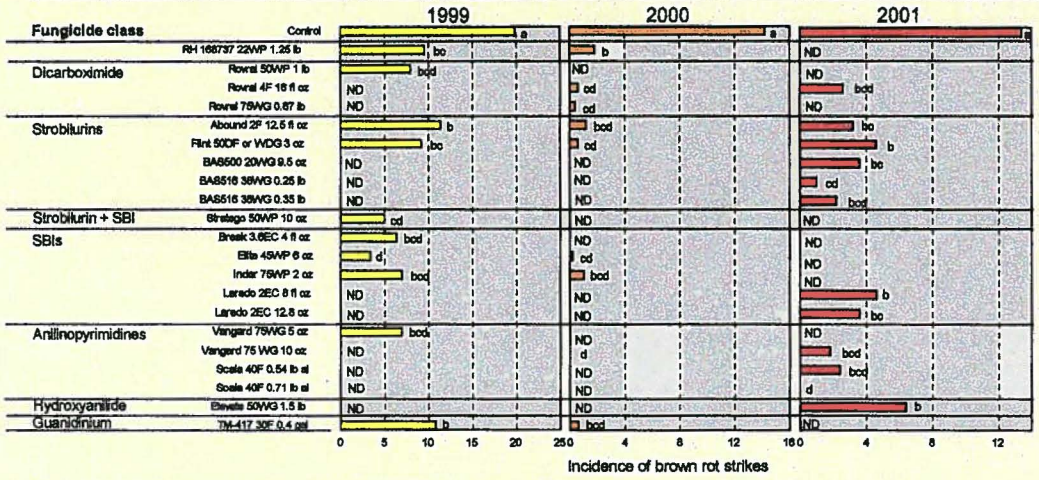
Brown rot blossom blight of almond: 1) Sporodochia or spore pads of *Monilinia* sporulating on previous season's dead blossoms as new blossoms emerge in the spring; 2) Close-up of spore pads where conidia are produced and disseminated by wind or rain to blossoms; 3) Close-up of conidia; 4) Pink-bud (5% bloom); and 5) Blighted blossom (upper left) and twig infection.

Relative efficacy of selected fungicides for management of spring-time foliar diseases of almond.

Fungicides	Class	Mode of Action	Efficacy: Brown Rot	Jacket Rot	Anthracnose	Shothole	Scab	Rust
Ziram	Dithiocarbamate	Multiple	+	+	++	+++	++	?
Captan	Phthalimide	Multiple	++	++	++	+++	+++	+
Topsin-M	Benzimidazole	Single	+++	+++	-	-	+++	++
Rovral	Dicarboximide	Multiple	+++	+++	-	+++	-	-
Break*	SBI	Single	+++	-	++	+	-	++
Elite*	SBI	Single	+++	+	+++	+	-	+++
Rally, Laredo	SBI	Single	++	-	++	+	-	?
Abound	Strobilurin	Single	++	-	+++	+++	+++	+++
Flint*	Strobilurin	Single	++	-	+++	+++	+++	?
Vangard	Anilinopyrimidine	Single	+++	+++	-	++	?	?
Elevate	Hydroxyanilide	Single	++	+++	-	+	-	-

* = not registered on almond
Fungicides selected are representative of fungicides registered or planned for registration.
Ratings: +++ = Best; ++ = Good; + = Fair; - = Not effective; and ? = not evaluated.

Efficacy of blossom fungicide treatments for management of brown rot blossom blight of Drake almond at the UC Davis orchard



Treatments were applied using an air-blast sprayer at a rate of 100 gal/A at pink bud, full bloom, and petal fall (1999 at pink bud and full bloom only). Incidence was based on the number of infected spurs per 100 counted per replication. Bars with different letters are significantly different based on an analysis of variance. ND= not done.

Because of concerns about the effects of new fungicide chemistries on almond, a yield study was done with fenhexamid (Elevate 50WG) on Price and Nonpareil in Merced Co. No statistical difference in yield (kernel dry weight) was measured in trees treated with 4 applications of Elevate (1.5 lb/A/appl.) or 2 applications of Rovral and Captan.