
Control of grape powdery mildew with synthetic, biological, and organic fungicides: 2009 field trials

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Report Summary

Powdery mildew is an economically-important pathogen of grapes worldwide. This report details the findings of our annual powdery mildew fungicide trials on grapevine cultivar Chardonnay (*Vitis vinifera*). The trials were conducted at Herzog Ranch, near Courtland, California in 2009. Treatments were placed in five adjacent trials in the vineyard. Spraying commenced in mid April, shortly after a heavy rainfall event that likely promoted the release of powdery mildew (*Uncinula necator*) ascospores from overwintering chasmothecia. Spraying was completed in mid July and treatments were evaluated for disease incidence and severity on 21 July 2009, at about the beginning of veraison.

Trial I consisted of IR-4-funded biofungicide research that focused on two products: caprylic acid (a novel control agent in current development) and Actinovate (a registered product containing the bacterium *Streptomyces lydicus* WYEC106). Trials II-V included various fungicide products (either currently registered or in various stages of product development) including strobilurins, demethylase inhibitors, oils, and other materials. Spray frequencies varied from weekly applications to 21 day intervals.

Temperatures were mild during much of the 2009 growing season, providing optimal conditions for the asexual reproduction and dispersal of powdery mildew. Risk index data was high from about mid-May through the rest of the evaluation period and the pathogen quickly colonized leaves. Disease pressure was higher than in similar trials conducted in 2007 or 2008. By mid-June, heavy to severe mildew was evident on untreated clusters.

Treatment performances varied widely. Biological fungicides generally reduced disease severity, but were more effective when used in a combination program with synthetic materials. As a stand-alone product, caprylic acid was most effective when applied weekly at a concentration of 0.3% (v/v). At a concentration of 0.5% it consistently showed phytotoxic effects on berries. A few organic materials performed well, lowering disease severity to <10%: paraffinic oil + Foliar Supreme (sulfur + nutrient cocktail) and two types of fertilizers alternated with trifloxystrobin. Among synthetic products, difenoconazole + cyprodinil, flutriafol, fluopyram, fluopyram + tebuconazole, quinoxyfen + alcohol ethoxylate (an adjuvant), various GWN4617 treatments, picoxystrobin, penthiopyrad, boscalid + pyraclostrobin alternated with triflumizole, and metrafenone gave good to excellent control of disease severity on fruit. These trials easily separate highly effective materials from those which give only moderate control of powdery mildew, however long-term assessment of treatment efficacy is best evaluated with experiments conducted at multiple locations, across several growing seasons, and on multiple grape cultivars.

Materials and Methods

A. Experimental design

Trial I: IR-4 biofungicide treatments

Experimental design	Complete randomized design with 6 replicates.		
Experimental unit	2 adjacent vines = 1 plot		
Plot area	154 ft ² (row spacing = 11 ft, vine spacing = 7 ft)		
Area/treatment	924 ft ² (6 reps. = 1 treatment)	Area/treatment	0.0212 acre/treatment
Volume water/acre	100 gallons (pre-bloom in mid-April), = 2.1 gallons/6 replicates 150 gallons (pre-bloom to pea-sized berries, late April - early June), = 3.2 gallons/6 reps 200 gallons (late season), = 4.2 gallons/6 reps		
Application method	Handgun sprayers (attached to Nifty Fifty brand 25 or 50 gallon sprayers).		

Trials II-V: Synthetic and organic treatments

Experimental design	Complete randomized design with 5 replicates.		
Experimental unit	2 adjacent vines = 1 plot		
Plot area	154 ft ² (row spacing = 11 ft, vine spacing = 7 ft)		
Area/treatment	770 ft ² (5 reps. = 1 treatment)	Area/treatment	0.0177 acre/treatment
Volume water/acre	100 gallons (pre-bloom in mid-April), = 1.8 gallons/5 replicates 150 gallons (pre-bloom to pea-sized berries, late April - early June), = 2.7 gallons/5 reps 200 gallons (late season), = 3.5 gallons/5 reps		
Application method	Handgun sprayers (attached to Nifty Fifty brand 25 or 50 gallon sprayers).		

B. Experimental treatments

The treatments described in this report were conducted for **experimental purposes only** and crops treated in a similar manner may not be suitable for commercial or other use.

Trial I

Treatment ¹	Active ingredient(s)	Flag	Frequency (days)	Application rate (per acre)	FP ² /6 replicates
Unsprayed control	none	BKS	none	none	none
Water control	water	RS	7	150 gallons then 200 gallons	3.2 gal (at 150 gal) 4.2 gal (at 200 gal)
AMV-4024	caprylic acid	GD	7	0.3% (v/v)	36 ml (at 150 gal) 48 ml (at 200 gal)
AMV-4024	caprylic acid	YKC	14	0.5% (v/v)	61 ml (at 150 gal) 81 ml (at 200 gal)
AMV-4024	caprylic acid	GS	21	0.5% (v/v)	61 ml (at 150 gal) 81 ml (at 200 gal)
AMV-4024 alt ³ Actinovate	caprylic acid, <i>Streptomyces lydicus</i>	K	14 alt 7	0.5% (v/v) alt 12 oz	61 ml (at 150 gal) 81 ml (at 200 gal) alt 7.2 g
JMS Stylet-oil alt AMV-4024	paraffinic oil, caprylic acid	KD	14	1% (v/v) alt 0.5% (v/v)	121 ml (at 150 gal) 161 ml (at 200 gal) alt 61 ml (at 150 gal) 81 ml (at 200 gal)
Flint alt AMV-4024	trifloxystrobin, caprylic acid	KS	21 alt 14	2 oz alt 0.5% (v/v)	1.2 g alt 61 ml (at 150 gal) 81 ml (at 200 gal)
Quintec alt AMV-4024	quinoxifen, caprylic acid	O	21 alt 14	6.6 fl oz alt 0.5% (v/v)	4.1 ml alt 61 ml (at 150 gal) 81 ml (at 200 gal)
Flint	trifloxystrobin	OD	21	2 oz	1.2 g
Actinovate	<i>Streptomyces lydicus</i>	OKS	7	12 oz	7.2 g
Serenade MAX	<i>Bacillus subtilis</i>	YS	7	32 oz	19.2 g
Actinovate alt Serenade MAX	<i>Streptomyces lydicus</i> , <i>Bacillus subtilis</i>	Pu	7	12 oz alt 32 oz	7.2 g 19.2 g
JMS Stylet-oil	paraffinic oil	RD	14	1% (v/v)	121 ml (at 150 gal) 161 ml (at 200 gal)
JMS Stylet-oil alt Actinovate	paraffinic oil, <i>Streptomyces lydicus</i>	RKC	14 alt 7	1% (v/v) alt 12 oz	121 ml (at 150 gal) 161 ml (200 gal) alt 7.2 g
Whey	whey	RKD	7	6 lb	57.7 g
Actinovate + Whey	<i>Streptomyces lydicus</i> & whey	RKS	7	12 oz + 6 lb	7.2 g + 57.7 g
Flint alt Actinovate AG	trifloxystrobin, <i>Streptomyces lydicus</i>	W	21 alt 7	2 oz alt 12 oz	1.2 g alt 7.2 g
Flint alt Quintec	trifloxystrobin, quinoxifen	YC	21	2 oz alt 6.6 fl oz	1.2 g alt 4.1 ml
Kumulus	sulfur	YKS	14	6 lb	57.7 g
Flint alt Companion	trifloxystrobin, <i>Bacillus subtilis</i>	YRD	21 alt 7	2 oz alt 3 qt	1.2 g alt 60 ml

¹ On April 15, Flint was applied at approximately 2 oz/acre in 100 gallons water/acre on all treatments except the unsprayed control. Vines showed no canopy at this stage (shoots were typically only a few dm length). ² FP = formulated product. ³ alt = alternated with.

Trial II

Treatment ¹	Active ingredient(s)	Flag	Frequency (days)	Application rate (per acre)	FP ² /5 replicates
Unsprayed control	none	BD	none	none	none
Quintec alt ³ Flint	quinoxifen, trifloxystrobin	BS	21	6.6 fl oz alt 2 oz	3.5 ml alt 1.0 g
Inspire Super (2x) alt Flint	difenoconazole + cyprodinil, trifloxystrobin	G	14	14 fl oz (2x) alt 2 oz	7.3 ml (2x) alt 1.0 g
Inspire Super (2x) alt Flint	difenoconazole + cyprodinil, trifloxystrobin	GKD	14	20 fl oz (2x) alt 2 oz	10.5 ml (2x) alt 1.0 g
Inspire Super (2x) alt Flint	difenoconazole + cyprodinil, trifloxystrobin	GS	21	20 fl oz (2x) alt 2 oz	10.5 ml (2x) alt 1.0 g
Inspire Super (2x) alt Flint	difenoconazole + cyprodinil, trifloxystrobin	KS	14-21 (RI)	20 fl oz (2x) alt 2 oz	10.5 ml (2x) alt 1.0 g
Regalia + NuFilm P	<i>Reynoutria sachalinensis</i> extract	OC	7	0.5% (v/v) + 0.02% (v/v)	51 ml (at 150 gal) 68 ml (at 200 gal) + 2.0 ml (at 150 gal) 2.7 ml (at 200 gal)
Topguard	flutriafol	OD	14	5 fl oz	2.6 ml
Topguard	flutriafol	OKS	14	8 fl oz	4.2 ml
Topguard	flutriafol	OS	14	10 fl oz	5.2 ml
Topguard	flutriafol	OYS	14	28 fl oz	14.7 ml
Phyton 016-B	copper sulfate pentahydrate	RC	14	40 fl oz	20.9 ml
OM-1 (JMS Stylet-oil with 1 % adjuvant)	paraffinic oil	RD	14	2% (v/v)	204 ml (at 150 gal) 272 ml (at 200 gal)
OM-2 (JMS Stylet-oil with 2 % adjuvant)	paraffinic oil	RKC	14	2% (v/v)	204 ml (at 150 gal) 272 ml (at 200 gal)
OM-2 + Foliar Supreme	paraffinic oil, sulfur + potash + phosphoric acid	RKS	14	2% (v/v) + 80 fl oz	204 ml (at 150 gal) 272 ml (at 200 gal) + 42 ml
SilverDYNE	silver colloid	Pu	14	0.015% (v/v)	1.0 ml (at 100 gal) 1.5 ml (at 150 gal) 2.0 ml (at 200 gal)
SilverDYNE	silver colloid	YD	14	0.03% (v/v)	2.0 ml (at 100 gal) 3.1 ml (at 150 gal) 4.0 ml (at 200 gal)
Unicorn	sulfur + tebuconazole	YKC	14-21	2.0 lb	16.1 g
Unicorn	sulfur + tebuconazole	YRD	14-21	2.5 lb	20.1 g
Prev AM	sodium tetraborohydrate decahydrate	OKD	14	0.4% (v/v)	41 ml (at 150 gal) 54.5 ml (at 200 gal)
JMS Stylet-oil then PureSpray + Champion (2x) then PureSpray	paraffinic oil, petroleum oil, copper hydroxide	YS	14	1% then 1% (v/v) + 2 lb then 1% (v/v)	102 ml (at 150 gal) then 102 ml + 16.1 g then 102 ml (at 150 gal) 136 ml (at 200 gal)

¹ On April 15, Pristine was applied at approximately 8 oz/acre in 100 gallons water/acre on all treatments except the unsprayed controls, Inspire Super treatments, and both SilverDYNE treatments. Vines showed no canopy at this stage (typically a few dm length). ²FP = formulated product.

³alt = alternated with.

Trial III

Treatment ¹	Active ingredient(s)	Flag	Frequency (days)	Application rate (per acre)	FP ² /5 replicates
Unsprayed control	none	BKS	none	none	none
Adament alt ³ Quintec	trifloxystrobin + tebuconazole & quinoxifen	GD	21	4 oz alt 6.6 fl oz	2.0 g 3.5 ml
USF2015	unknown	GKD	21	5 fl oz	2.6 ml
USF2017	unknown	GS	21	6 fl oz	3.1 ml
USF2017 alt Flint	unknown, trifloxystrobin	K	21	6 fl oz 2 oz	3.1 ml 1.0 g
MicroThiol	sulfur	KC	14	5 lb	40.1 g
MicroThiol + Vintre	sulfur, alcohol ethoxylate	KD	14	3 lb 0.25% (v/v)	24.1 g + 25.5 ml (at 150 gal) 34 ml (at 200 gal)
MicroThiol + Vintre	sulfur & alcohol ethoxylate	KS	14	5 lb 0.25% (v/v)	40.1 g + 25.5 ml (at 150 gal) 34 ml (at 200 gal)
Quintec	quinoxifen	O	14	4 fl oz	2.1 ml
Quintec + Vintre	quinoxifen, alcohol ethoxylate	OD	14	4 fl oz 0.25% (v/v)	2.1 ml + 25.5 ml (at 150 gal) 34 ml (at 200 gal)
Flint	trifloxystrobin	OKS	14	2 oz	1.0 g
Flint + Vintre	trifloxystrobin, alcohol ethoxylate	OS	14	2 oz + 0.25% (v/v)	1.0 g + 25.5 ml (at 150 gal) 34 ml (at 200 gal)
Vintre	alcohol ethoxylate	Pu	14	0.25% (v/v)	25.5 ml (at 150 gal) 34 ml (at 200 gal)
Nutrol (KeeP) + Hi Wett + Kumulus	fertilizer, sulfur	RC	14	7 lb + 2 fl oz + 1.5 lb	56.2 g + 1.0 ml + 12.0 g
Nutrol (KeeP) + Hi Wett alt Flint	fertilizer, trifloxystrobin	RD	14	10 lb + 2 fl oz alt 2 oz	80.3 g + 1.0 ml alt 1.0 g
HiPeak + Hi Wett + Kumulus	potassium phosphate salts, sulfur	RKC	14	7 lb + 2 fl oz + 1.5 lb	56.2 g + 1.0 ml + 12.0 g
HiPeak fertilizer + Hi Wett alt Flint	potassium phosphate salts, trifloxystrobin	RKD	14	10 lb + 2 fl oz alt 2 oz	80.3 g + 1.0 ml alt 1.0 g
GWN-4617	unknown	RS	10-14 RI	3.4 fl oz	1.8 ml
GWN-4617	unknown	W	14-21 RI	3.4 fl oz	1.8 ml
GWN-4617	unknown	YC	21	3.4 fl oz	1.8 ml
GWN-4617 (3x) Pristine (1x) then Vintage (1x) Flint (1x)	unknown, pyraclostrobin + boscalid, fenarimol, trifloxystrobin	YKC	14 then 21 then 14 then 21	3.4 fl oz then 10.5 oz then 5 fl oz then 2 oz	1.8 ml then 5.3 g then 2.6 ml then 1.0 g
Pristine (1x) then GWN-4617 (3x) then Vintage (1x) then Flint (1x)	pyraclostrobin + boscalid, unknown, fenarimol, trifloxystrobin	YKS	21 then 14 then 14 then 21	10.5 oz 3.4 fl oz then 5 fl oz then 2 oz	5.3 g then 1.8 ml then 2.6 ml then 1.0 g
Pristine (1x) then Vintage (1x) then Flint (1x) then GWN-4617 (3x)	pyraclostrobin + boscalid, fenarimol, trifloxystrobin, unknown	YRD	21 then 14 then 21 then 14	10.5 oz then 5 fl oz then 2 oz then 3.4 fl oz	5.3 g then 2.6 ml then 1.0 g then 1.8 ml
GWN-4617 alt Vintage	unknown alt fenarimol	YRS	14	3.4 fl oz alt 5 fl oz	1.8 ml alt 2.6 ml

¹ On April 15-16, approximately 4-8 oz/acre of Pristine was applied in about 50-100 gallons/acre on all treatments except the unsprayed control. Vines showed no canopy at this stage (typically a few dm length). Treatments OD, OKS, and OS were accidentally treated with Topguard on 26 May, but they were rinsed with water on the same day; correct products were applied the next day. ²FP = formulated product. ³alt = alternated with.

Trial IV

Treatment ¹	Active ingredient(s)	Flag	Frequency (days)	Application rate (per acre)	FP ² /5 replicates
Unsprayed control	none	BD	none	none	none
Quintec + Sylgard 309	quinoxifen, polysiloxane	BS	21	6.6 fl oz + 0.03% (v/v)	3.5 ml + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
BAS560 03F + Sylgard 309	metrafenone, polysiloxane	G	14	10.24 fl oz + 0.03% (v/v)	5.4 ml + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
BAS560 03F + Sylgard 309	metrafenone, polysiloxane	GKD	21	15.36 fl oz + 0.03% (v/v)	8.0 ml + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
Pristine + Sylgard 309	pyraclostrobin + boscalid, polysiloxane	GS	21	10.5 oz + 0.03% (v/v)	5.3 g + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
Sovran + Sylgard 309	kresoxim methyl, polysiloxane	K	21	5 oz + 0.03% (v/v)	2.5 g + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
Pristine	pyraclostrobin + boscalid	KD	14	8 oz	4.0 g
YT669	picoxystrobin	KS	14	12 fl oz	6.3 ml
LEM17 SC	penthiopyrad	O	14	20 fl oz	10.5 ml
LEM17 SC	penthiopyrad	OD	14	24 fl oz	12.6 ml
LEM17 SC	penthiopyrad	OKS	21	24 fl oz	12.6 ml
LEM17 SC + Kumulus	penthiopyrad, sulfur	OS	14	14 fl oz + 6 lb	7.3 ml + 48.2 g
LEM17 SC + Kumulus	penthiopyrad, sulfur	OYS	14	20 fl oz + 6 lb	10.5 ml + 48.2 g
LEM17 SC + Kumulus	penthiopyrad, sulfur	Pu	21	20 fl oz + 6 lb	10.5 ml + 48.2 g
LEM17 SC + Kumulus	penthiopyrad, sulfur	RC	21	24 fl oz + 6 lb	12.6 ml + 48.2 g
Mettle + Sylgard 309	tetraconazole, polysiloxane	RD	21	5 fl oz + 0.03% (v/v)	2.6 ml + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal)
Timorex Gold	tea tree oil	RKC	14	0.5% (v/v)	51 ml (at 150 gal) 68 ml (at 200 gal)
Timorex Gold	tea tree oil	RKD	14	0.75% (v/v)	77 ml (at 150 gal) 103 ml (at 200 gal)
Pristine alt ³ Timorex Gold	pyraclostrobin + boscalid, tea tree oil	RKS	14	8 oz alt 0.5 %	4.0 g alt 51 ml (at 150 gal) 68 ml (at 200 gal)
Viticulture	triflumizole	RS	21	6 fl oz	3.1 ml
Viticulture	triflumizole	W	21	8 fl oz	4.2 ml
Quintec alt Viticulture	quinoxifen alt triflumizole	YC	21	6.6 fl oz alt 8 fl oz	3.5 ml alt 4.2 ml
Flint then Flint + Viticulture	trifloxystrobin, triflumizole	YD	21	2 oz then 2 oz + 8 fl oz	1.0 g then 1.0 g + 4.2 ml
Pristine + Sylgard 309 alt Viticulture	pyraclostrobin + boscalid, polysiloxane, triflumizole	YKC	21	10.5 oz + 0.03 % (v/v) alt 8 fl oz	5.3 g + 3.1 ml (at 150 gal) 4.1 ml (at 200 gal) alt 4.2 ml
Ph-D	polyoxin-D	YKS	14	6.2 oz	3.1 g
Ph-D	polyoxin-D	YS	14	12 oz	6.0 g

¹ On April 15, Pristine was applied at approximately 8 oz/acre in 100 gallons water/acre on all treatments except the unsprayed control. Vines showed no canopy at this stage (typically a few dm length). ²FP = formulated product. ³alt = alternated with.

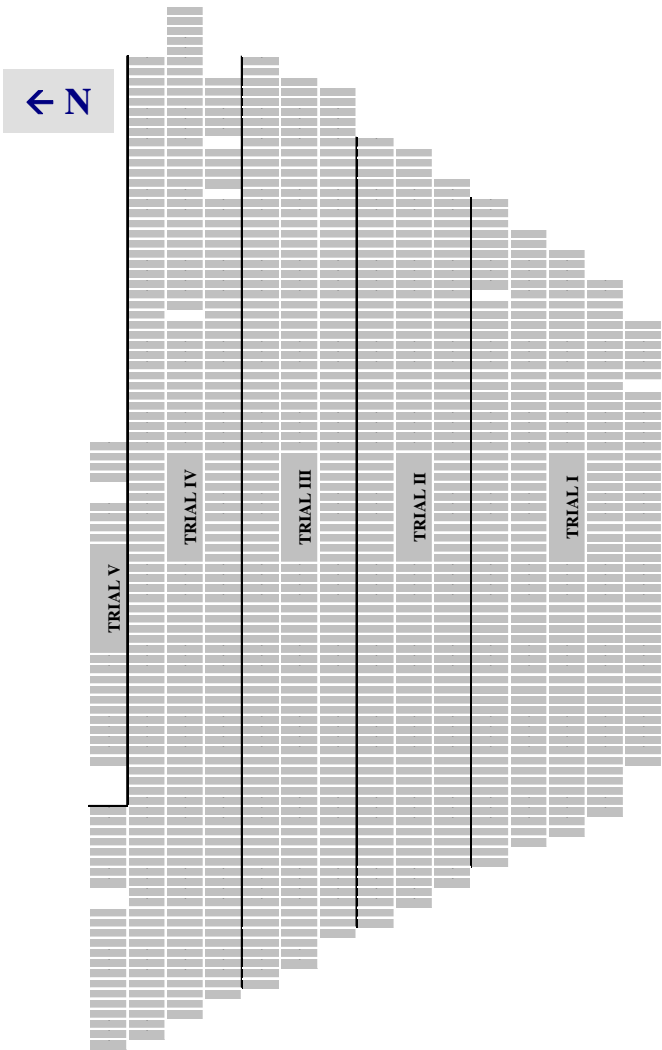
Trial V¹

Treatment ¹	Active ingredient(s)	Flag	Frequency (days)	Application rate (per acre)	FP ² /5 replicates
Unsprayed control	none	K+YD	none	none	none
Cueva	copper octanoate	GD	14	1% (v/v)	102 ml (at 150 gal) 136 ml (at 200 gal)
Cueva	copper octanoate	YRD	14	2% (v/v)	204 ml (at 150 gal) 272 ml (at 200 gal)

¹ This experiment was started relatively late; first applications made on 8 May 2009. ²FP = formulated product.

C. Maps of the trials

Overview map



TRIAL II

← N

Pu	:	:
G	OC	BD
OYS	KS	G
:	BD	OS
RKS	RKC	YRD
RC	OYS	GKD
GS	YRD	YD
YRD	OS	KS
YS	Pu	OC
YD	BS	GKD
GKD	OKD	YKC
KS	OYS	OKS
RKC	OS	YKC
YKC	RC	Pu
BS	RKS	BS
RKC	G	RKC
RC	OD	YD
OS	KS	GS
G	RD	RC
OD	YS	OC
YS	OKD	BD
RD	OC	OKD
YKC	YRD	RD
OYS	YD	Pu
OKS	OKS	G
RD	YKC	GS
OKD	OYS	BD
GKD	RKS	YRD
YS	OD	RC
OD	YD	OKD
OKS	GS	GS
BS	KS	BS
RKS	OC	OKS
OS	Pu	OD
GKD	RKS	BD
YS	RKC	
RD		

Vineyard row	8	7	6
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TRIAL I

[illegible]

TRIALS IV&V

TRIAL III

← N

			Pu	
			YKS	
			O	
		BS	W	
		YC	YKS	
		RKS	Pu	
		RS	OS	
		OD	OYS	
		OS	RC	
		K	.	GKD
		GS	OKS	OKS
		YS	RD	GS
		OS	KD	G
		RKD	GKD	O
		GS	W	RD
		RD	OYS	KS
		RKS	YKS	GKD
		KD	RS	OYS
		W	RC	OD
		O	YS	RD
		KS	BD	OD
		BS	RKS	YC
		YS	OYS	GKD
		OS	Pu	RS
		KS	YS	OD
		YC	RC	RS
		OKS	YKC	RKS
		YD	KD	KS
		G	YC	BD
		GS	KS	YKC
		BS	W	OD
		YKC	RKS	K
		K	YD	RKC
	*	G	KD	O
	GKD	YD	BS	RKD
	RD	KD	BD	YKS
	YKC	OKS	O	Pu
	RKD	K	RKC	OKS
	.	RKC	BD	W
	RC	RC	YD	RKD
	RKC	K	YC	G
	RS	G	RKC	YKS
	OS	Pu	YKC	OYS
	YD	BD	GS	
	RKD	YS		
	BS			

		RD	
KS	GKD		
	GS		
RKC	O	W	
RC	YKC	RS	
W	GD	KD	
KD	OS	OKS	
Pu	KS	RKD	
BKS	BKS	YRS	
OS	Pu	YRD	
YKC	RD	YC	
O	YKS	O	
YC	OKS	RD	
OD	RS	YKS	
KS	K	GS	
W	Pu	GKD	
KC	O	RS	
OS	YRS	OD	
K	W	GD	
KD	KC	KD	
GS	RC	K	
YKC	YC	BKS	
YKS	W	RC	
OD	KC	GD	
OS	RKC	GKD	
RKC	RD	RKD	
YRD	YRS	KC	
GD	YC	YC	
RS	BKS	GKD	
RC	RKC	YRD	
YKS	RD	GS	
KS	Pu	OD	
GKD	BKS	YKC	
RKD	OKS	YKS	
YKC	YRD	OKS	
K	OD	K	
O	OS	OKS	
Pu	RC	KD	
KC	RKD	RS	
GD	KS	YRS	
YRS	YRD		
RKD	RKC		
GS			

Vineyard row

15

14

13

12

11

10

9

D. Application history

TRIAL I

Trt no. Treatment		Dates product applied																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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DISEASE EVALUATION

TRIAL II

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DISEASE EVALUATION

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DISEASE EVALUATION

TRIAL V

[illegible]

E. Vine management

During the evaluation period (mid-April to mid-July), vines were irrigated one time by flooding. Sucker shoots were removed by local field personnel on approximately 28 May 2009. Leaf removal around the clusters (on only the north side of the vines) was conducted by our research group on 29 May 2009. Additional small-scale removal of leaves, suckers, and overhanging shoots was also conducted at various times during the season.

F. Data collection and statistics

Daily temperature and precipitation data were obtained from the Russell Road weather station, located close to the research site (data at <http://www.ipm.ucdavis.edu>). Gubler-Thomas Risk Index values were computed using data from a Metos weather station situated between trials IV and V (indicated by a * on map above).

Disease was assessed on 21 July at early veraison. Normally, 20-25 clusters were evaluated for powdery mildew incidence and severity in each plot. Incidence was defined as the proportion of clusters in a plot hosting at least some living powdery mildew. Severity was determined by estimating the percentage of berries in a cluster that were infected; the severity value of all clusters was then averaged to give a plot wide estimate of disease severity. Visual estimates of severity were made for more heavily infected clusters. However, when disease was less common, the number of infected berries per cluster was counted. This value was then converted into a percentage by dividing by the average number of berries for 4 cluster size classes (small: 65 berries/cluster; medium: 91 berries/cluster; large: 145 berries/cluster; extra-large: 198 berries/cluster). Mean incidence and severity values and standard errors were computed for each treatment and compared statistically by using Fisher's LSD test (at $\alpha = 0.10$) in SAS9.1. Trial IV showed a number of very substantial outlying plots with elevated disease, often towards the eastern end of the trial, perhaps due to poor or no spray coverage (see grayish plots on map above). These plots were removed prior to analysis.

Results

Figure 1. (A) Powdery mildew on unsprayed clusters in trial I. (B) Berry phytotoxicity due to application of AMV-2024 at 0.5 % in Trial I.

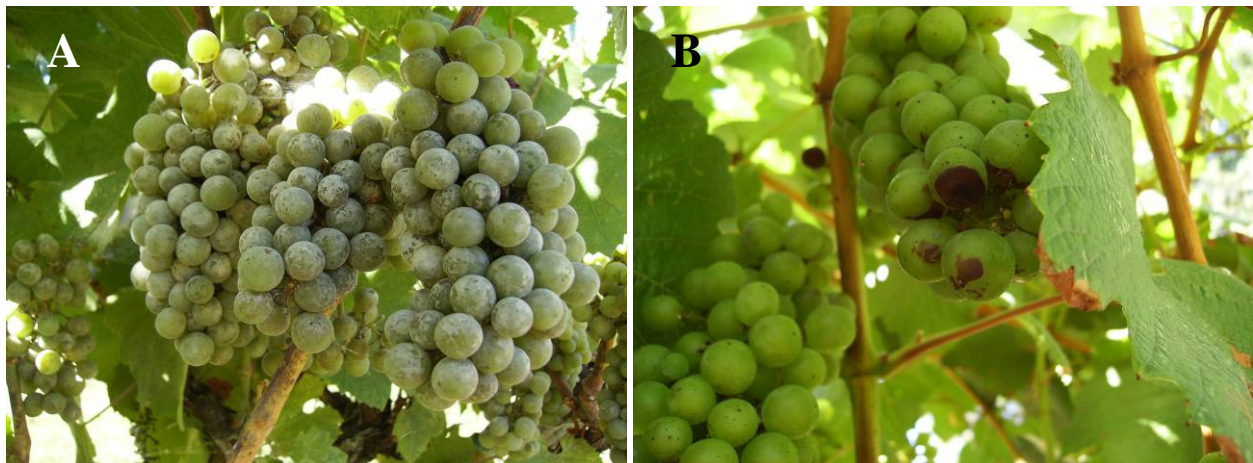


Figure 2. Weather data, powdery mildew risk index values, and disease progression in the trials from April to until disease evaluation on 21 July. (A-B) daily records of precipitation and temperatures for the CIMIS Russell Road weather station (<http://www.cimis.water.ca.gov/>). (C) Powdery mildew risk index, calculated by an on site Metos weather station. (D) Powdery mildew incidence on the upper surface of untreated leaves collected every 1-2 weeks from the general research area (means \pm 1 standard deviation; n=6).

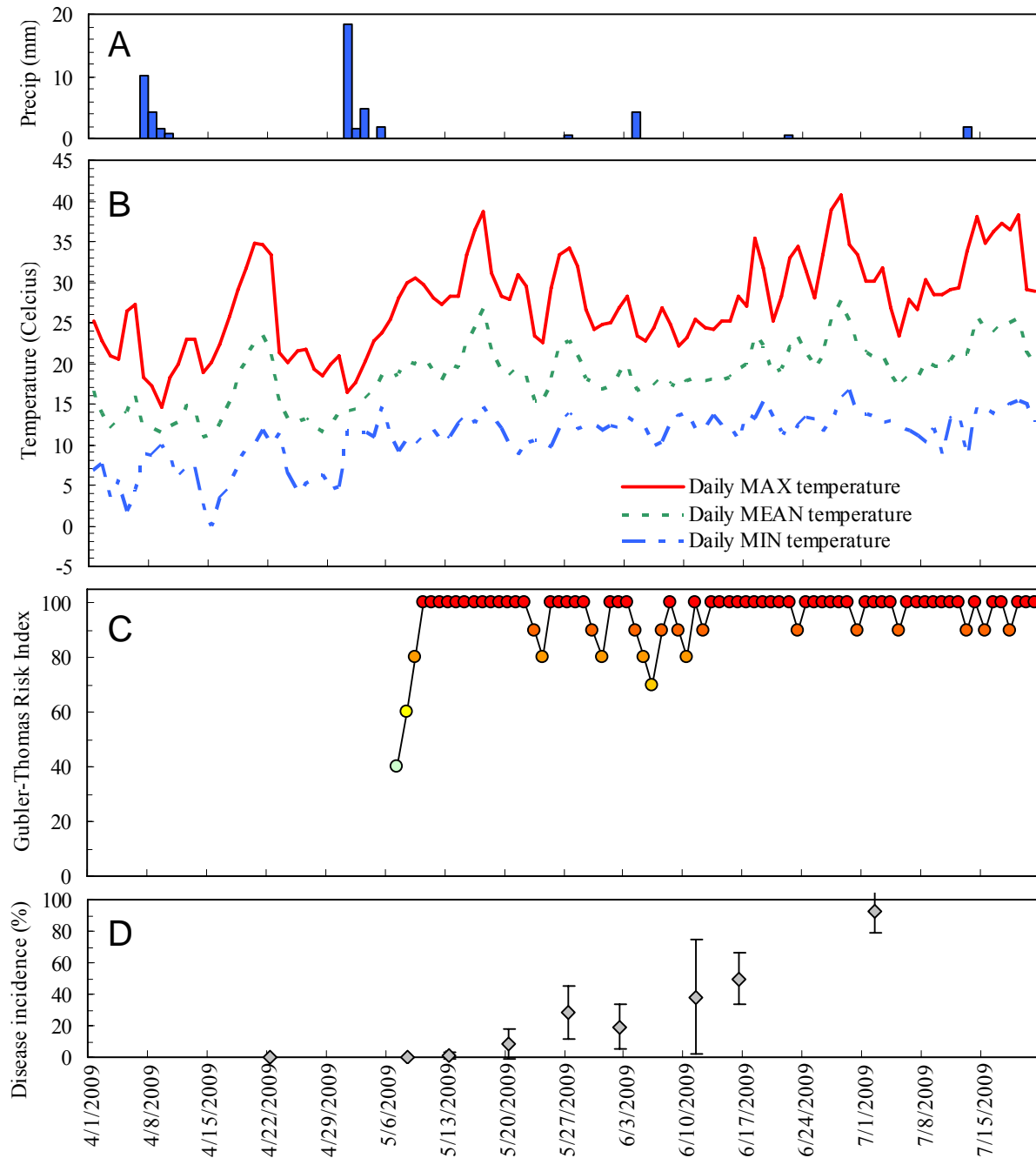


Table 1. Disease severity and incidence in trial I treatments (means \pm 1 SE; n = 6). Product names are followed by amount applied (per acre) and the frequency of application. Treatment means with the different letters are significantly different according to Fisher's LSD test at $\alpha = 0.10$; alt = alternated with.

Treatment	Disease Severity (%)	Disease Incidence (%)
Flint, 2 oz, 21 d alt Companion, 3 qt, 7 d	8.0 \pm 3.7 i	75.5 \pm 8.2 f
Flint, 2 oz, 21 d alt Quintec, 6.6 fl oz, 21 d	8.8 \pm 3.0 hi	78.2 \pm 8.3 f
Flint, 2 oz, 21 alt AMV-4024, 0.5%, 14 d	9.1 \pm 1.3 hi	91.2 \pm 3.5 abcde
Quintec, 6.6 fl oz, 21 d alt AMV-4024, 0.5%, 14 d	9.6 \pm 2.3 hi	84.8 \pm 5.8 cdef
Flint, 2 oz, 21 d	12.6 \pm 4.2 hi	86.8 \pm 6.1 bcdef
Flint, 2 oz, 21 d alt Actinovate, 12 oz, 7 d	13.4 \pm 4.2 ghi	82.5 \pm 9.3 def
AMV-4024, 0.3%, 7 d	17.2 \pm 4.7 fghi	81.0 \pm 9.1 ef
Actinovate, 12 oz, 7 d alt Serenade MAX, 32 oz, 7 d	23.4 \pm 6.9 efghi	94.8 \pm 2.0 abc
Actinovate, 12 oz + Whey, 6 lb, 7 d	24.2 \pm 7.5 defgh	93.5 \pm 4.3 abcd
Kumulus, 6 lb, 14 d	29.0 \pm 8.3 cdefg	96.7 \pm 3.3 ab
Serenade MAX, 32 oz, 7 d	30.4 \pm 5.6 bcdef	98.7 \pm 1.3 a
Whey, 6 lb, 7 d	30.5 \pm 9.5 bcdef	90.7 \pm 4.9 abcde
JMS Stylet-oil, 1%, 14 d	33.8 \pm 7.4 bcde	95.0 \pm 3.4 abc
AMV-4024, 0.5%, 14 d	34.8 \pm 6.6 bcde	100.0 \pm 0.0 a
JMS Stylet-oil, 1%, 14 d alt Actinovate, 12 oz, 7 d	34.8 \pm 11.0 bcde	95.3 \pm 3.3 abc
JMS Stylet-oil, 1%, 14 d alt AMV-4024, 0.5%, 14 d	37.7 \pm 9.8 bcde	98.3 \pm 1.7 a
Actinovate, 12 oz, 7 d	39.7 \pm 5.9 bcd	100.0 \pm 0.0 a
AMV-4024, 0.5%, 14 d alt Actinovate, 12 oz, 7 d	41.6 \pm 6.7 bc	98.3 \pm 1.7 a
AMV-4024, 0.5%, 21 d	45.1 \pm 7.8 b	98.7 \pm 1.3 a
Water control, 7 d	45.8 \pm 11.0 b	95.3 \pm 4.7 abc
Unsprayed control	91.1 \pm 4.6 a	100.0 \pm 0.0 a

Table 2. Disease severity and incidence in trial II treatments (means \pm 1 SE; n = 5). Product names are followed by amount applied (per acre) and the frequency of application. Treatment means with the different letters are significantly different according to Fisher's LSD test at $\alpha = 0.10$; alt = alternated with.

Treatment	Disease Severity (%)	Disease Incidence (%)
Inspire Super, 20 fl oz, 14 d (2x) alt Flint, 2 oz, 14 d	0.6 \pm 0.3 f	18.4 \pm 7.0 i
Topguard, 28 fl oz, 14 d	2.6 \pm 1.0 f	34.4 \pm 14.2 ghi
Topguard, 5 fl oz, 14 d	2.9 \pm 1.0 f	49.6 \pm 10.8 efgh
Topguard, 8 fl oz, 14 d	6.1 \pm 1.8 ef	59.2 \pm 14.2 def
OM-2, 2% + Foliar Supreme, 80 fl oz, 14 d	6.9 \pm 3.1 ef	50.7 \pm 11.9 efgh
Inspire Super, 20 fl oz, 14-21 d (2x) alt Flint, 2 oz, 14-21 d	6.9 \pm 6.1 ef	32.8 \pm 17.6 hi
Topguard, 10 fl oz, 14 d	12.1 \pm 8.0 def	57.6 \pm 14.9 defg
OM-2, 2%, 14 d	13.8 \pm 6.4 def	60.8 \pm 13.4 def
Inspire Super, 14 fl oz, 14 d (2x) alt Flint, 2 oz, 14 d	15.6 \pm 14.9 def	41.6 \pm 13.8 fghi
Quintec, 6.6 fl oz, 21 d alt Flint, 2 oz, 21 d	16.0 \pm 11.3 def	68.0 \pm 18.1 cde
Inspire Super, 20 fl oz, 21 d (2x) alt Flint, 2 oz, 21 d	18.2 \pm 9.8 cdef	74.4 \pm 9.7 bcd
Unicorn, 2.5 lb, 14-21 d	24.1 \pm 3.8 cde	96.0 \pm 3.1 ab
JMS Stylet-oil, 1 % then Purespray, 1%, 14 d	27.6 \pm 9.9 cd	100.0 \pm 0.0 a
Unicorn, 2 lb, 14-21 d	28.9 \pm 9.1 bcd	90.4 \pm 6.0 abc
Phyton 016-B, 40 fl oz, 14 d	36.0 \pm 7.5 bc	99.2 \pm 0.8 a
Regalia, 0.5% + NuFilm P, 0.02%, 7 d	37.2 \pm 7.8 bc	98.4 \pm 1.0 a
OM-1, 2%, 14 d	37.6 \pm 15.4 bc	96.8 \pm 3.2 ab
Prev AM, 0.4%, 14 d	48.2 \pm 15.6 b	99.2 \pm 0.8 a
SilverDYNE, 0.03%, 14 d	80.4 \pm 7.2 a	100.0 \pm 0.0 a
SilverDYNE, 0.015%, 14 d	88.4 \pm 5.5 a	100.0 \pm 0.0 a
Unsprayed control	95.8 \pm 3.7 a	100.0 \pm 0.0 a

Table 3. Disease severity and incidence in trial III treatments (means \pm 1 SE; n = 5). Product names are followed by amount applied (per acre) and the frequency of application. Treatment means with the different letters are significantly different according to Fisher's LSD test at $\alpha = 0.10$; alt = alternated with.

Treatment	Disease Severity (%)	Disease Incidence (%)
USF2017, 6 fl oz, 21 d alt Flint 2 oz, 21 d	0.2 \pm 0.1 g	10.4 \pm 4.8 j
USF2017, 6 fl oz, 21 d	0.2 \pm 0.1 g	7.2 \pm 4.5 j
Quintec, 4 fl oz + Vintre, 0.25%, 14 d	0.6 \pm 0.2 g	24.8 \pm 7.5 hij
GWN-4617, 3.4 fl oz, 10-14 d	0.7 \pm 0.5 g	18.4 \pm 7.5 ij
GWN-4617, 3.4 fl oz, 14 d alt Vintage, 5 fl oz, 14 d	1.0 \pm 0.2 g	44.8 \pm 8.3 fghi
USF2015, 5 fl oz, 21 d	1.3 \pm 1.1 fg	20.8 \pm 13.5 ij
Pristine, 10.5 oz, 21 d then Vintage, 5 fl oz, 14 d then Flint, 2 oz, 21 d then GWN-4617, 3.4 fl oz, 14 d (2x)	1.6 \pm 1.1 fg	40.0 \pm 15.4 ghi
Flint, 2 oz + Vintre, 0.25%, 14 d	1.8 \pm 1.7 fg	24.0 \pm 17.1 hij
Quintec, 4 fl oz, 14 d	2.7 \pm 1.3 fg	52.8 \pm 15.6 efg
Flint, 2 oz, 14 d	3.9 \pm 2.7 efg	45.6 \pm 16.4 fghi
Adament, 4 oz, 21 d alt Quintec 6.6 fl oz, 21 d	4.4 \pm 2.5 efg	51.2 \pm 20.0 efg
Pristine, 10.5 oz, 21 d then GWN-4617, 3.4 fl oz, 14 d (3x) then Vintage, 5 fl oz, 14 d then Flint, 2 oz	4.4 \pm 1.3 efg	60.8 \pm 9.2 defg
GWN-4617, 3.4 fl oz, 21 d	5.0 \pm 2.5 efg	64.8 \pm 8.9 cdefg
HiPeak, 10 lb + Hi Wett, 2 fl oz, 14 d alt Flint, 2 oz, 14 d	5.6 \pm 3.0 efg	54.4 \pm 17.5 efg
GWN-4617, 3.4 fl oz, 14-21 d	6.6 \pm 3.6 efg	54.4 \pm 18.5 efg
GWN-4617, 3.4 fl oz, 14 d (3x) then Pristine, 10.5 oz, 21 then Vintage, 5 fl oz, 14 d then Flint, 2 oz	6.6 \pm 3.6 efg	73.6 \pm 12.3 abcde
Nutrol, 10 lb + Hi Wett, 2 fl oz, 14 d alt Flint, 2 oz, 14 d	9.6 \pm 5.9 defg	72.0 \pm 12.1 bcdef
MicroThiol, 5 lb + Vintre 0.25%, 14 d	12.7 \pm 6.7 def	67.2 \pm 12.7 cdefg
Vintre, 0.25%, 14 d	14.8 \pm 4.3 cde	97.6 \pm 1.0 ab
HiPeak, 7 lb + Hi Wett, 2 fl oz + Kumulus, 1.5 lb, 14 d	14.9 \pm 8.2 bcde	82.4 \pm 7.9 abcd
MicroThiol, 3 lb + Vintre, 0.25%, 14 d	18.2 \pm 7.2 bcd	90.4 \pm 5.5 abc
MicroThiol, 5 lb, 14 d	25.7 \pm 12.5 bc	91.2 \pm 4.5 abc
Nutrol, 7 lb + Hi Wett, 2 fl oz + Kumulus, 1.5 lb, 14 d	26.3 \pm 11.0 b	86.4 \pm 7.5 abcd
Unsprayed control	94.5 \pm 4.7 a	100.0 \pm 0.0 a

Table 4. Disease severity and incidence in trial IV treatments (means \pm 1 SE); plots from the end of rows 13 and 14 were removed prior to analysis (n = 3 to 5, depending on treatment). Product names are followed by amount applied (per acre) and the frequency of application. Treatment means with the different letters are significantly different according to Fisher's LSD test at $\alpha = 0.10$; alt = alternated with.

Treatment	Disease Severity (%)	Disease Incidence (%)
Pristine, 10.5 oz + Sylgard 309, 0.03%, 21 d	0.1 \pm 0.0 d	5.3 \pm 1.3 k
YT669, 12 fl oz, 14 d	0.1 \pm 0.1 d	7.2 \pm 3.4 k
LEM17, 20 fl oz, 14 d	0.7 \pm 0.7 d	17.0 \pm 14.4 ik
LEM17, 24 fl oz, 14 d	0.9 \pm 0.3 d	28.0 \pm 10.2 hijk
Pristine, 10.5 oz + Sylgard 309, 0.03%, 21 d alt Viticure 8 fl oz, 21 d	1.2 \pm 0.9 d	25.0 \pm 10.8 ijk
LEM17, 20 fl oz + Kumulus, 6 lb, 14 d	1.8 \pm 0.9 d	29.6 \pm 7.9 hijk
Pristine, 8 oz, 14 d alt Timorex Gold, 0.5%, 14 d	2.0 \pm 1.0 d	21.3 \pm 7.1 ijk
LEM17, 24 fl oz + Kumulus, 6 lb, 21 d	2.5 \pm 0.8 d	42.4 \pm 9.3 eghij
BAS560 03F, 15.36 fl oz + Sylgard 309, 0.03%, 21 d	2.6 \pm 2.2 d	33.3 \pm 17.3 ehijk
Flint, 2 oz, 21 d then Flint, 2 oz + Viticure 8 fl oz, 21 d	2.8 \pm 1.8 d	42.4 \pm 17.2 eghij
LEM17, 20 fl oz + Kumulus, 6 lb, 21 d	2.9 \pm 0.9 cd	50.7 \pm 14.7 defhi
LEM17, 24 fl oz, 21 d	3.4 \pm 2.0 d	47.2 \pm 17.2 defhj
Quintec, 6.6 fl oz, 21 d alt Viticure, 8 fl oz, 21 d	3.7 \pm 1.7 cd	56.0 \pm 15.1 defh
Quintec, 6.6 fl oz + Sylgard 309, 0.03%, 21 d	5.7 \pm 2.7 cd	62.0 \pm 21.0 def
Viticure, 6 fl oz, 21 d	6.8 \pm 3.6 cd	56.0 \pm 15.7 defh
Viticure, 8 fl oz, 21 d	7.9 \pm 3.3 cd	65.0 \pm 15.6 cdg
Pristine, 8 oz, 14 d	8.1 \pm 3.0 cd	56.8 \pm 12.0 defh
Sovran, 5 oz + Sylgard 309, 0.03%, 21 d	8.6 \pm 7.5 cd	50.0 \pm 16.8 defhj
Mettle, 5 fl oz + Sylgard 309, 0.03%, 21 d	12.4 \pm 4.3 cd	72.0 \pm 11.4 abdf
LEM17, 14 fl oz + Kumulus 6 lb, 14 d	13.0 \pm 7.5 cd	66.7 \pm 18.5 bdef
BAS560 03F, 10.24 fl oz + Sylgard 309, 0.03%, 21 d	17.7 \pm 12.2 c	50.4 \pm 20.1 defhj
Timorex Gold, 0.5%, 14 d	45.4 \pm 11.5 b	95.2 \pm 2.3 abf
Ph-D, 6.2 oz, 14 d	50.7 \pm 10.0 b	96.0 \pm 2.3 abc
Ph-D, 12 oz, 14 d	57.7 \pm 12.0 b	99.0 \pm 1.0 ab
Timorex Gold, 0.75%, 14 d	59.3 \pm 13.8 b	98.0 \pm 1.2 ab
Unsprayed control	90.0 \pm 7.7 a	100.0 \pm 0.0 a

Table 5. Disease incidence and severity in trial V treatments (means \pm 1 SE; n = 5). Product names are followed by amount applied (per acre) and the frequency of application. Treatment means with the different letters are significantly different according to Fisher's LSD test at $\alpha = 0.10$.

Treatment	Disease Severity (%)	Disease Incidence (%)
Cueva, 2 %, 14 d	61.4 \pm 7.3 b	96.0 \pm 4.0 a
Cueva, 1 %, 14 d	75.2 \pm 8.8 b	99.2 \pm 0.8 a
Unsprayed control	100.0 \pm 0.0 a	100.0 \pm 0.0 a

Acknowledgements

We thank Herzog Ranch for permission to conduct research at their site. Trial I was funded largely by grants from the IR-4 program supported by the USDA and EPA; other support was provided as gifts to the UC Davis Plant Pathology Department. Various industry donors provided testing materials. We thank R. Herche for assistance with spraying and P. Backup, E. Hand, E. Huang, S. Mathauda and P. Parikh for help in the laboratory. P. Backup, J. Broome, E. Bruez, E. Hand, R. Herche, J. Hurtado, F. Peduto, A. Sutherland and F. Swiecki assisted with disease evaluation in the field. J. Broome kindly supplied risk index data.

Appendix: Materials

Product	Active ingredient(s) and concentration	Manufacturer or distributor	Chemical class
Actinovate AG	<i>Streptomyces lydicus</i> WYEC 108 (0.0371%)	Natural Industries, Inc.	biological - microbial
Adament 50WG	trifloxystrobin (25%) + tebuconazole (25%)	Bayer	QoI (strobilurin) + DMI (triazole)
AMV-4024	caprylic acid (extract of palm and coconut oil)	Summerdale Inc., oil supplied by Cognis Oleochemical	biological
BAS56 003F	metrafenone (300 g/L)	BASF	benzophenone
Champion	copper hydroxide (77%)	Nufarm Americas, Inc.	copper
Companion	<i>Bacillus subtilis</i> GB03 (0.03%)	Growth Products, Ltd	biological - microbial
Cueva	copper octanoate (10%)	Neudorff	fatty acid-linked copper salt
Flint 50WG	trifloxystrobin (50%)	Bayer	QoI
Foliar Supreme	phosphoric acid (P ₂ O ₅) (16%) + potash (K ₂ O) (10%) + sulfur (30%)	First Choice	sulfur + other
GWN-4617	unknown	Gowan Co.	unknown
HiPeak	potassium dihydrogenorthophosphate + dipotassium hydrogenorthophosphate	Rotem Amvert Negal, Ltd.	fertilizer
Hi Wett	polysiloxane polyether copolymer, polyoxyethylene-polyoxypropylene copolymer & alcohol ethoxylate (100%)	First Choice	adjuvant
Inspire Super	difenoconazole (8.4%) + cyprodinil (24%)	Syngenta Crop Protection, Inc.	DMI (triazole) + anilinopyrimidine
JMS Stylet-oil	paraffinic oil (97.1%)	JMS Flower Farms, Inc.	oil
Kumulus DF	sulfur (80%)	BASF	sulfur
LEM17 SC	penthiopyrad (20%)	DuPont	carboxamide
Mettle	tetraconazole (10-12.5%)	Isagro-USA	DMI (triazole)
MicroThiol	sulfur (80%)	Ceresagri, Inc.	sulfur
NuFilm P	poly-1-p-menthene	Miller Chemical and Fertilizer Corporation	adjuvant
Nutrol (KeeP fertilizer)	phosphate (50%), potash (30%)	Rotem BKG	fertilizer
OM1	paraffinic oil + OE444 (an oil-based adjuvant)	OE444: DuGussa/Goldschmidt	oil
OM2	paraffinic oil + OE444	OE444: DuGussa/Goldschmidt	oil
Phyton-016-B	copper sulfate pentahydrate (21.4%)	Phyton Corporation	other
Ph-D	polyoxin-D (11.3%)	Arysta Life Sciences	chitin synthesis inhibitor
PrevAM	sodium tetraborohydrate decahydrate (0.99%)	OroAgri, Inc.	
Pristine	pyraclostrobin (12.8%) boscalid (25.2%)	BASF	QoI + carboxamide
PureSpray	petroleum oil (98%)	Petro-Canada	oil
Quintec	quinoxifen (22.6%)	Dow AgroSciences LLP	quinoline
Regalia SC	<i>Reynoutria sachalinensis</i> extract	Marrone Organic Innovations	biological
Rubigan	fenarimol (12%)	Gowan Co.	DMI (pyrimidine)
Serenade MAX	<i>Bacillus subtilis</i> QST713 (14.6%)	AgraQuest Inc.	biological - microbial
SilverDYNE	silver colloid (3.6%)	World Health Alliance International Inc.	other
Sovran	kresoxim methyl (50%)	BASF	QoI
Sylgard 309	polysiloxane (80%)	Dow Corning Corp	adjuvant
Timorex Gold	oil derived from the tea tree, <i>Melaleuca alterniflora</i> (23.8%)	Biomor Israel Ltd.	oil
Topguard	flutriafol (12%)	Cheminova	DMI (triazole)
Unicorn	sulfur (70%) + tebuconazole (4.5%)	Sulfur Mills, Ltd.	sulfur, DMI
USF2015 (Luna Privilege)	fluopyram	Bayer	pyridinyl ethylbenzamide
USF2017 (Luna Experience)	fluopyram + tebuconazole	Bayer	pyridinyl ethylbenzamide, DMI (triazole)
Vintage SC	fenarimol (11.6%)	Gowan Co.	DMI (pyrimidine)
Vintre	alcohol ethoxylate (8.92%)	OroAgri	adjuvant
Viticulture	triflumizole (42.14%)	Crompton Manufacturing Company (Chemtura Corp.)	DMI (imidazole)
Whey	whey		other
YT669	picoxystrobin (250 mg/L)	DuPont	QoI

Appendix sources: (1) Janousek et al. 2006, 2007 and 2008 grape powdery mildew reports at <http://plantpathology.ucdavis.edu/ext/>, (2) Adaskaveg et al. 2008 at <http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2008/>, (3) <http://www.epa.gov/oppr001/factsheets/>, (4) http://www.frac.info/frac/publication/anhag/FRAC_Code_List_2007_web.pdf, (5) <http://www.bayercropsscience.com/>, (6) product-specific MSDS and/or labels or personal communication.