Control of powdery mildew in grapes: 2007 field trials

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Published at http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2007, October 2007.

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I. Introduction

Powdery mildew is a pervasive foliar and fruit disease on cultivated grape (*Vitis vinifera*) caused by the pathogen *Erysiphe necator*. In the Sacramento River delta region of California, disease onset typically occurs during April or May. In the absence of preventative fungicide applications, pathogen populations can quickly overwhelm crops and render them unmarketable.

We conducted six field trials in a mature Chardonnay vineyard in Sacramento County to determine the efficacy of selected chemical and biological fungicides (including new experimental materials) against the development of powdery mildew. Each trial consisted of an unsprayed control treatment and several fungicide treatments applied to 2-vine experimental plots. Water controls were added to two trials. We evaluated the overall performance of the various materials using analysis of variance coupled with calculation of standardized effect sizes.

II. Materials and Methods

A. Layout of Trials 1-5

Experimental design	Complete randomized design with 6 replicates (trial 1). Randomized complete block design with 6 replicates (trials 2-5).		
Experimental unit	2 vines = 1 plot		
Row spacing	11 ft	Vine spacing within row	7 ft
Plot unit area	154 ft^2		
Area/treatment	1008 ft^2 (6 reps. = 1 treatment)	Area/treatment	0.021 acre/treatment
Volume water/acre	150 gallons 200 gallons 250 gallons	Vol. water/treatment	3.2 gallons 4.2 gallons 5.2 gallons
Application method	Handgun sprayers (25 or 50 gallon capacity) at about 100-175 PSI.		

B. Layout of Trial 6

Experimental design	Randomized complete block design with 8 replicates.		
Experimental unit	2 vines = 1 plot		
Row spacing	11 ft	Vine spacing within row	7 ft
Plot unit area	154 ft^2		
Area/treatment	1232 ft^2 (8 reps. = 1 treatment)	Area/treatment	0.028 acre/treatment
Volume water/acre	150 gallons 200 gallons 250 gallons	Vol. water/treatment	4.2 gallons 5.6 gallons 7.0 gallons
Application method	Handgun sprayers (25 or 50 gallon capacity) dispensed at about 100-175 PSI (Biological products sprayed at ≤ 145 PSI).		

Prior to commencement of the trials, the grower applied 1% JMS Stylet Oil (on 2 April 2007) and sulfur (on 13 April, 16 April, and 23 April 2007) across the entire research area.

C. Experimental treatments

Trial 1

Trial 1 consisted of an unsprayed control, a water only control, and 12 fungicide treatments all applied at 21 day intervals (4 total applications were made during the growing season). A7402 (difenoconazole), A13703 (difenoconazole + azoxystrobin) and A16001 (difenoconazole + cyprodinil) are experimental materials produced by Syngenta Corporation. We also tested the performance of another experimental material, USF2010 (tebuconazole + trifloxystrobin), against Flint (triflozystrobin).

Trt no.	Flag	Product(s)	Frequency (days)	FP[1]/Acre	FP/Treatment
1	RC	Unsprayed control	none	none	none
2	GS	Water control	21	water only	water only
3	GKD	USF 2010 50WG	21	3.0 oz	1.8 g
4	BS	USF 2010 50WG	21	4.0 oz	2.4 g
5	Pu	A7402	21	3.0 fl oz	1.8 ml
6	LG	A7402	21	4.0 fl oz	2.5 ml
7	RD	A7402	21	5.0 fl oz	3.1 ml
8	YS	A7402	21	7.0 fl oz	4.4 ml
9	OYS	A13703	21	8.0 fl oz	5.0 ml
10	OKS	A16001	21	11.5 fl oz	7.2 ml
11	YKS	Rally 40WP	21	5.0 oz	3.0 g
12	OC	Flint 50WG	21	2.5 oz	1.5 g
13	PKD	A7402 alt Flint 50WG	21	7.0 fl oz alt 2.0 oz	4.1 ml alt 1.2 g
14	GD	Quintec 2.08SC then Quintec 2.08SC alt[2] Flint 50WG	21	6.6 fl oz then 6.6 fl oz alt 2.0 oz	4.1 ml then 4.1 ml alt 1.2 g

Notes: [1] FP=formulated, tank-mixed product. [2] alt = alternated with.

Trial 2

Trial 2 was composed principally of treatments of Topguard (flutriafol) at different spray intervals and product concentrations. An industry standard, Quintec, and a confidential experimental product (EXP90As) were also included.

Trt no.	Flag	Product	Frequency (days)	FP/Acre	FP/Treatment
1	RC	Unsprayed control	none	none	none
2	KS	Quintec 2.08SC	21	5.0 fl oz	3.1 ml
3	PKD	EXP90A	14	0.088 lb ai[1]	2.8 ml
4	Y	EXP90A	14	0.176 lb ai	5.6 ml
5	GD	Topguard	10	5.0 fl oz	3.1 ml
6	YS	Topguard	10	8.0 fl oz	5.1 ml
7	RD	Topguard	10	10.0 fl oz	6.2 ml
8	GKC	Topguard	14	5.0 fl oz	3.1 ml
9	OKS	Topguard	14	8.0 fl oz	5.0 ml
10	YKS	Topguard	14	10.0 fl oz	6.2 ml
11	RKC	Topguard	17	5.0 fl oz	3.1 ml
12	O	Topguard	17	8.0 fl oz	5.0 ml
13	B	Topguard	17	10.0 fl oz	6.2 ml

Note: [1] ai = active ingredient

Trial 3

In trial 3, three new copper formulations (Badge SC, Badge DF and Kentan DF) were tested in tandem with organic copper hydroxide (Kocide 3000). The demethylase inhibitors Rally, Elite, Eminent and Procure were included in the trial along with 2 concentrations of Sporan, a mixture of natural aromatic oils.

Trt no.	Flag	Product(s)	Frequency (days)	FP/Acre	FP/Treatment
1	RC	Unsprayed control	none	none	none
2	BD	Rally 40W	14	4.0 oz	2.4 g
3	RD	Elite 45DF	14	4.0 oz	2.4 g
4	YKS	Eminent 125ME	14	4.0 fl oz	2.5 ml
5	YS	Eminent 125ME	14	5.0 fl oz	3.1 ml
6	PKD	Eminent 125ME	14-21	5.0 fl oz	3.1 ml
7	GS	Procure 480SC	14	6.0 fl oz	3.8 ml
8	GKD	Procure 480SC alt Pristine + Latron B-1956	14	6.0 fl oz 10.5 oz 400 ml	3.8 ml 6.2 g 8.4 ml
9	LG	JMS Stylet Oil (single application) then Kocide 3000	14	0.5 % 1.5 lb	61 ml (150 gal) 14.4 g
10	Pu	Badge 2.27SC	14	1.5 pt[1]	15.0 ml
11	YKD	Badge 28DF	14	1.5 lb[1]	14.4 g
12	OKS	Kentan 40DF	14	1.5 lb[1]	14.4 g
13	OS	Sporan + Silwet L-77	14	3.0 pt 0.03 %	29.9 ml 3.6 ml (150 gal) 4.8 ml (200 gal) 6.0 ml (250 gal)
14	K	Sporan + Silwet L-77	14	6.0 pt 0.03 %	59.7 ml 3.6 ml (150 gal) 4.8 ml (200 gal) 6.0 ml (250 gal)

Note: [1] 2.0 pt/acre or 2.0 lb/acre used for the first application.

Trial 4

In trial 4, the experimental products LEM17 (Dupont) and BAS5600 00F (BASF Corp.) were tested at 14 and 21 day spray intervals. Kelpak, a seaweed-derived fertilizer, was also included in the trial. The performances of Pristine and the experimental BAS560 00F were compared with and without use of the spray adjuvant Silwet L-77.

Trt no.	Flag	Product(s)	Frequency (days)	FP/Acre	FP/Treatment
1	RC	Unsprayed control	none	none	none
2	B	LEM17 SC	14	3.0 fl oz	1.8 ml
3	RKS	LEM17 SC	14	4.3 fl oz	2.7 ml
4	GS	LEM17 SC	21	4.3 fl oz	2.7 ml
5	OKS	LEM17 SC	14	5.0 fl oz	3.1 ml
6	BKS	LEM17 SC	21	5.0 fl oz	3.1 ml
7	YKS	Pristine 38WDG	14	8.0 oz	4.8 g
8	GKC	Pristine 38WDG	21	10.5 oz	6.2 g
9	BD	Pristine 38WDG + Silwet L-77	21	10.5 oz 4.0 fl oz	6.2 g 2.5 ml
10	PC	BAS 560 00F	14	10.24 fl oz	6.4 ml
11	OKD	BAS 560 00F	21	15.36 fl oz	9.5 ml
12	YC	BAS 560 00F + Silwet L-77	14	10.24 fl oz 4.0 fl oz	6.4 ml 2.5 ml
13	OD	BAS 560 00F + Silwet L-77	21	15.36 fl oz 4.0 fl oz	9.5 ml 2.5 ml
14	KS	Kelpak	14	3.0 pt	29.9 ml

Trial 5

The experimental products Phyton-016-B (Phyton Corp.), V-10118 (Valent), Evito (Arysta), and SilverDYNE (a silver-based water purification product) were examined in this trial. Quintec, Rally alternated with Quintec, and JMS Stylet Oil (mineral oil), all registered products, were also evaluated.

Trt no.	Flag	Product(s)	Frequency (days)	FP/Acre	FP/Treatment
1	RC	Unsprayed control	none	none	none
2	KD	Phyton-016-B	7	20 fl oz	12.5 ml
3	BS	Phyton-016-B	7	30 fl oz	18.7 ml
4	YC	V-10118	14	0.02 lb ai	3.9 ml
5	RKS	V-10118	14	0.03 lb ai	5.9 ml
6	PS	Evito 480SC	14	5.0 fl oz	3.1 ml
7	GKC	Endorse 11.3DF + Evito 480SC	14	16.0 oz 5.0 fl oz	9.5 g 3.1 ml
8	KS	Endorse 11.3DF + Evito 480SC	14	8.0 oz 5.0 fl oz	4.8 g 3.1 ml
9	OC	JMS Stylet Oil	14	0.5 %	61 ml (150 gal) 81 ml (200 gal) 101 ml (250 gal)
10	GS	SilverDYNE	7	0.04%	6.3 ml (200 gal) 7.9 ml (250 gal)
11	YKS	SilverDYNE	7	0.06%	9.4 ml (200 gal) 11.8 ml (250 gal)
12	BKS	SilverDYNE	7	0.08%	12.6 ml (200 gal) 15.8 ml (250 gal)
13	PKD	Rally + Induce[1] alt Quintec + Induce	14	4.0 oz + 0.125% 4.0 fl oz 0.125%	2.4 g 20 ml (200 gal) 25 ml (250 gal) 2.5 ml 20 ml (200 gal) 25 ml (250 gal)
14	W	Quintec + Induce[1]	21	6.6 fl oz 0.125%	4.1 ml 20 ml (200 gal) 25 ml (250 gal)
15	BC	Quintec + Induce[1]	14	4.0 fl oz 0.125%	2.5 ml 20 ml (200 gal) 25 ml (250 gal)

Note: [1] Induce adjuvant not used for the first application made on 4 May 2007.

Trial 6

Trial 6 consisted of an evaluation of several biological products. Actinovate (*Steptomyces lydicus* from Natural Industries, Inc.) was tested at the high end of the label rate (12 oz/acre) at 7 and 14 day intervals and in rotation with Sonata ASO (*Bacillus pumilis* from AgraQuest, Inc.). Sonata ASO was also evaluated in a multi-product regime that included standard synthetic fungicides such as Quintec and Rally. Procedural controls (water only and water + the adjuvant Silwet L-77) were incorporated into the trial.

Trt no.	Flag	Product(s)	Rate (day)	FP/Acre	FP/Treatment
1	YS	Unsprayed control	none	none	none
2	RKC	Water control	14	water only	water only
3	KC	Silwet L-77 control	14	200 ml	5.7 ml
4	OKD	Rally alt Flint	14	4.0 oz 2.0 oz	3.2 g 1.6 g
5	GS	Quintec (application A) then Sonata ASO (B) then Flint (C) then Sonata ASO (D) then Rally (E) then Quintec (F)	14	8.0 fl oz 3.0 qt 2.0 oz 3.0 qt 4.0 oz 8.0 fl oz	6.7 ml 81 ml then 1.6 g then 81 ml then 3.2 g alt 6.7 ml
6	LG	Actinovate + Silwet L-77	7	12.0 oz 200 ml	9.6 g 5.7 ml
7	BD	Actinovate + Silwet L-77	14	12.0 oz 200 ml	9.6 g 5.7 ml
8	YKD	Actinovate + Silwet L-77 alt Sonata ASO + Silwet L-77	14	12.0 oz 200 ml alt 3.0 qt 200 ml	9.6 g 5.7 ml alt 81 ml 5.7 ml

Please note that the treatments described in this report were conducted for experimental purposes only and some crops treated in a similar manner may not be suitable for commercial use or consumption.

D. Fungicide applications: Trial 1

Trt no.	Treatment	Apr 30	May 1	May 7	May 24	Jun 14	Jul 5
1	Unsprayed control						
2	Water control	X			X	X	X
3	USF 2010, 3 oz			X	X	X	X
4	USF 2010, 4 oz			X	X	X	X
5	A7402, 3 fl oz		X		X	X	X
6	A7402, 4 fl oz	X			X	X	X
7	A7402, 5 fl oz	X			X	X	X
8	A7402, 7 fl oz	X			X	X	X
9	A13703, 8 fl oz		X		X	X	X
10	A16001, 11.5 fl oz		X		X	X	X
11	Rally, 5 oz		X		X	X	X
12	Flint, 2.5 fl oz		X		X	X	X
13	A7402, 7 fl oz alt	X				X	
	Flint, 2 oz				X		X
14	Quintec, 6.6 fl oz alt	X			X		X
	Flint, 2 oz					X	

Dates product applied: April 28 – July 23 (daily columns; only application dates shown). TRIAL RATING: July 23.

Trial 2

Dates product applied (April 28 – July 23; TRIAL RATING at July 23)

Trt no.	Treatment	April	May	June	July
1	Unsprayed control				
2	Quintec, 21 d, 5 fl oz	30	24	12	5
3	EXP90A, 0.088 lb ai		1, 15, 29	12, 26	9
4	EXP90A, 0.176 lb ai		1, 15, 29	12, 26	9
5	Topguard, 10 d, 5 fl oz		1, 10, 24	4, 14, 26	5, 19
6	Topguard, 10 d, 8 fl oz		1, 10, 24	4, 14, 26	5, 19
7	Topguard, 10 d, 10 fl oz		1, 10, 24	4, 14, 26	5, 19
8	Topguard, 14 d, 5 fl oz		1, 15, 29	12, 26	9
9	Topguard, 14 d, 8 fl oz		1, 15, 29	12, 26	9
10	Topguard,14 d, 10 fl oz		1, 15, 29	12, 26	9
11	Topguard, 17 d, 5 fl oz		1, 17	4, 21	9
12	Topguard, 17 d, 8 fl oz		1, 17	4, 21	9
13	Topguard, 17 d, 10 fl oz		1, 17	4, 21	9

Trial 3

Dates product applied

Trt no.	Treatment	May 1	May 3	May 4	May 16	May 24	May 29	May 30	June 12	June 27	June 28	July 5	July 9	July 23 (TRIAL RATING)
1	Unsprayed control													
2	Rally, 4 oz	X			X			X	X		X		X	
3	Elite, 4 oz	X			X			X	X	X			X	
4	Eminent, 4 fl oz	X			X		X		X	X			X	
5	Eminent, 5 fl oz	X			X		X		X	X			X	
6	Eminent, 5 fl oz, 14-21 d	X				X			X			X		
7	Procure, 6 fl oz		X		X		X		X	X			X	
8	Procure, 6 fl oz alt		X				X			X				
	Pristine, 10.5 oz				X				X				X	
9	JMS Stylet Oil, then			X										
	Kocide 3000, 1.5 lb				X		X		X	X			X	
10	Badge 2.27 SC, 1.5 pt	X			X		X		X	X			X	
11	Badge 28DF, 1.5 lb		X		X		X		X	X			X	
12	Kentan, 1.5 lb	X			X		X		X	X			X	
13	Sporan, 3 pt	X			X			X	X	X			X	
14	Sporan, 6 pt	X			X			X	X	X			X	

Trial 4

Trt no.	Treatment	May 1	May 15	May 24	May 29	June 12	June 27	June 28	July 5	July 9
1	Unsprayed control									
2	LEM17, 3 fl oz, 14 d	X	X		X	X	X			X
3	LEM17, 4.3 fl oz, 14 d	X	X		X	X	X			X
4	LEM17, 4.3 fl oz, 21 d	X	X	X		X			X	
5	LEM17, 5 fl oz, 14 d	X	X		X	X	X			X
6	LEM17, 5 fl oz, 21 d	X	X	X		X			X	
7	Pristine, 8 oz, 14 d	X	X		X	X	X			X
8	Pristine, 10.5 oz, 21 d	X		X		X			X	
9	Pristine, 10.5 oz + Silwet L-77, 21 d	X		X		X			X	
10	BAS 56000F, 10.2 fl oz, 14 d	X	X		X	X	X			X
11	BAS 56000F, 15.4 fl oz, 21 d	X		X		X			X	
12	BAS 56000F, 10.2 fl oz + Silwet L-77, 14 d	X	X		X	X	X			X
13	BAS 56000F, 15.4 fl oz + Silwet L-77, 21 d	X		X		X			X	
14	Kelpak, 3 pt	X	X		X	X		X		X

Dates product applied (April 28 – July 23); TRIAL RATING: July 23

Trial 5

Trt no.	Treatment	May 4	May 10	May 16	May 24	May 30	June 6	June 12	June 14	June 21	June 28	July 5	July 12	July 19	July 23 (TRIAL RATING)
1	Unsprayed control														
2	Phyton-016-B, 20 fl oz	X	X	X	X	X	X		X	X	X	X	X	X	
3	Phyton-016-B, 30 fl oz	X	X	X	X	X	X		X	X	X	X	X	X	
4	V-10118, 14 d, 0.02 lb ai	X		X		X		X			X		X		
5	V-10118, 14 d, 0.03 lb ai	X		X		X		X			X		X		
6	Evito, 5 fl oz	X		X		X		X			X		X		
7	Evito + Endorse, 16 oz	X		X		X		X			X		X		
8	Evito + Endorse, 8 oz	X		X		X		X			X		X		
9	JMS Stylet Oil, 0.5%	X		X		X		X			X				
10	SilverDYNE, 0.04%	X	X	X	X	X	X		X	X	X	X	X	X	
11	SilverDYNE, 0.06%	X	X	X	X	X	X		X	X	X	X	X	X	
12	SilverDYNE, 0.08%	X	X	X	X	X	X		X	X	X	X	X	X	
13	Rally + Induce alt	X				X					X				
	Quintec + Induce			X				X					X		
14	Quintec + Induce, 21 d	X			X			X				X			
15	Quintec + Induce, 14 d	X		X		X		X			X		X		

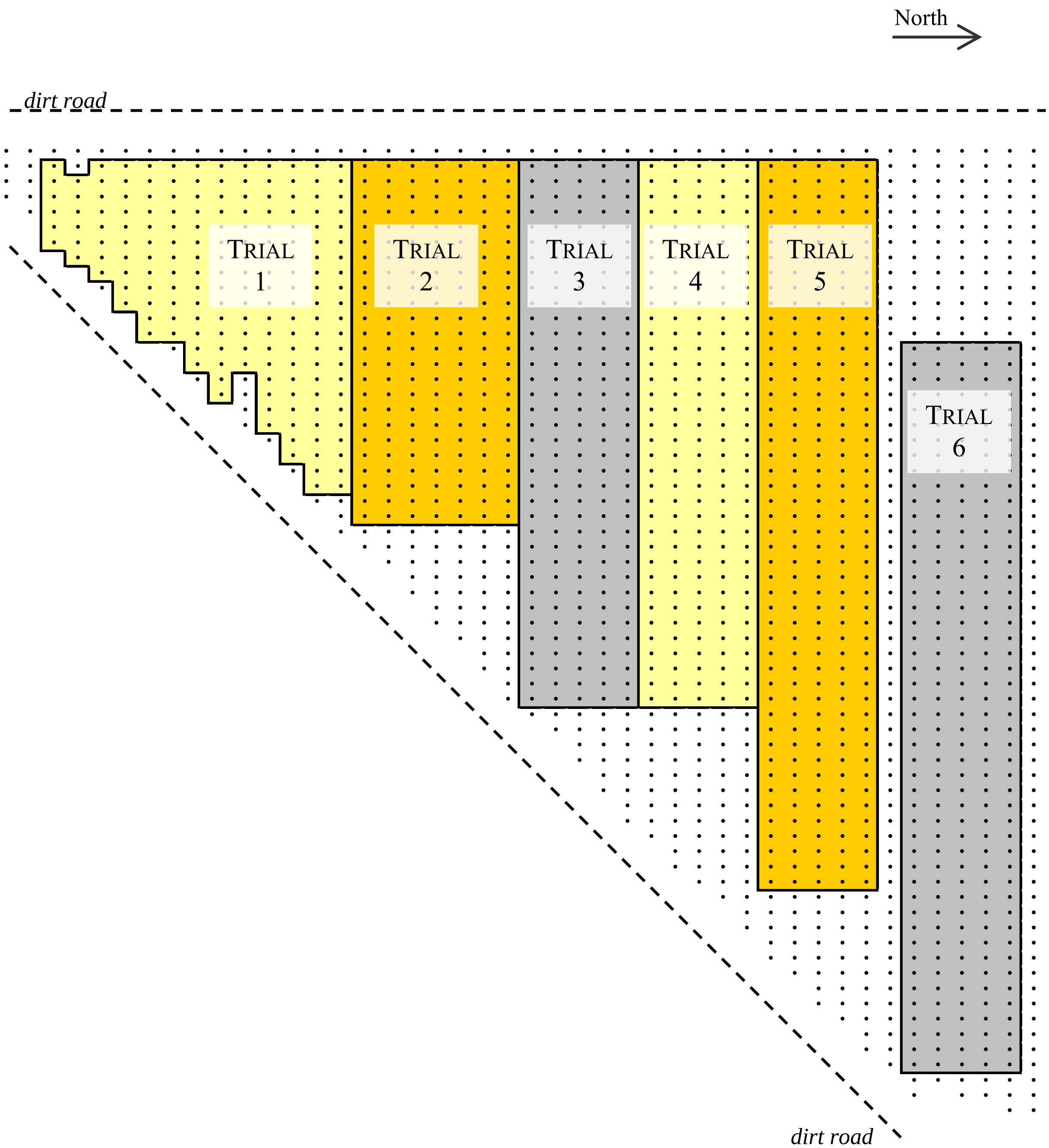
Trial 6

Trt no.	Treatment	May 4	May 10	May 17	May 24	May 30	June 6	June 14	June 21	June 28	July 5	July 12	July 23 (TRIAL RATING)
1	Unsprayed control												
2	Water control	X		X		X		X		X		X	
3	Silwet L-77, 200ml	X		X		X		X		X		X	
4	Rally, 4 oz alt	X				X				X			
	Flint, 2 oz			X				X				X	
5	Quintec, 8 oz	X										X	
	Sonata ASO, 3 qt			X				X					
	Flint, 2 oz					X							
	Rally, 4 oz									X			
6	Actinovate, 12 oz, 7d	X	X	X	X	X	X	X	X	X	X	X	
7	Actinovate, 12 oz, 14 d	X		X		X		X		X		X	
8	Actinovate 12 oz alt	X				X				X			
	Sonata ASO 3 qt			X				X				X	

F. Trial maps

The trials were conducted in a Chardonnay vineyard at Herzog Ranch. Due to the configuration of the general research area, trial 1 was organized in a complete randomized design; all other trials were conducted in a randomized complete block design with blocks oriented in an east-west direction and perpendicular to irrigation. The overview map below is followed by 6 maps showing the specific location of treatment plots in each experiment. All trials contain additional flags for one or more treatments that are not included in the present report.

Overview map



Trial 1 (vineyard rows 31–45) **Trial 2** (vineyard rows 46–52)

Vineyard row	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Block 1	·	·	YKS	· Pu	GD	OKS	GKI	GS	OYS	KC	GKI	GS	PKD	RC	OYS	YKS	B	RD	RKC	GKC	PKD	Y
Block 1	· ·	· ·	OYS	YS	LG	PKD	RD	OKS	GD	Pu	OKS	PKD	YS	GD	OC	O	OKS	RC	KC	KS	GD	YS
Block 2			KC	OKS	GS	BS	GS	BS	LG	GD	YKS	OC	YKS	RD	BS	RC	O	GKC	Y	GD	RKC	KC
Block 2					KC	LG	OC	YS	BS	OKS	GKI	KC	GKI	Pu	YS	B	YKS	OKS	PKD	RD	YS	KS
Block 3					·	Pu	YKS	GS	YS	BS	OC	BS	RC	PKD	RC	YKS	KS	GD	RD	KC	RC	Y
Block 3							OC	OC	RD	RC	GKI	RD	KC	YS	OYS	PKD	YS	OKS	GKC	RKC	O	B
Block 4								·	RC	LG	LG	Pu	GD	GS	Pu	RD	GKC	RKC	RC	Y	GD	O
Block 4									·	GD	·	KC	YKS	GKI	RD	PKD	YKS	B	OKS	KS	KC	YS
Block 5											· ·	OKS	PKD	PKD	RC	RD	KS	O	RC	GKC	B	OKS
Block 5												·	OYS	LG	OYS	RKC	KC	YS	YKS	GD	Y	PKD
Block 6													·	YKS	RD	OKS	YKS	Y	PKD	O	YS	KS
Block 6														·	· ·	KC	RKC	GKC	GD	RC	B	RD
															·	·	·	·	·	·	·	·
																·	·	·	·	·	·	·
																	·	·	·	·	·	·

Trial 3

Vineyard row	Block 1			Block 2			Block 3			Block 4			Block 5			Block 6		
53	PKD	Pu	RD	LG	PKD	RD	K	RD	OKS	YS	KC	YKI	BD	LG	GS	RD	BD	K
54	RC	GS	KC	KC	RC	GKI	YKI	LG	YKS	K	LG	OS	RC	K	GKI	YKS	YS	KC
55	YKI	LG	YS	GS	OS	OKS	GS	GKI	OS	BD	OKS	GS	Pu	KC	YKS	Pu	PKD	RC
56	GKI	OS	YKS	YKS	YS	Pu	KC	Pu	RC	GKI	RC	YKS	OKS	PKD	YKI	GS	GKI	OKS
57	BD	K	OKS	K	YKI	BD	PKD	YS	BD	Pu	RD	PKD	RD	YS	OS	YKI	OS	LG

Trial 4

Vineyard row	Block 1			Block 2			Block 3			Block 4			Block 5			Block 6		
58	OKI	KC	OKS	PC	BD	KC	B	YKS	GKC	YKS	B	BKS	KC	BKS	OKS	GS	RKS	B
59	RKS	GKC	PC	KS	GS	GKC	KC	KS	BD	OKI	RKS	OKS	YKS	YC	RKS	PC	RC	GKC
60	KS	OD	BD	OKI	RC	YKS	GS	BKS	OKI	OD	KS	GKC	B	KS	BD	YKS	YC	OD
61	YC	YKS	RC	RKS	YC	B	RKS	PC	OKS	RC	YC	KC	PC	OKI	GS	BD	BKS	OKS
62	GS	B	BKS	BKS	OKS	OD	RC	OD	YC	GS	PC	BD	OD	GKC	RC	OKI	KS	KC

Trial 5

Vineyard row	63	64	65	66	67
Block 1	KC	RKS	KS	YKS	RD
	W	B	BC	KD	GKC
	Pu	GS	OC	BKS	BS
	PKD	RC	PS	YKI	YC
Block 2	PS	BKS	OC	YKI	KD
	GS	GKC	RD	KC	KS
	RKS	Pu	PKD	B	BC
	W	YC	YKS	RC	BS
Block 3	KD	GKC	BS	BKS	OC
	RKS	YC	YKI	W	GS
	KS	YKS	KC	B	BC
	PS	RC	Pu	PKD	RD
Block 4	KD	GS	PS	GKC	BC
	YKI	RC	KC	YC	B
	BS	RKS	KS	W	PKD
	Pu	BKS	RD	YKS	OC
Block 5	OC	GS	Pu	KC	PS
	YKI	GKC	RC	YKS	YC
	RD	KD	W	BS	PKD
	BKS	BC	KS	B	RKS
Block 6	BC	PKD	YKS	PS	BS
	B	RD	YC	Pu	BKS
	OC	GS	W	RKS	KD
	KC	KS	RC	GKC	YKI

Trial 6

Vineyard row	69	70	71	72	73
	13 ROWS…				
Block 1	YRD	YKC	YS	RKC	KC
	GS	OKI	OKS	BD	RC
	GKC	PKD	OD	LG	YKI
Block 2	OKI	YKC	GKC	YKI	YS
	BD	KC	RC	LG	YRD
	OKS	PKD	RKC	OD	GS
Block 3	PKD	YS	BD	OD	RC
	GS	YKI	KC	YKC	GKC
	RKC	LG	OKI	YRD	OKS
Block 4	LG	OKS	YKC	GS	RC
	OD	GKC	RKC	KC	PKD
	BD	OKI	YS	YKI	YRD
Block 5	KC	GKC	YS	YKI	YKC
	OKS	LG	OKI	YRD	RKC
	GS	RC	BD	OD	PKD
Block 6	LG	YRD	KC	YS	OKS
	RKC	GKC	GS	OD	PKD
	OKI	BD	RC	YKC	YKI
Block 7	GKC	KC	RKC	YKC	OKS
	OD	YKI	YS	GS	OKI
	RC	LG	YRD	BD	PKD
Block 8	YS	RKC	PKD	YKI	GS
	OD	KC	LG	OKS	YKC
	OKI	YRD	GKC	BD	RC

G. Disease evaluation and statistical analysis

Field rating. Powdery mildew colonization on grape clusters was evaluated on 20 July 2007 (Trial 6) and 23 July (Trials 1-5). Our sampling units consisted of at least 10 (usually ≥15) fruit clusters within the inner portion of each two-vine plot (plot edges were not evaluated because of potential overspray, etc.). The disease level on each cluster was estimated either (a) as the proportion of berries within the cluster hosting living mildew, or (b) as a count of the number of infected berries. Count data were subsequently converted to proportions by dividing the number of infected berries by the mean number of berries determined for three size classes of clusters. (For trials 1-5: "small" clusters = 47, "medium" = 71, and "large" = 145 berries/cluster. For trial 6: small clusters = 36 or 55, medium = 75 or 80, and large = 132 or 130 berries/cluster depending on the identity of the rater.)

From the cluster data, plot-level estimates of disease incidence and severity were obtained for statistical analysis. Disease *incidence* within a plot was calculated as the proportion of clusters showing at least some living powdery mildew. Disease *severity* was estimated as the mean proportion of mildew infection across all observed clusters in a plot. Since powdery mildew populations at the site represented a mixture of living, senescing, or dead colonies, our field estimates represent an approximation of living disease levels at the time of veraison (grape softening).

Statistics. Homoscedasticity (equality of variance) of incidence and severity data was evaluated by inspecting residual plots. In many cases, inverse sine transformation of incidence data did not greatly improve the distribution of residuals, so raw data was used. In some cases (e.g., Trial 6), square-root transformation of severity data did moderately improve the distribution of residuals, but raw data were analyzed throughout for consistency and ease of standard error calculations.

Treatment means were evaluated statistically with Type III, one-factor ANOVA (Trial 1) or Type III, two-factor ANOVA (for the block designs of Trials 2-6). *A posteriori* comparisons of individual treatments were conducted with Fisher's α, a test which tends towards higher power and fewer Type II errors, but is not conservative with respect to experiment-wise Type I error (Rao 1998).

Effect sizes. The magnitude of treatment effects on disease severity relative to untreated vines was also evaluated by calculating effect sizes. We first calculated the effect size index, $\mathbf{h} = \varphi_f - \varphi_c$, using severity data, where φ_f = transformed mean of a given fungicide treatment, φ_c = transformed mean of unsprayed plots, φ is calculated as $\varphi = 2\sin^{-1}\sqrt{p}$, and p = disease severity (as a proportion) for the treatment (Cohen 1988). Values of **h** range from 0 (no effect) to 3.14 (π), the maximum theoretical difference if control plots showed 100% disease severity and powdery mildew was completely absent from fungicide-treated plots. Next, we scaled each calculated effect size to a novel metric ($\mathbf{h}_{adj}$) that adjusts effect sizes to the amount of disease present in untreated plots ($\mathbf{h}_{adj} = \mathbf{h}/\varphi_c$). This latter index allows much better comparison of treatment effect sizes across different trials because disease severity in untreated plots in different experiments may vary due to geographic location, other natural sources, or human error.

III. Results and discussion

A. Disease progression and powdery mildew risk index

Overall disease pressure at Herzog Ranch was low during much of the 2007 field season, but reached moderate levels by the time of veraison in mid-July. Powdery mildew was not detected in trial 6 on 10 May 2007, but by 23 May was evident in the trial (Figure 1). Cluster-level disease incidence was highly variable in trial 4 and, in late June, was only 50%. Interestingly, the Gubler-Thomas powdery mildew risk index suggested that environmental conditions were conducive to successful disease development beginning about 12 May (Figure 2). Application of JMS Stylet Oil, a mildew eradicant, by the grower in early April may have reduced innoculum levels sufficiently to substantially delay the onset and proliferation of the pathogen.

Figure 1. Progression of disease incidence in leaves (trial 6) or clusters (trial 4) observed in unsprayed plots. Data in means ±S.D.

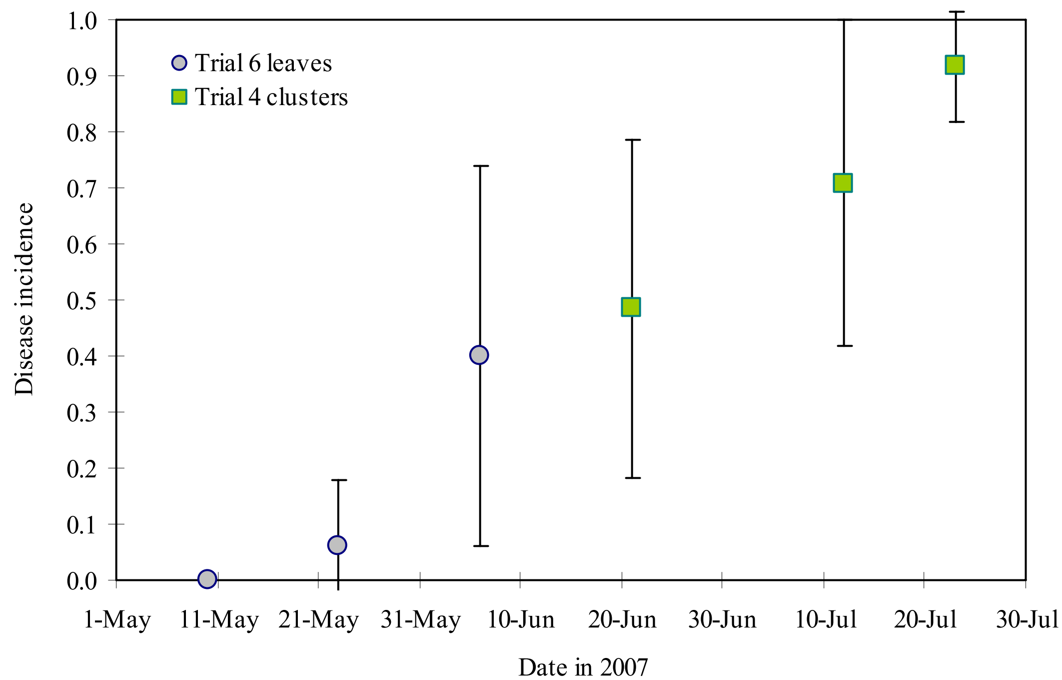
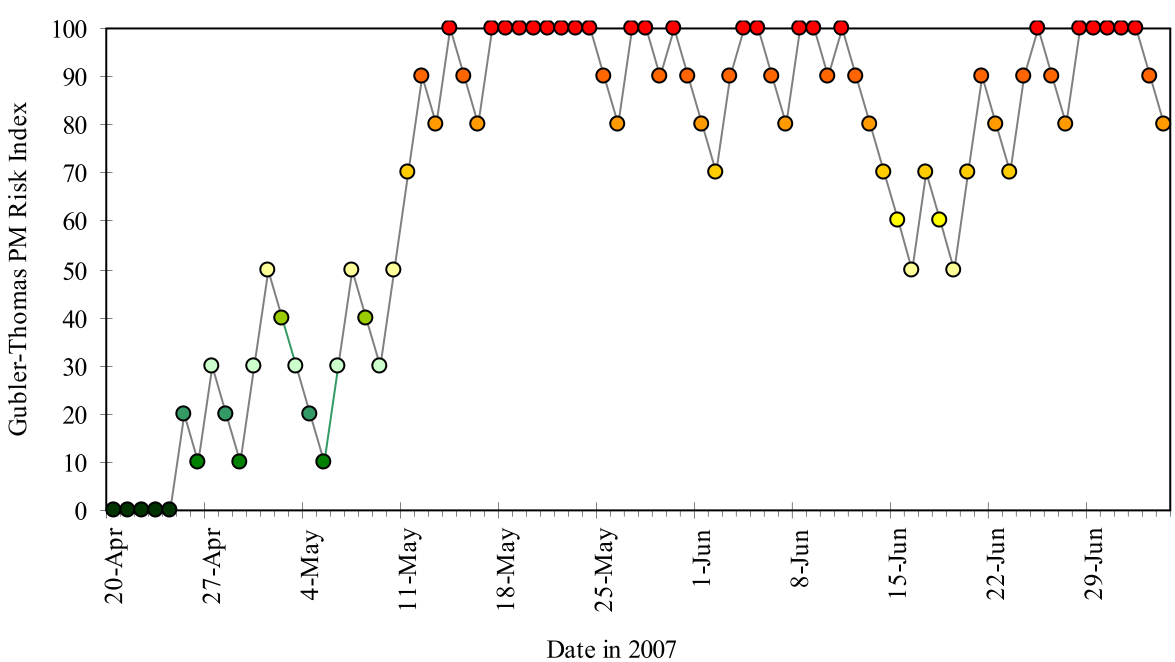


Figure 2. Variation in the Gubler-Thomas powdery mildew risk index over the 2007 growing season. Risk indices ≥60 indicate a high potential for disease proliferation. Data from www.wfsweather.net.



B. Trial 1

Powdery mildew levels in trial 1 control plots reached moderate levels at the time of veraison. All fungicide treatments significantly reduced both disease incidence ($F_{13,68} = 18.4$, $p < 0.0001$; Figure 3) and disease severity ($F_{13,68} = 7.1$, $p < 0.0001$; Figure 4) relative to the unsprayed controls and vines sprayed with only water. Although there was no statistical difference among the 12 fungicide treatments, data suggested a trend toward slightly higher levels of disease incidence in plots treated with Flint (2.5 oz/acre) and Rally (5 oz/acre). The experimental products A7402, A16001, and A13703 all showed low disease incidence and severity. USF 2010 applied at 3 and 4 oz/acre (a mixture of the DMI, tebuconazole, and the stobilurin, trifloxystrobin) tended towards better disease management than Flint (triflozystrobin only), but this was not evident statistically (see also effect sizes of these treatments in Tables 4 and 6).

Figure 3. Disease incidence (mean ± S.E.) in trial 1 treatments. Product names are followed, generally, by application amount (quantity per acre). All treatments in trial 1 were applied on a 21 day spray schedule (the first two applications of both USF2010 treatments were separated by 14 days). Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant. n=6 for all treatments, except n=4 for Flint applied at 2.5 oz/acre.

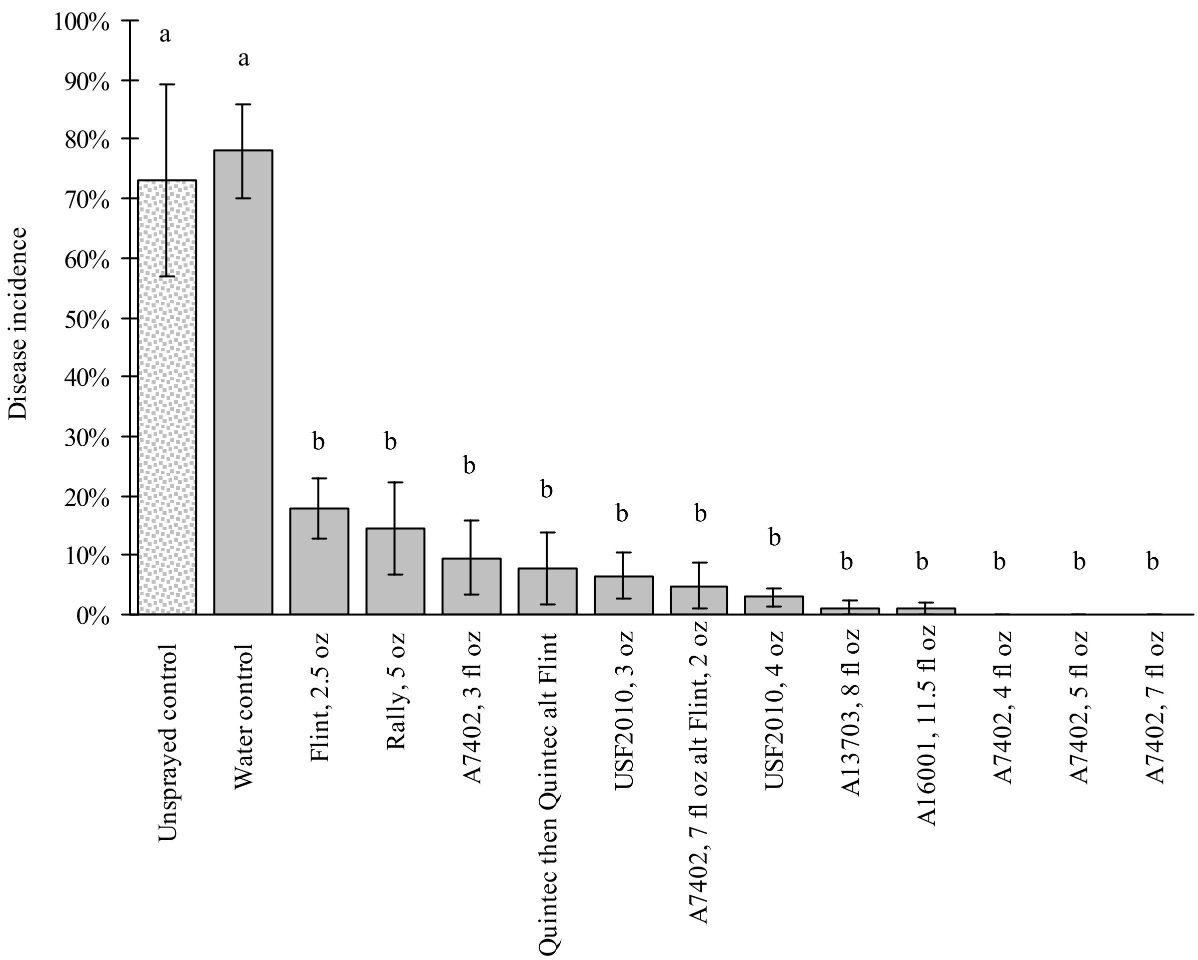
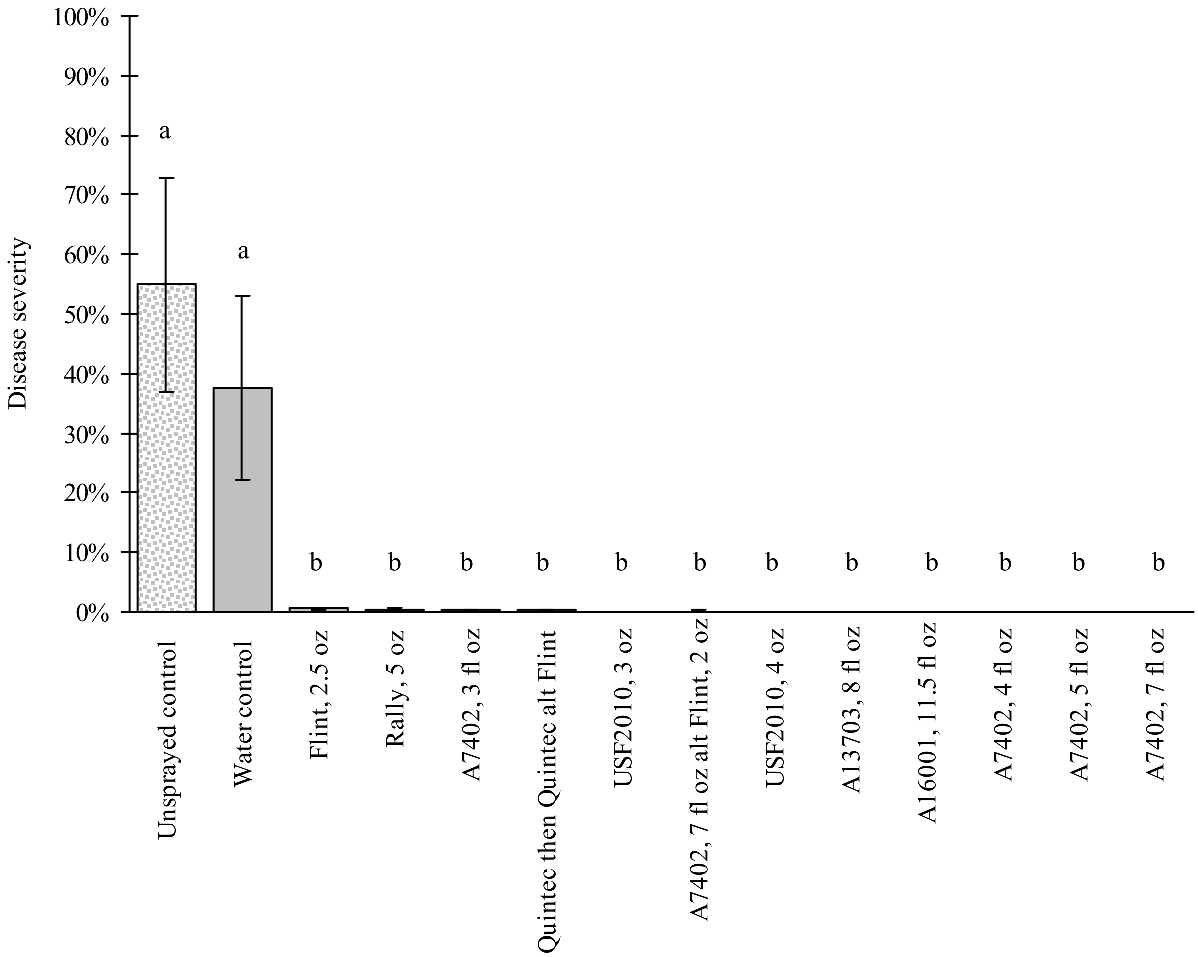


Figure 4. Disease severity (mean ± S.E.) on grape clusters in trial 1. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



C. Trial 2

Disease incidence within unsprayed plots reached nearly 100%, although severity was relatively low at 43%. Fungicide treatments significantly reduced both disease incidence ($F_{12,60} = 256.4$, $p < 0.0001$; Figure 5) and severity ($F_{12,60} = 11.2$, $p < 0.0001$; Figure 6). All Topguard treatments showed very low disease incidence and showed better disease management than EXP90A applied at the lower rate of 0.088 lb ai/acre. All fungicides reduced disease severity approximately equally well (Figure 6). Perhaps due to low disease pressure during this growing season, we were unable to statistically distinguish between Topguard applications made at different spray intervals or tank concentrations. In a series of similar Topguard treatments tested in 2006 at the same site (but under higher disease pressure) data suggested that disease severity increased with both longer intervals and lower concentrations of product (Janousek et al. 2006). Low rates of Topguard (5-8 fl oz/acre) applied every 14-17 days may be acceptable for disease management under low pressure conditions, but higher rates may be necessary in high risk situations.

Figure 5. Disease incidence (mean ± S.E.) in trial 2 treatments. Product names are followed by application frequency (in days) and application amount (quantity per acre). Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant. All treatment n=6.

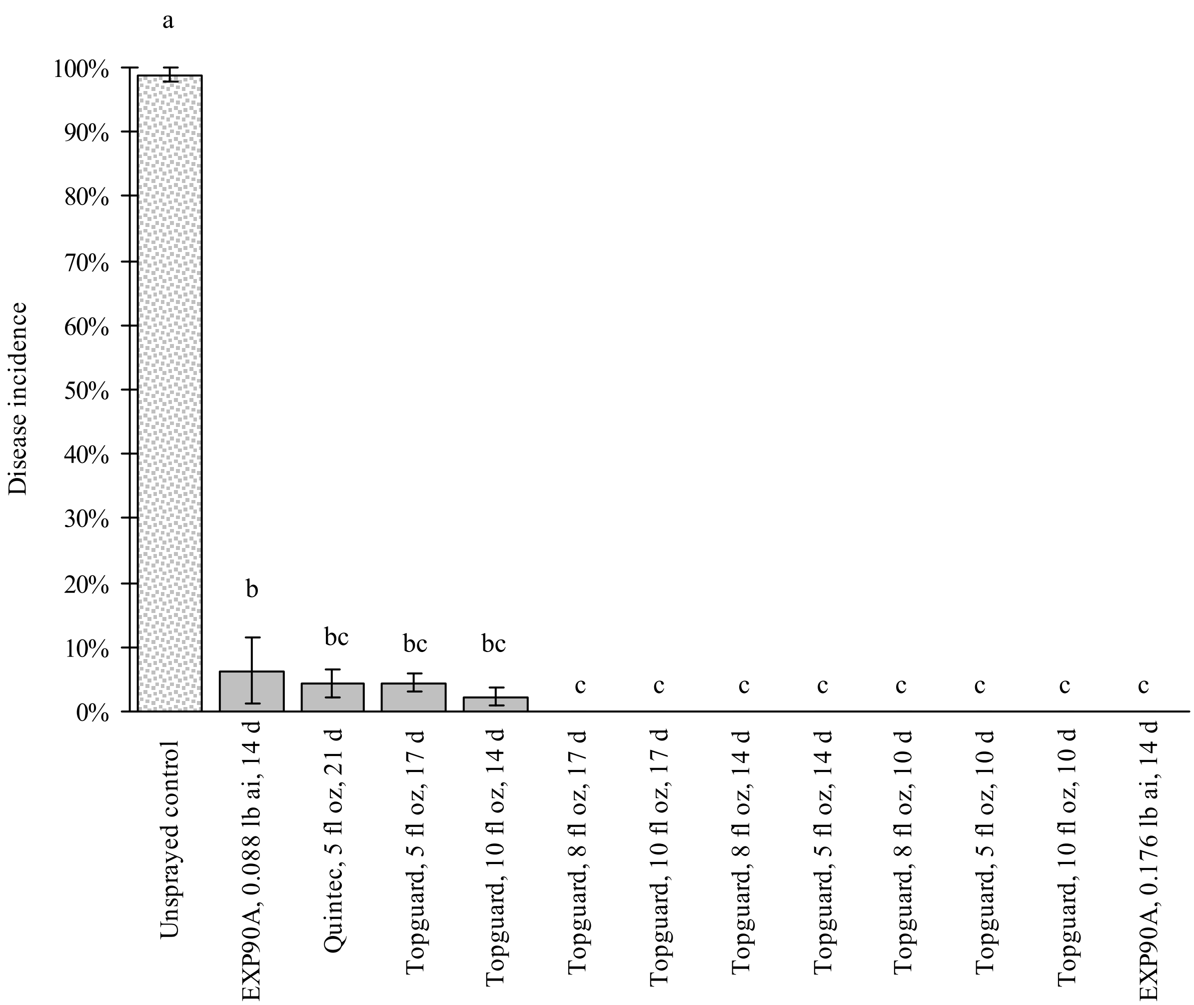
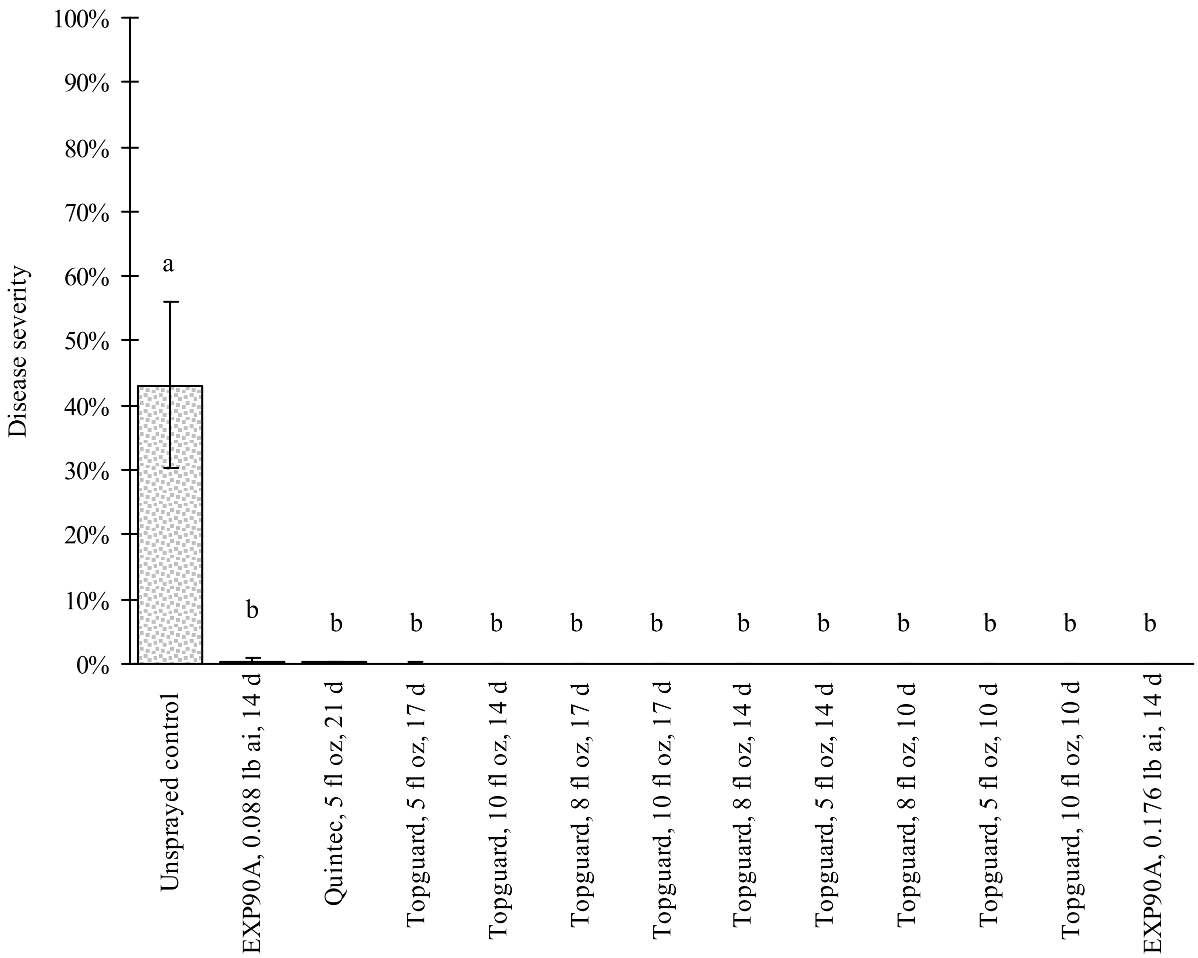


Figure 6. Disease severity (mean ± S.E.) in trial 2 treatments. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



D. Trial 3

Untreated vines reached 97% disease incidence in trial 3. Incidence was reduced in most fungicide treatments however ($F_{13,65} = 18.0$, $p < 0.0001$) and was zero in Procure alternated with Pristine and all three Eminent treatments. Copper treatments showed the highest disease incidence of any fungicide, and the liquid formulation of Badge (copper hydroxide + copper oxychloride) was not statistically better than untreated vines. All products did however, significantly reduce disease severity relative to untreated vines ($F_{13,65} = 32.6$, $p < 0.0001$). Powdery mildew severity in Badge SC was 20% but did not exceed 10% in all other treatments. All Eminent treatments, Procure alone, Procure alternated with Pristine, Elite, Rally and both Sporan concentrations reduced disease levels to < 2%, suggesting that these products are most likely to satisfy market demand for a clean crop. Many of these same materials performed reasonably well in 2006, a year of high disease pressure (Janousek et al. 2006). However, Sporan applied at 14 days (4.4 pt/acre without adjuvant) had 56% disease severity in 2006 and a Procure treatment similar to that tested this year (6.5 fl oz/acre each 14 days) showed 17% disease severity.

Figure 7. Disease incidence (mean ± S.E.) in trial 3 treatments. Product names are followed by application amount (quantity per acre). All treatments were applied on a 14 day schedule, except one Eminent treatment applied at 14 or 21 days. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant.

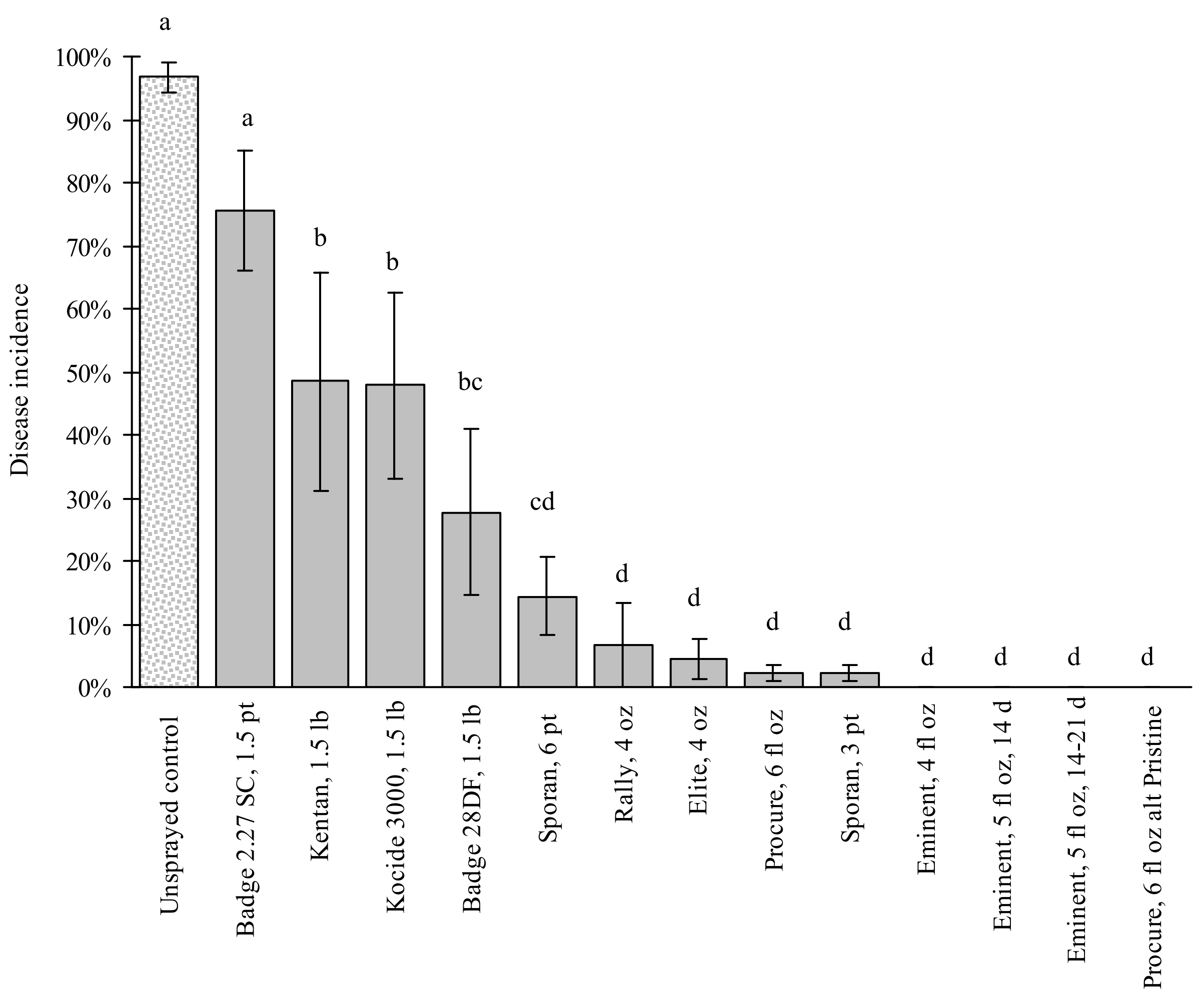
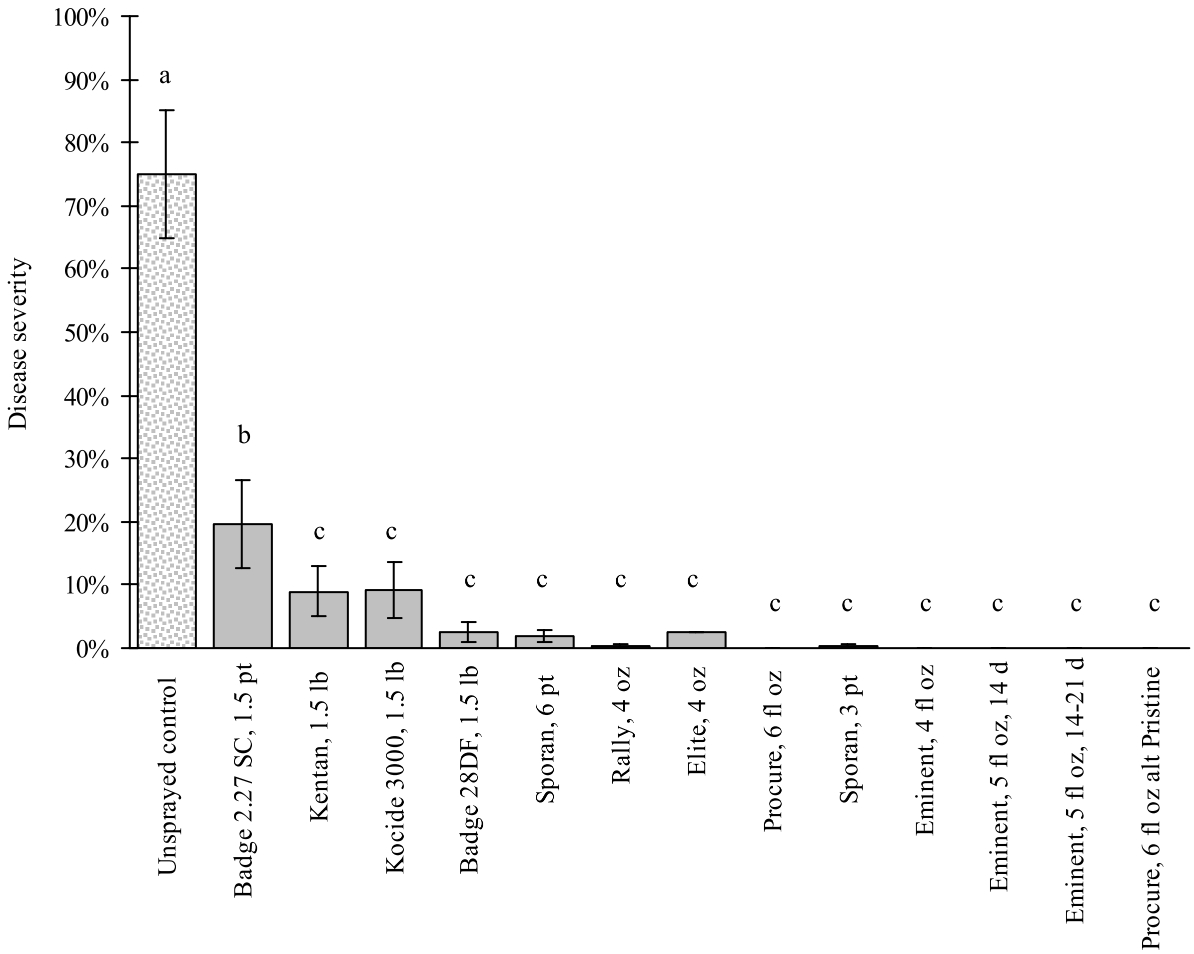


Figure 8. Disease severity (mean ± S.E.) in trial 3. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



E. Trial 4

In trial 4, unsprayed clusters reached disease incidence levels of 92%. Treatment type significantly affected disease incidence ($F_{13,65} = 17.1$, $p < 0.0001$). Kelpak was the worst performing product followed by all LEM17 treatments; the 8 best products (all BAS560 00F and Pristine treatments and LEM17 at 5 fl oz each 14 days) formed a single statistical group. Disease severity also differed across the trial ($F_{13,65} = 5.1$, $p < 0.0001$) with the untreated control (33% severity) and Kelpak (31%) forming a statistical group and all other fungicide treatments (severity of 0-6%) forming a second statistical group. Most treatments reduced disease severity to a level acceptable for commercial harvest (<3%). Our 2007 research generally supports the 2006 finding that BAS560 00F confers good disease control, but LEM17 performance in 2007 was not as good as in 2006 (Janousek et al. 2006).

Figure 9. Disease incidence (mean ± S.E.) in trial 4 treatments. Product names are followed by application frequency (in days) and application amount (quantity per acre). Silwet L-77 concentrations are 4 fl oz/acre. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant.

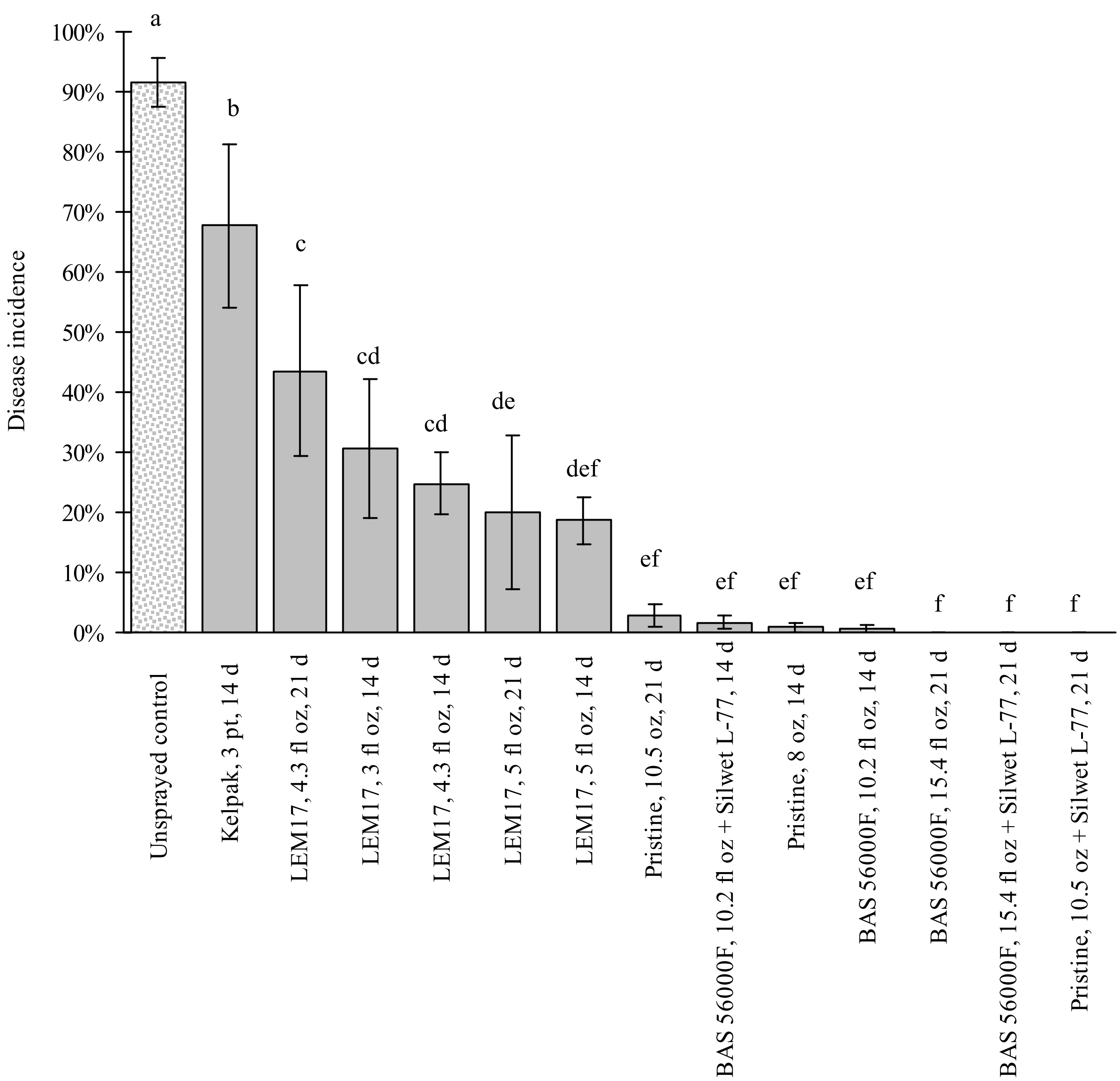
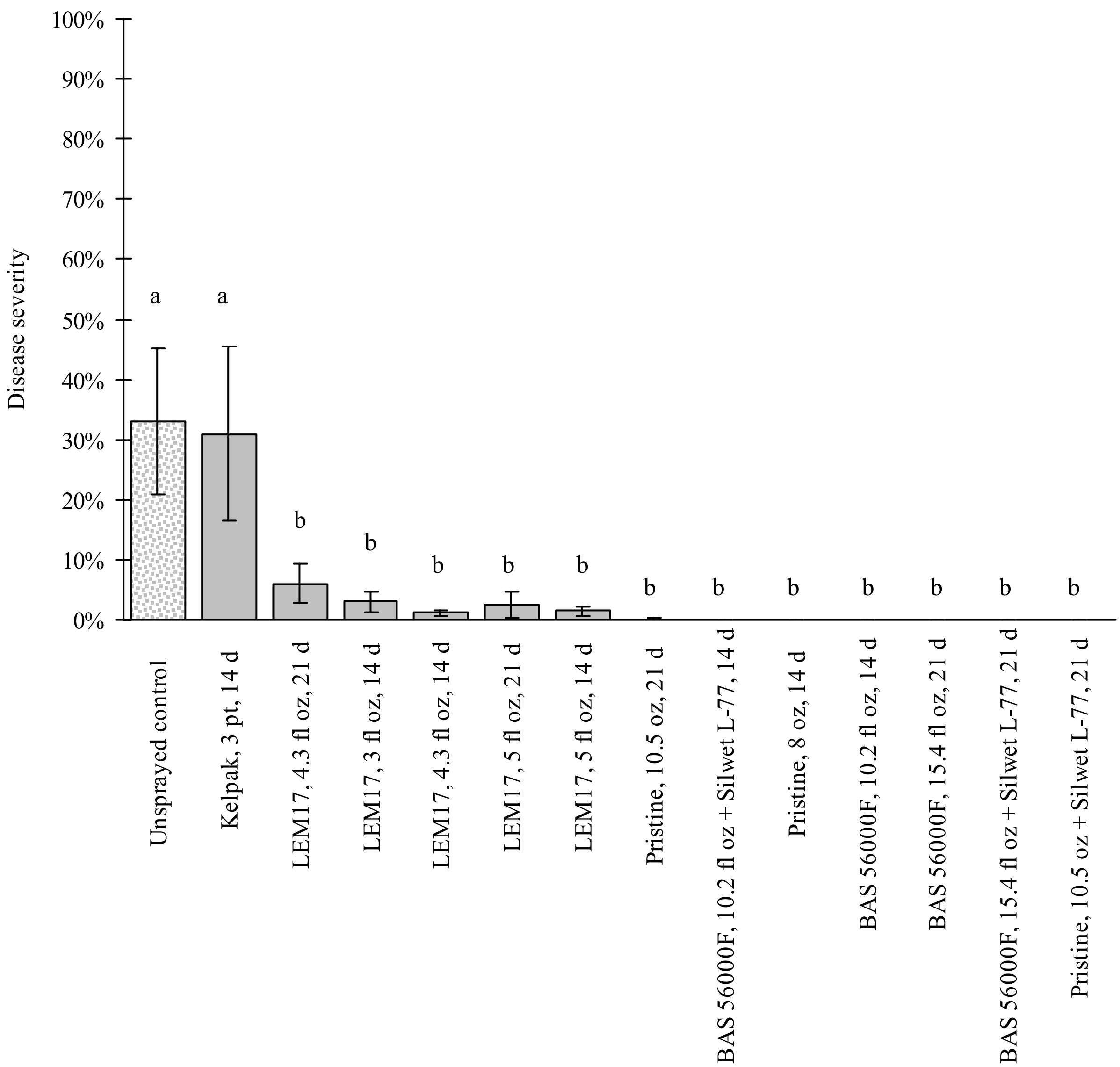


Figure 10. Disease severity (mean ± S.E.) in trial 4. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



F. Trial 5

Disease incidence was high across much of trial 5, with untreated plots showing 100% incidence (Figure 11). The majority of fungicides reduced disease incidence relative to untreated vines ($F_{14,70} = 19.2$, $p < 0.0001$). Quintec, Rally alternated with Quintec, the experimental material V-10118 and Phyton-016-B (applied at 20 fl oz/acre) tended towards lowest incidence in the trial. These products were statistically better than JMS Stylet Oil, Evito treatments, SilverDYNE treatments, and Phyton-016-B applied at 30 fl oz/acre. It is unknown why the higher concentration of Phyton-016-B showed higher disease incidence (severity levels were nearly identical; see Figure 12).

Powdery mildew severity was high (81%) in untreated plots but significantly lower in all other treatments ($F_{14,70} = 45.2$, $p < 0.0001$; Figure 12). V-10118, Quintec, and Rally alternated with Quintec led to the lowest levels of disease severity (all <1%), but several other products - Phyton-016-B, Evito + Endorse and SilverDYNE at 0.06% - grouped with these statistically. The strong anti-mildew performance of the experimental V-10118 is corroborated by other recent work on grape (Janousek et al. 2006; Wilcox and Riegel 2005, 2007).

Figure 11. Disease incidence (mean ± S.E.) in trial 5 treatments. Product names are generally followed by application frequency (in days) and application amount (quantity per acre). SiverDYNE spray concentrations are in % v/v. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant. All treatment n=6.

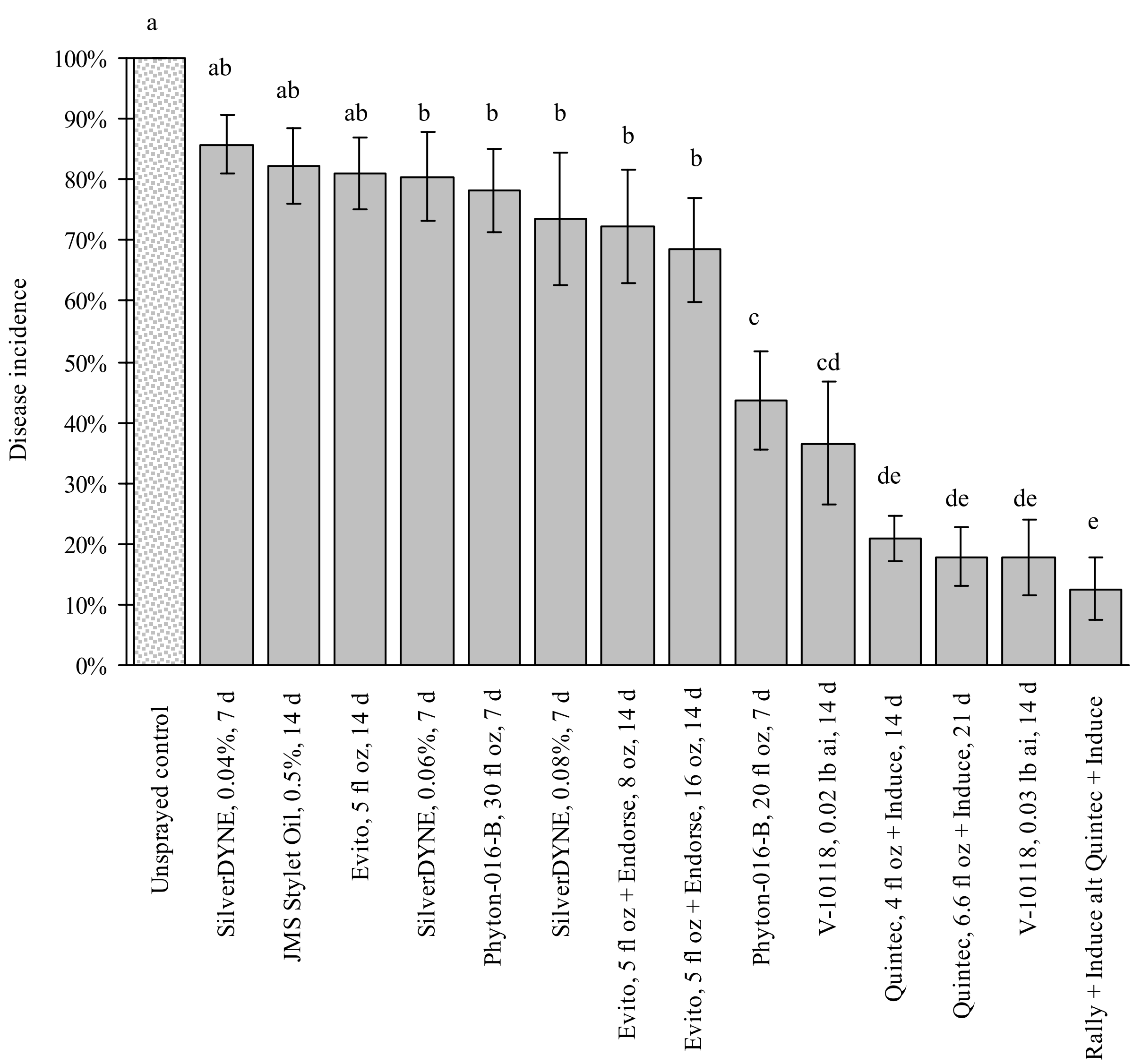
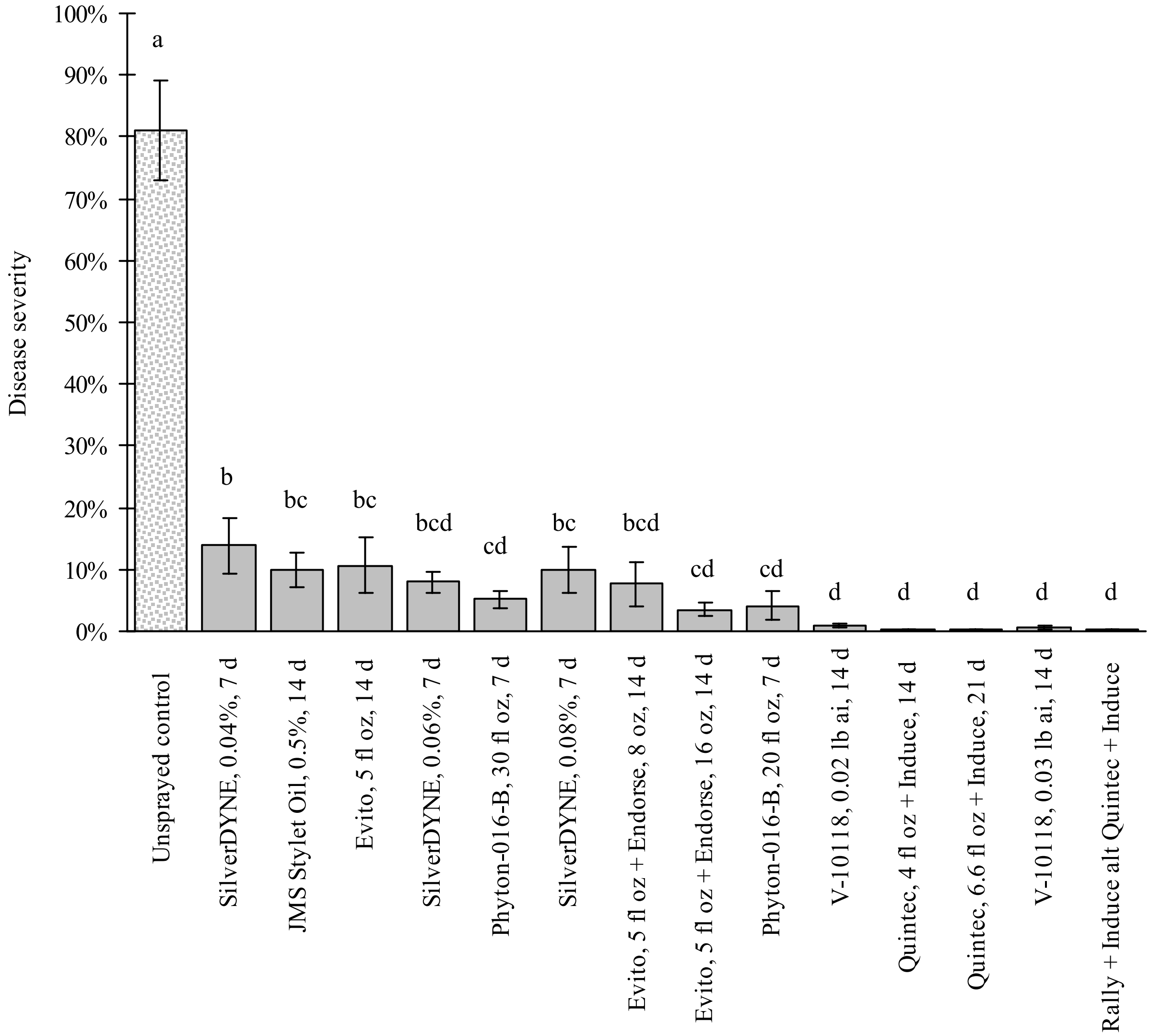


Figure 12. Disease severity (mean ± S.E.) in trial 5. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



G. Trial 6

Powdery mildew incidence was high across all of trial 6 (Figure 13). Untreated plots, plots treated with only water, and vines treated with the adjuvant Silwet L-77 all showed nearly 100% disease incidence. Incidence also exceeded 90% in two biological treatments: Actinovate at 12 oz/acre (14 day interval) and Actinovate alternated with Sonata ASO. We still observed a treatment effect on disease incidence ($F_{7,49} = 12.7$, $p < 0.0001$).

Powdery mildew severity in untreated vines reached 83% at the time of disease rating, matching levels in trial 5, but it was higher than disease in unsprayed vines from other trials (Figure 14). Application of water, adjuvant alone, biofungicides, and the chemical standard (Rally alternated with Flint) significantly reduced disease severity (overall ANOVA: $F_{7,49} = 28.8$, $p < 0.0001$). Actinovate applied on a 14 day interval and Actinovate alternated with Sonata ASO resulted in levels of disease severity similar to that of the adjuvant used alone, but Actinovate (at the same concentration) applied weekly reduced disease to 7.3% and performed about as well as Rally alternated with Flint or Sonata ASO used in a program of rotation with Quintec, Flint, and Rally.

Figure 13. Disease incidence (mean ± S.E.) in trial 6 treatments. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means. Treatments bearing the same letter are not statistically significant. The "Sonata ASO/synthetic fungicide regime" was sprayed at a 14 day interval; please see section C of materials and methods for product concentrations. All treatment n=8.

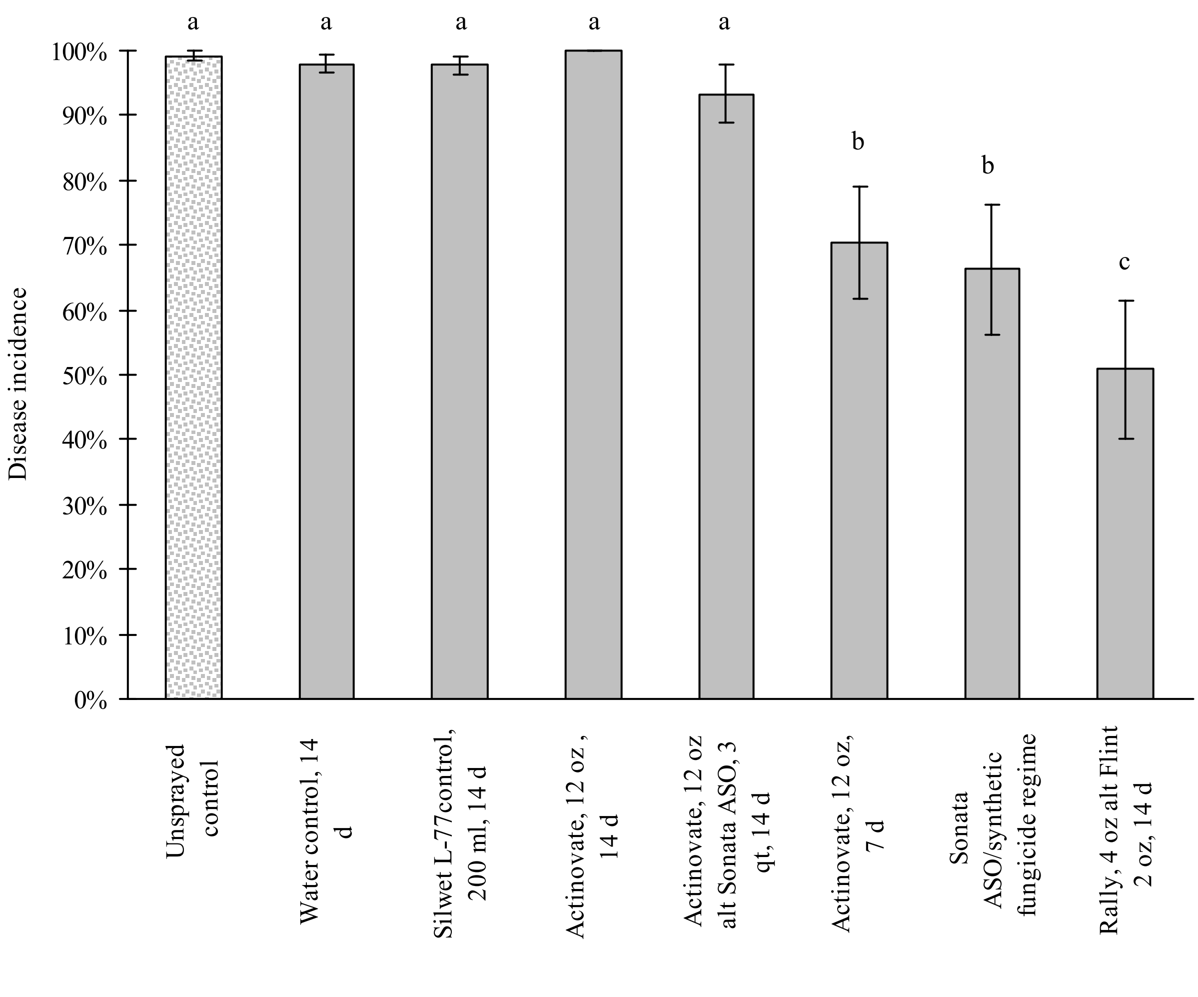
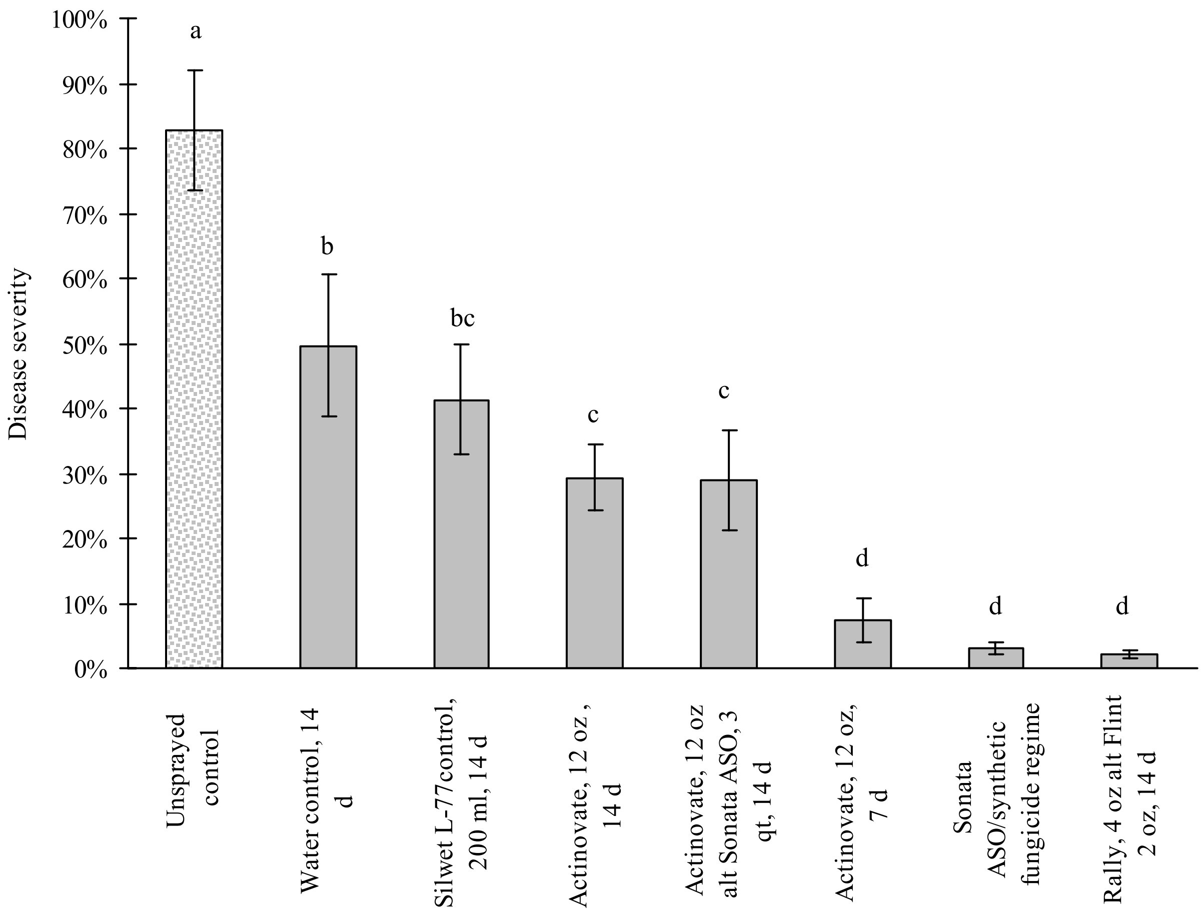


Figure 14. Disease severity (mean ± S.E.) in trial 6. Results of *a posteriori* comparisons of means with Fisher's α test are shown above means.



H. Treatment effect sizes

Analysis of fungicide trial data via traditional hypothesis testing is a common means of determining the efficacy of different products, but possesses several shortcomings with regard to the interpretation of data. Perhaps one of the most important limitations is that statistical significance is influenced by sample size (Murphy and Myors 2004), which is often very low in fungicide field trials (Janousek, unpublished data). Because of low replication, the frequency of Type II error can be high, meaning that two fungicide products that likely differ in efficacy (perhaps only to a small or moderate degree) might be (falsely) concluded to be equally effective statistically because of low experimental power. To complement the hypothesis testing approach, we have also determined the magnitude of our treatment effects on disease severity by calculation of effect sizes. We first determined the effect size metric used for proportion data, **h**, as described in Cohen (1988) to quantify the efficacy of various products used across the 6 fungicide trials conducted this year. These calculations were then scaled to the level of disease in the unsprayed treatment to form a novel metric, $\mathbf{h}_{adj}$. This statistic allows direct comparison of treatments from different trials wherein unsprayed disease levels may differ. Formulas for calculation of **h** and $\mathbf{h}_{adj}$ are given in *Material and Methods, part G.*

For the purpose of comparison, treatments have been grouped according to major classes of compounds, irrespective of trial: (1) water and adjuvant applications, (2) quinolines, (3) carboxyanalides, (4) strobilurins, (5) DMIs, (6) treatments containing a combination of strobilurin and DMI active ingredients, (7) other treatments with active ingredients from 2 chemical classes, (8) coppers, (9) oils, (10) biofungicides, and (11) unclassified products and products with unknown active ingredients.

Water, the adjuvant Silwet L-77, and Kelpak (a fertilizer) had small or negligible effects on disease severity (Tables 1, 12). In contrast, most other fungicides showed high (> 0.80) effect sizes. The best products (e.g., Eminent, A7402, A16001, A13703, Pristine + Silwet L-77) showed effect sizes of 0.98-1.00, suggesting near total inhibition of powdery mildew development on clusters (Tables 5-7). In terms of chemical class, treatments that consisted of (a) DMI compounds, (b) DMI + strobilurin mixtures, or (c), combinations of two different chemical classes, tended showed the highest effect sizes and thus greatest control of disease severity (Tables 5-7). Copper-based products and biofungicides were generally less effective than other fungicides (Tables 8, 10).

Table 1. Effect sizes ($\mathbf{h}_{adj}$) of water and Silwet L-77 (a non-ionic adjuvant) on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
Water	14	N/A	N/A	6	0.32
Water	21	N/A	N/A	1	0.21
Silwet L-77	14	200 ml	trisilicone ethoxylate	6	0.39

Table 2. Effect sizes ($\mathbf{h}_{adj}$) of quinoline (FRAC group 13) treatments on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
Quintec + Induce[1]	14	4 fl oz	quinoxyfen	5	0.95
Quintec	21	5 fl oz	quinoxyfen	2	0.94
Quintec + Induce[1]	21	6.6 fl oz	quinoxyfen	5	0.95

[1] Induce (an adjuvant) was applied at 0.125% for all (except the first) applications.

Table 3. Effect sizes ($\mathbf{h}_{adj}$) of treatments containing carboxyanalide compounds (FRAC group 7) on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
LEM17	14	3 fl oz	penthiopyrad	4	0.72
LEM17	14	4.3 fl oz	penthiopyrad	4	0.83
LEM17	21	4.3 fl oz	penthiopyrad	4	0.59
LEM17	14	5 fl oz	penthiopyrad	4	0.80
LEM17	21	5 fl oz	penthiopyrad	4	0.74

Table 4. Effect sizes ($\mathbf{h}_{adj}$) of stobilurin-containing treatments on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
Evito	14	5 fl oz	fluoxastrobin	5	0.70
Flint 50WG	21	2.5 oz	trifloxystrobin	1	0.91

Table 5. Effect sizes ($\mathbf{h}_{adj}$) of treatments containing demethylase inhibitors (DMIs) on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
Rally	14	4 oz	myclobutanil	3	0.94
Rally	21	5 oz	myclobutanil	1	0.92
Eminent	14	4 fl oz	tetraconazole	3	1.00
Eminent	14	5 fl oz	tetraconazole	3	1.00
Eminent	14 or 21	5 fl oz	tetraconazole	3	1.00
Procure	14	6 fl oz	triflumizole	3	0.99
Elite	14	4 oz	tebuconazole	3	0.97
A7402	21	3 fl oz	difenconazole	1	0.94
A7402	21	4 fl oz	difenconazole	1	1.00
A7402	21	5 fl oz	difenconazole	1	1.00
A7402	21	7 fl oz	difenconazole	1	1.00

Table 6. Effect sizes ($\mathbf{h}_{adj}$) of treatments containing combinations of DMIs and strobilurins on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredients	Trial	$\mathbf{h}_{adj}$
USF 2010	21	3 oz	tebuconazole + trifloxystrobin	1	0.96
USF 2010	21	4 oz	tebuconazole + trifloxystrobin	1	0.97
A7402 alt Flint	21	7 fl oz alt 2 oz	difenoconazole alt trifloxystrobin	1	0.95
Rally alt Flint	14	4 oz alt 2 oz	myclobutanil alt trifloxystrobin	6	0.87
A13703	21	8 fl oz	difenoconazole + azoxystrobin	1	0.99

Table 7. Effect sizes ($\mathbf{h}_{adj}$) of treatments containing other combinations of 2 or more fungicide chemical groups (e.g., strobilurins + carboxyanalides) on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredients and chemical class	Trial	$\mathbf{h}_{adj}$
Quintec with Flint[1]	21	6.6 fl oz	quinoxyfen (quinoline) with trifloxystrobin (strobilurin)	1	0.95
Rally alt Quintec[2]	14	4 oz alt 4 fl oz	myclobutanil (DMI) alt quinoxyfen (quinoline)	5	0.95
Pristine	14	8 oz	boscalid (carboxyanilide) + pyraclostrobin (strobilurin)	4	0.98
Pristine	21	10.5 oz	boscalid + pyraclostrobin	4	0.95
Pristine + Silwet L-77[3]	21	10.5 oz	boscalid + pyraclostrobin	4	1.00
A16001	21	11.5 fl oz	difenoconazole (DMI) + cyprodinil (anilinopyrimidine)	1	0.98

[1] Flint was applied at 2 oz/acre on the third of 4 total fungicide applications in this treatment.
[2] Induce, an adjuvant, was applied at 0.125% on all but the first application.
[3] Silwett L-77, an adjuvant, was included at 4 fl oz/acre.

Table 8. Effect sizes (**h**$_{adj}$) of copper-containing products on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient(s)	Trial	**h**$_{adj}$
Phyton-016-B	14	20 fl oz	copper sulfate[1]	5	0.82
Phyton-016-B	14	30 fl oz	copper sulfate[1]	5	0.80
Badge 2.27 SC	14	1.5 pt	copper hydroxide + copper oxychloride	3	0.56
Badge 28DF	14	1.5 lb	copper hydroxide + copper oxychloride	3	0.85
Kocide 3000	14	1.5 lb	copper hydroxide	3	0.71
Kentan	14	1.5 lb	copper hydroxide	3	0.71

[1] Also contains tannic acid.

Table 9. Effect sizes (**h**$_{adj}$) of oil-based fungicides on powdery mildew severity at Herzog Ranch in 2007. Effect sizes were determined relative to disease levels on unsprayed control vines.

Product	Frequency (days)	Concentration (per acre)	Active ingredient(s)	Trial	**h**$_{adj}$
Sporan, 14d, 3 pt	14	3 pt	clove, rosemary & thyme oils	3	0.94
Sporan, 14d, 6 pt	14	6 pt	clove, rosemary & thyme oils	3	0.87
JMS Stylet Oil, 0.5%	14	0.5% (v/v)	mineral oil	5	0.71

Table 10. Effect sizes (**h**) of biofungicides on disease severity tested at Herzog Ranch. Effect sizes relative to unsprayed controls and application of adjuvant only are presented. ND = no data; NA = not applicable. All biofungicide treatments include the adjuvant Silwet L-77. Product concentrations are given per acre.

Product	Frequency (days)	Concentration (per acre)	Organism and Active ingredient	Trial	**h**$_{adj}$
Actinovate[1]	7	12 oz	*Streptomyces lydicus*	6	0.76
Actinovate[1]	14	12 oz	*Streptomyces lydicus*	6	0.50
Actinovate alt Sonata ASO[1]	14	12 oz alt 3 qt	*Streptomyces lydicus* alt *Bacillus pumilis*	6	0.85
Synthetic fungicides with Sonata ASO[2]	14	various	various with *Bacillus pumilis*	6	0.50

[1] The adjuvant Silwett L-77 was included in this treatment at 200 ml/acre.
[2] This treatment consisted of Quintec (8 fl oz/acre) followed by Sonata ASO (3 qt/acre), then Flint (2 oz/acre), then Sonata ASO (3 qt/acre) then Rally (4 oz/acre) and finally Quintec (8 fl oz/acre).

Table 11. Effect sizes (**h**) of non-classified products (and products with unknown active ingredients) on disease severity tested at Herzog Ranch. Effect sizes relative to unsprayed controls and application of adjuvant only are presented.

Product	Frequency (days)	Concentration (per acre)	Active ingredient	Trial	$\mathbf{h}_{adj}$
SilverDYNE, 0.04%	7	0.04% (v/v)	silver colloid	5	0.66
SilverDYNE, 0.06%	7	0.06% (v/v)	silver colloid	5	0.74
SilverDYNE, 0.08%	7	0.08% (v/v)	silver colloid	5	0.71
Kelpak	14	3 pt	seaweed-derived fertilizer	4	0.04
BAS560 00F	14	10.2 fl oz	unknown	4	0.98
BAS560 00F[1]	14	10.2 fl oz	unknown	4	0.97
BAS560 00F	21	15.4 fl oz	unknown	4	1.00
BAS560 00F[1]	21	15.4 fl oz	unknown	4	1.00
EXP90A	14	0.088 lb ai	unknown	2	0.91
EXP90A	14	0.176 lb ai	unknown	2	1.00
V-10118	14	0.02 lb ai	unknown	5	0.91
V-10118	14	0.03 lb ai	unknown	5	0.93

[1] The adjuvant Silwett L-77 was included in this treatment at 4 fl oz/acre.

IV. References

Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Lawrence Erlbaum Associates, Hillsdale, NJ, 567 pp.

Janousek, C.N., K.C. Asay and W.D. Gubler. 2006. Control of powdery mildew by fungicides in grapes: results of 2006 trials. Published at http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2006.htm; in 5 sections.

Murphy, K.R. and B. Myors. 2004. *Statistical Power Analysis. A Simple and General Model for Traditional and Modern Hypothesis Tests* 2nd ed., Lawrence Erlbaum Associates, Mahwah, NJ., 160 pp.

Rao, P.V. 1998. *Statistical Research Methods in the Life Sciences*. Duxbury Press, Pacific Grove, CA, 889 pp.

Wilcox, W.F. and D.G. Riegel. 2005. Evaluation of fungicide programs for control of grapevine powdery mildew. 2004. *F & N Tests* 60:SMF034.

Wilcox, W.F. and D.G. Riegel. 2007. Evaluation of fungicide programs for control of grapevine powdery mildew, 2006. *Plant Disease Management Reports* 1:SMF005.

V. Acknowledgements

We thank Herzog Ranch for permission to conduct these trials on their property and the numerous chemical company donors who funded this research and supplied materials. We thank P. Backup, J. Broome, A. Eskalen, L. Gallegos, T. Pitman, H. Su, B. Tooker, F. Trouillas, and especially R. Herche, who contributed to various aspects of the research.

VI. Appendix: fungicide materials

Chemical products

Product	Active ingredient(s) and concentration(s)
A7402 EC (=Inspire 2.08EC)	difenoconazole (25%)
A13703G	difenoconazole (11.36%) + azoxystrobin (18.18%)
A16001A	difenoconazole (8.4%) + cyprodinil (24%)
Badge 2.27 SC	copper hydroxide (10-12.5%) + copper oxychloride (10-12.5%)
Badge 28DF	copper hydroxide (40-50%) + copper oxychloride (40-50%)
BAS 56000F SC	unknown (300 g/L)
Elite 45DF	tebuconazole (45%)
Eminent 125ME	tetraconazole (125 g/l)
Endorse 11.3DF	polyoxin D zinc salt (11.3%)
Evito 480SC	fluoxastrobin (40.3%)
EXP90A 2.5SC	confidential product (2.5 lb/gal)
Flint 50WG	trifloxystrobin (50%)
Induce	alkyl aryl polyoxyethylene
JMS Stylet Oil	mineral oil
Kelpak (fertilizer derived from *Ecklonia maxima* [Phaeophyceae; Laminariales])	N (all chemical species: 0.309 %) + P_2O_5 (1.7 %) + K_2O (potash: 0.6 %)
Kentan 40DF	copper hydroxide (40-42%)
Kocide 3000	copper hydroxide (46.1%)
Latron B-1956	non-ionic surfactant (77%)
LEM17 SC	penthiopyrad (20%)
Phyton-016-B	copper sulfate (21.36%) + tannic acid (1.08%)
Pristine 38WDG	boscalid (25.2%)+ pyraclostrobin (12.8%)
Procure 480SC	triflumizole (480g/L)
Quintec 2.08SC	quinoxyfen (22.6 %)
Rally 40WP	myclobutanil (40%)
SilverDYNE	colloidal silver (0.39%)
Silwet L-77	trisilicone ethoxylate (>97%)
Sporan EC	thyme oil (10%) + clove oil (10%) + rosemary oil (18%)
Topguard	flutriafol 1.04SC (12%)
USF 2010 50WG	tebuconazole (25 g/L) + trifloxystrobin (25 g/L)
V-10118 0.41EC	unknown (0.41 lb/gallon)

Biological products

Product	Organism
Actinovate Soluble	*Streptomyces lydicus* WYEC 108 (0.0371 %)
Sonata ASO	*Bacillus pumilis*

Appendix references: 1. www.agraquest.com. 2. Crop Protection Reference. 2002. C&P Press, New York, NY. 3. National Pesticide Information Retrieval System, Purdue Research Foundation, http://ppis.ceris.purdue.edu/htbin/ppisprod.com. 4. Pscheidt, J.W. and C. M. Ocamb (editors). 2006. *2006 Pacific Northwest Plant Disease Management Handbook.* Oregon State University. 607 pp. 5. Quintec® Fungicide Label. Dow AgroSciences, www.dowagro.com/usag/prod/084.htm.