Epidemiology and Control of Alternaria Leaf Spot

Project No.: **10-PATH3-Adaskaveg**

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Objectives:

I. Etiology
   A. Identify pathogenic species of *Alternaria* using molecular methods.
   B. Determine the pathogen species composition within selected orchards. This objective is contingent on the development of molecular methods for identification of the pathogens.

II. Management
   A. Evaluate new and registered fungicides for their efficacy in managing Alternaria leaf spot. Fungicides to be evaluated include non-QoI fungicides (e.g., fluopyram - Luna Privilege, metconazole - Quash, difenoconazole - Inspire, polyoxin-D - Ph-D, chlorothalonil – Bravo and efficacy will be compared to QoI fungicides (e.g., Pristine, Luna Sensation, BAS703).
      i. Small-scale trials – all materials listed above
      ii. Large-scale trials – registered materials (i.e., Inspire, Quash, Ph-D) alone and in mixtures at high and low application volumes
      iii. Evaluate rotation programs of different fungicide chemistries
   B. Establish baseline sensitivities and monitor for shifts in sensitivity in populations of *Alternaria* spp. to SDHIs (carboxamides and benzamides such as fluxopyroxad), DMIs, polyoxin-D, and QoIs.
   C. Evaluation of natural products and organic experimental materials as treatments against Alternaria leaf spot with direct activity against the pathogen (e.g., the organic formulation of Ph-D), treatments that change the leaf microflora (e.g., biocontrol agents), or that change the pH of the host tissue (these treatments may also change the microclimate of the leaf surface).
   D. Use the DSV model with defined parameters for forecasting infection periods of the disease and timing of fungicide treatments as compared to calendar programs.

Interpretive Summary:
(Note-This report is based on our 2010 data because our 2011 project is ongoing. Goals and plans for the 2011 season are discussed).

Alternaria leaf spot of almond caused by three very closely related species in the *Alternaria alternata* complex (*A. arborescens*, *A. alternata*, and *A*. *tenuissima* occurs mostly in the southern and northern production regions of California but continues to spread into new areas. Severe outbreaks occur in areas with dew, stagnant air, and where temperatures are high during the summer months. The disease can also be severe in high-density plantings or in orchards with soils with inadequate drainage and where trees require frequent and extended irrigations into the summer. Under favorable conditions for disease development, trees can be completely defoliated by early to mid-summer. Because Alternaria leaf spot is greatly influenced by microclimatic conditions such as temperature and wetness within orchards, we previously successfully modified the Disease Severity Value (DSV) model to predict infection periods and to time fungicide treatments.

Resistance to the single-site mode of action QoI and SDHI (i.e., boscalid) fungicides in populations of *Alternaria* spp. is now widespread throughout California. With this, some of the previously most effective fungicides such as azoxystrobin (Abound), trifloxystrobin (Gem), and pyraclostrobin-boscalid (Pristine) cannot be used anymore effectively. Thus, in 2010 we continued our evaluations on new treatments and their best usage pattern, and we worked with the agrochemical industry and regulatory agencies toward the registration of new effective materials of different modes of action. Three-spray programs with polyoxin-D (Ph-D), the DMIs metconazole (Quash) and difenoconazole (Inspire), as well as mixtures of these two classes were again the most effective in reducing the incidence and severity of Alternaria leaf blight as well as tree defoliation. Through our research, Ph-D (Arysta Life Science) has received federal registration as a biopesticide, was exempted from tolerance in 2009 for a number of crops including almond, and is registered as of April 2010. Metconazole (Quash) was registered directly by Valent USA Corp. Agricultural Products; whereas difenoconazole (Inspire, Syngenta Crop Protection) was registered through the IR-4 specialty crop pesticide registration program. Effective pre-mixtures in 2010 included Adament, Luna Sensation, Quadris Top, and Quilt Excel. These latter products, however, all have a QoI component, and thus, they will exacerbate QoI resistance. Chlorothalonil (Bravo, Echo, Equus) that was also effective in our 2010 field studies was recommended and accepted into the IR-4 program for extended usage into the spring season (change of the current preharvest interval of 150 days to 60 days). Expected registration with a new label is 2013. This multi-site mode of action fungicide will be an important component in management programs and may prevent the over-use of DMIs and provide an alternative to QoIs and SDHIs where resistance is present.

Materials and Methods:

The DSV model for predicting infection periods and timing fungicide applications. The original DSV model was developed for predicting black mold of tomato caused by *Alternaria alternata*. In our studies, we used data from weather monitoring systems to summarize data collected from almond orchards including different sites where fungicide efficacy trials were conducted over numerous years. Temperature-leaf wetness data were summarized daily and

plotted as daily values, a 7-day index (incremental addition and removal of newest and oldest daily values in a 7-day increment), and a seasonal accumulation. Forecasting of the disease was based on these parameters and actual disease progress was evaluated and compared in each year of the study. This model is used in each year of our studies to determine the initial spring application and subsequent infection periods.

Fungicide evaluations for management of Alternaria leaf spot of almond in 2010. Three trials were established: two trials in Colusa Co. (cvs. Carmel and Fritz) and one in Kern Co. (cv. Monterey). For the Colusa Co. trials, three-spray treatment programs started on 4-29-10 (cv. Carmel) with subsequent applications on 5-18 and 6-15-10 or on 5-20-10 (cv. Fritz) with subsequent applications on 6-10 and 6-29-10. In the Kern Co. trial, treatments started on 5-19-10 (which was after the first infection period as predicted by the DSV model). Subsequent treatments in this plot were done on 6-9 and 6-30-10.

Treatments included QoIs by themselves (Abound, Gem) or in pre-mixtures with a SDHI (i.e., Pristine, Luna Sensation) or a DMI fungicide (i.e., Adament, Quilt Excel, Quadris Top); DMI fungicides (i.e., Inspire, Tilt, Quash); a pre-mixture of a DMI with an AP (Inspire Super); a pre-mixture of two DMIs (Inspire XT); chlorothalonil (Bravo); the chitin inhibitor polyoxin-D (i.e., Ph-D, also in the organic formulation), mixtures of Bravo plus Inspire, Ph-D plus Quash, Ph-D plus Inspire Super, or Inspire Super plus Prophyt ; as well as various rotations. Additionally, in the Kern Co. trial a mixture of Ph-D and Moisturin was evaluated. Moisturin is an antitranspirant and thus, potentially could reduce relative humidity in the orchard and make environmental conditions less favorable for Alternaria leaf spot. Evaluations were done between late August and late September. For disease evaluation in the field, trees were rated for defoliation based on a scale from 0 (= no defoliation) to 4 (= more than 75% of the leaves had fallen). Approximately 100 leaves from each of four single-tree replications were evaluated for incidence (% leaves infected of the total number of leaves) and severity (number of lesions per leaf).

Results and Discussion:

DSV model for predicting infection periods and timing fungicide applications. Alternaria leaf spot of almond is greatly influenced by microclimatic conditions such as temperature and wetness within orchards. The Disease Severity Value (DSV) model has been modified and evaluated on almond in our previous trials over several years and we have been successful in forecasting Alternaria leaf spot of almond. There is a close correlation between the increase in actual disease and increases in DSV that are determined by the number of hours of wetness within an adjusted threshold temperature of >62 F (**Table 1**). We demonstrated that the actual development of disease correlated with environmental conditions that occurred 25 days ($\pm$ 7 days) before the onset of disease symptoms (latency period of the disease progress curve).

Table. 1. The DSV model for forecasting diseases caused by *Alternaria alternata*

Disease severity values (DVS) as a function of leaf wetness duration and average air temperature during the wetness period.

Mean temperature (C) during wetness	Leaf wetness duration (hours)				
15-17*	0-6	7-15	16-20	21	---
17.1-20	0-3	4-8	9-15	16-22	23+
20.1-25	0-2	3-5	6-12	13-20	21+
25.1-29	0-3	4-8	9-15	16-20	23+
DSV	0	1	2	3	4

* - Original model was 11 -17C. Original model was 11

Websites for DSV model:
1) www.irrigate.net
2) www.ipm.ucdavis.edu/DISEASE/DATABASE/tomatoblackmold.html

* Note: Models not modified.at these websites.

Fungicide evaluations for management of Alternaria leaf spot of almond in 2010. Our research in 2011 is ongoing, we are planning to evaluate our plots in Aug./Sept. Thus, information is presented here for 2010. In both trials conducted in Colusa Co., disease pressure was lower than in the Kern Co. trial. There was an average of 1.1 to 2.1 lesions per leaf on the control trees in Colusa Co. as compared to 3.2 lesions in Kern Co. Tree defoliation rating was 1 and 1.8 as compared to 3.3, respectively. In the first trial in Colusa on cv. Carmel Co., three calendar-based treatments significantly reduced the incidence and severity (number of lesions per leaf) of disease as well as tree defoliation for all materials as compared to the control (**Figure 1**). The most effective treatments with numerically the lowest disease incidence (21.5% to <40%) included Ph-D, Quash, Inspire, Adament, Quadris Top, and the three rotation programs. Abound and Gem were not very effective due to the high incidence (i.e., 79%) of QoI resistance. Pristine was intermediately effective due to an incidence of boscalid resistance of only 8%. In the second Colusa Co. trial on cv. Fritz, three mixture and one rotation program were evaluated. Under low disease pressure, all treatments were highly effective reducing disease incidence/severity from 85.3%/1.1 lesions in the control to 15.6 to 18.7%/ 0.2 lesions among the treatments (**Figure 2**).

Nineteen treatments were evaluated in the Kern Co. trial under high disease pressure and with a high incidence of QoI and boscalid resistance in the *Alternaria* spp. population. Disease incidence/severity was reduced to 65.4%/0.9 lesions for the best treatments (i.e., Ph-D plus Quash or Inspire) as compared to 100%/3.2 lesions per leaf in the untreated control. Tree defoliation was lowest for the Ph-D/Inspire mixture with a rating of 0.3 as compared to the control with a rating of 3.3 (**Figure 3**). Other treatments that had a tree defoliation rating of less than 1 (i.e., the tree lost up to 25% of its canopy) included the organic formulation of Ph-D, the Ph-D-Quash/Inspire mixtures, and two of the rotation programs. Based on the three disease evaluation parameters, the organic formulation of Ph-D performed equally well or numerically better than the standard formulation.

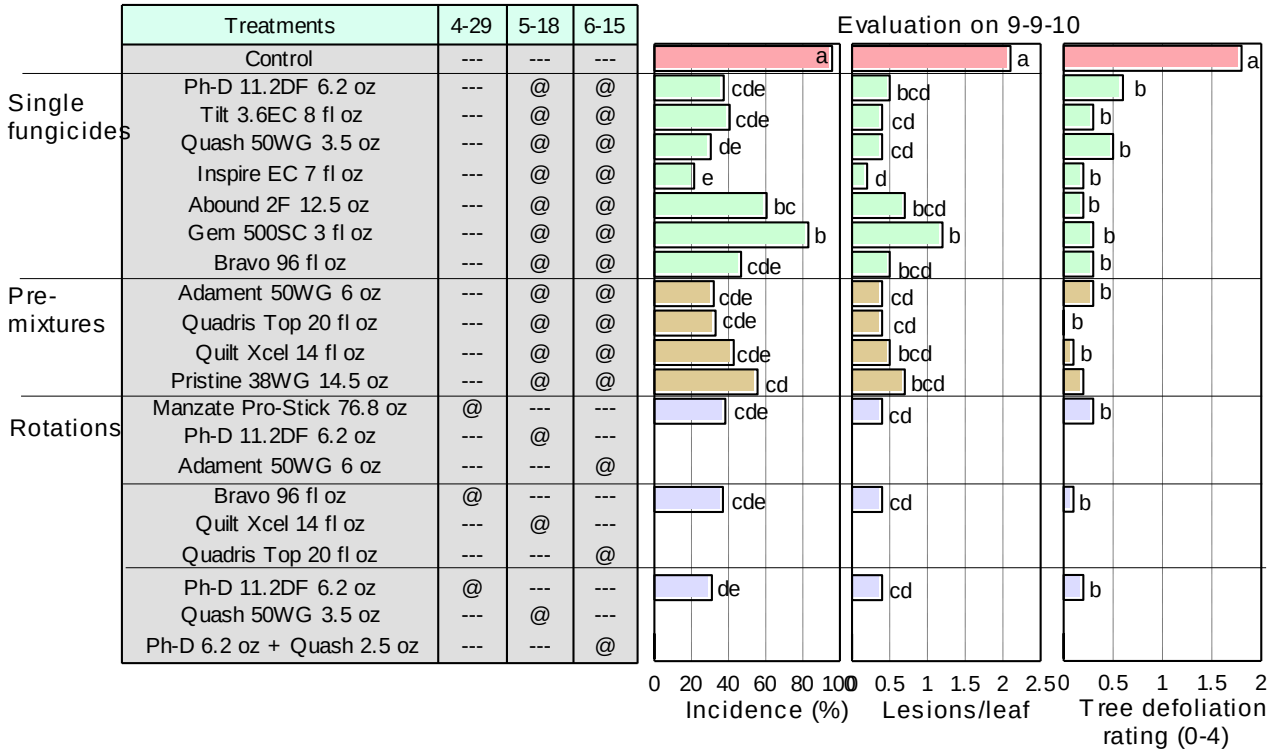
The addition of Moisturin to Ph-D did not improve efficacy of the latter compound. Moisturin is an anti-transpirant and thus, potentially could reduce relative humidity in the orchard and make environmental conditions less favorable for Alternaria leaf spot. This material probably has to

be used on a larger scale to have an impact on humidity in the orchard and therefore, single-tree applications would not show any effect.

Among the field trials conducted in 2010, the relative efficacy of many of the treatments was higher in the Colusa Co. plots (**Figures 1 and 2**) than in the Kern Co. plot (**Figure 3**). In addition to the higher disease pressure in Kern Co., this can be explained by the late start of the treatment program (May 19) in the Kern Co. plot. Although the programs also started late for most treatments in the Colusa Co. plots (5-18 or 5-20; **Figures 1, 2**), temperatures in this part of the state are generally lower at this time of the year as compared the the southern central valley. Thus, infections may have already occurred at the Kern Co. site when the first treatment was applied, and the mostly protective nature of the treatments resulted in a reduced efficacy.

Thus, as in previous years, Ph-D, DMIs, and mixtures of these two classes were the most effective in reducing the incidence and severity of Alternaria leaf blight as well as tree defoliation. Higher rates of Ph-D were evaluated previously and were found to be more effective; however, the material is only registered at up to 6.2-oz/A. Other fungicides with good activity were Adament, Luna Sensation, Quadris Top, and Quilt Excel. Because these latter products all have a QoI component, they will exacerbate QoI resistance. Chlorothalonil (Bravo, Echo, Equus) that was also effective in our 2010 field studies was recommended and accepted into the IR-4 program for extended usage into the spring season. Expected registration with a new label is 2013. Metconazole (Quash) was registered directly by Valent USA Corp. Agricultural Products; whereas difenoconazole (Inspire, Syngenta Crop Protection) was registered through the IR-4 specialty crop pesticide registration program. Ph-D (Arysta Life Science) has received federal registration as a biopesticide, was exempted from tolerance in 2009 for a number of crops including almond, and is registered as of April 2010. Because there is still a limited arsenal of highly effective fungicide classes available to manage Alternaria leaf spot we will continue to support the almond industry of California in evaluating new materials in the coming growing seasons. Currently registered fungicides are listed in **Table 2.**

Figure 1: Efficacy of fungicide treatments for management of Alternaria leaf spot on almond cv. Carmel - Colusa Co. 2010

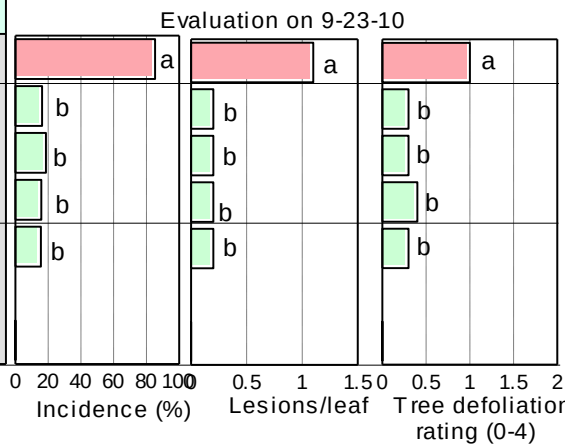


* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

** - For evaluation, 30 leaves from each of the 3 single-tree replications were evaluated for the presence of disease. Disease severity was based on a rating scale from 0= no lesions, 1= <25%, 2=25-75%, and 3=>75% of leaf area diseased. For evaluation of tree defoliation, trees were rated based on a scale from 0 (= full canopy) to 4 (>90% defoliation).

Figure 2. Efficacy of fungicide treatments for management of Alternaria leaf spot on almond cv. Fritz - Colusa Co. 2010

	Treatments	5-20	6-10	6-29
	Control	@	@	@
Mixtures	Bravo 96 fl oz + Inspire 7 fl oz	@	@	@
	Ph-D 6.2 oz + Quash 50WG 3.5 oz	@	@	@
	Ph-D 6.2 oz + Inspire Super 20 fl oz	@	@	@
Rotation	Ph-D 11.2DF 6.2 oz	@	---	---
	Quash 50WG 3.5 oz	---	@	---
	Ph-D 6.2 oz + Quash 50WG 3.5 oz	---	---	@

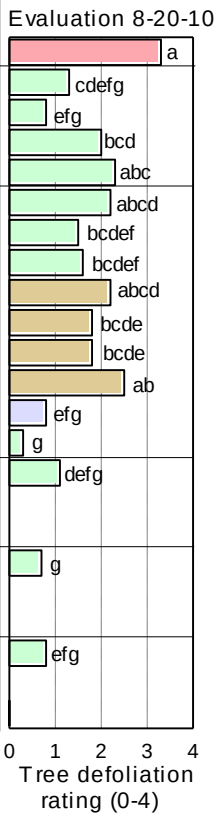


* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

** - For evaluation, 30 leaves from each of the 3 single-tree replications were evaluated for the presence of disease. Disease severity was based on a rating scale from 0= no lesions, 1= <25%, 2=25-75%, and 3=>75% of leaf area diseased. For evaluation of tree defoliation, trees were rated based on a scale from 0 (= full canopy) to 4 (>90% defoliation).

Figure 3: Efficacy of fungicide treatments for management of Alternaria leaf spot on almond cv. Monterey - Kern Co. 2010

	Treatments	5-19	6-9	6-30
	Control	---	---	---
Single fungicides	Ph-D 11.2DF 6.2 oz	@	@	@
	Ph-D 11.2DF organic form. 6.2 oz	@	@	@
	Quash 50WG 3.5 oz	@	@	@
	Bravo WS 6 pt	@	@	@
Pre-mixtures and mixtures	Adament 50WG 6 oz	@	@	@
	Luna Sensation 4 oz	@	@	@
	Inspire Super SC 20 fl oz	@	@	@
	Quadris Top 14 fl oz	@	@	@
	Inspire XT/Inspire EC 7 fl oz	XT	XT	I
	Inspire 7 fl oz/Bravo 4 pt	@	@	@
	Pristine 38WG 14.5 oz	@	@	
	Ph-D 6.2 oz + Quash3.5 oz /Inspire 7 fl oz	Q	I	Q
	Ph-D 6.2 oz + Inspire Super 20 fl oz	@	@	@
Rotations	Quash 50WG 3.5 oz	@		
	Luna Sensation 4 fl oz		@	
	Ph-D 6.2 oz + Inspire Super 20 fl oz			@
	Ph-D 11.2DF 6.2 oz	@		
	Inspire Super SC 20 fl oz		@	
	Ph-D 6.2 oz + Bravo 6 pt			@
	Ph-D 11.2DF 6.2 oz	@		
	Quash 50WG 3.5 oz		@	
	Ph-D 6.2 oz + Quash 2.5 oz			@



* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A and there were 3 single-tree replications for each treatment.

**- Evaluations for disease were done on 8-20-10. For evaluation of tree defoliation, trees were rated based on a scale from 0= full canopy, 1= up to 25%, 2= 26-50%, 3= 51-75%, and 4=>75% defoliation.

The following are guidelines for an Alternaria leaf spot management program with currently registered fungicides:

- Programs should start with 5-week after petal fall applications that include Rovral and Bravo (performance is variable and depends on the occurrence of favorable conditions).
- Up to three late-spring/early-summer applications (based on the DSV model) are done with other materials.
- Newly registered fungicides (e.g., Ph-D – Arysta LifeSciences, Quash - Valent USA, Inspire Super, Quadris Top, Quilt Xcel - Syngenta Crop Protection) will have to be strictly used in rotations and mixtures to reduce the development or spread of resistance.
- New products pending registration that have high efficacy include Luna Sensation, Luna Experience (Bayer Crop Science), and Merivon (BASF).
- Other components of an integrated approach in disease management (mite control, cultural practices that lead to decreased humidity in the orchard such as hedging, improvement of water penetration into the soil, and changing the watering or irrigation schedule to less frequent irrigation) are highly critical for management of Alternaria leaf spot.

Table 2: Relative efficacy of selected fungicides for management of Alternaria leaf spot of almond

Fungicide	Class	Mode of action	Efficacy	Comment/Registration
Bravo, Echo	Aromatic nitrile	Multiple	+	Label change requested (60 day PHI)
Captan	Pthalimide	Mutiple	+	2ee amendment (30 day PHI)
Ziram	Dithiocarbamate	Multiple	+	Registered bloom to petal fall*
Scala	Anilinopyrimidine	Single	+	2ee amendment (30 day PHI)
Rovral	Dicarboximide	Multiple	++	Registered bloom to petal fall*
Abound, Gem	QoI	Single	+++	Resistance (28 day PHI)
Pristine	QoI-SDHI	Multiple	+++	Resist. to both comp. (25 day PHI)
Adament	QoI-DMI	Multiple	++	Resist. to 1 comp. (60 day PHI)
Quadris Top	QoI-DMI	Multiple	++++	Resist. to 1 comp. (28 day PHI)
Inspire Super	DMI-AP	Multiple	+++	Registered (60 day PHI)
Quilt Excel	QoI-DMI	Multiple	+++	Reg.-Resist. to 1 comp. (60 day PHI)
Quash	DMI	Single	++++	Registered (25 day PHI)
PhD	Biofungicide	Single	++++	Registered (0 day PHI)
Luna Sensation	QoI-SDHI	Multiple	+++	Expected 2011, Potential Resistance
Luna Experience	QoI-DMI	Multiple	+++	Expected 2011, Potential Resistance
Merivon	QoI-SDHI	Multiple	+++	Expected 2012, Potential Resistance

Rating: ++++ = most effective, + = least effective