
Control of powdery mildew on pumpkin leaves by experimental and registered fungicides: 2007 trials

Christopher N. Janousek, Jacob D. Lorber, and W. Douglas Gubler
Department of Plant Pathology, University of California, Davis, CA 95616.

University of California Cooperative Extension,
Department of Plant Pathology,
University of California, Davis, March 2008

¹. Address correspondence to: wdgubler@ucdavis.edu or cnjanousek@ucdavis.edu
Published: March 2008 at <http://plantpathology.ucdavis.edu/ext/index.htm>
Copyright © 2007, 2008 by the Regents of the University of California, Davis campus. All Rights Reserved.

I. Introduction

Powdery mildew, caused by the pathogens *Podosphaera xanthii*, *Golovinomyces orontii* and *G. cucurbitacearum*, is an important global disease of cucurbit crops, with many pumpkin, squash, cucumber, and melon varieties being particularly susceptible to infection (Jahn et al. 2002). The disease negatively impacts fruit yield (Bost et al. 1991) and is traditionally controlled mainly by the application of fungicides (McGrath et al. 1996). However, pathogen resistance to chemical fungicides, particularly benomyl and trimefon (a DMI), has been documented in the field (McGrath et al. 1996), suggesting that new materials or novel cultural practices may need to be eventually integrated into current control regimes.

We conducted two adjacent trials at the University of California, Davis Plant Pathology Farm (Solano Co., CA) to test the efficacy of different fungicide products against foliar occurrence of powdery mildew on pumpkin cultivars of *Cucurbita pepo*, a highly morphologically variable species of Cucurbitaceae (Robison and Decker-Walters 1997, Paris 2001). In trial I, we evaluated different concentrations of the unregistered materials Topguard (active ingredient = flutriafol), LEM17 (penthioopyrad), and SilverDYNE (colloidal silver). Trial I also included the registered fungicides Pristine (boscalid + pyraclostrobin), Procure (triflumizole) and 2 combinations of Procure and Quintec (a rotation and tank mixture). In Trial II we tested the efficacy of microbial-based biofungicides and organic products. Treatments consisted of unsprayed and water only controls, two concentrations of Actinovate (*Streptomyces lydicus*), two concentrations of Sporan (plant-derived aromatic oils) and Companion (*Bacillus subtilis*) applied with and without Quintec. Following a 6 week test period, we determined disease incidence and severity on upper and lower leaf surfaces in both trials.

II. Materials and Methods

A. Layout of Trials

Experimental design	Randomized complete block design with 6 replicates (Trial 1). Randomized complete block design with 9 replicates (Trial 2).		
Application method	Tank sprayers.		
Plot length	14 feet	Row spacing	16 feet
No. plants/plot	≤ 8	Plot area	112 ft ² (14 ft by 8 ft)
Plant spacing	variable	Area/6 plots (Trial 1) Area/9 plots (Trial 2)	672 ft ² (= 0.0155 acres) 1008 ft ² (= 0.0232 acres)
Applications began	September 2007	Applications ended	October 2007

Trial 1	Volume water/acre	Volume water/treatment	Volume water/treatment (including additional 10%)
	150 gallons	2.3 gallons	2.6 gallons

Trial 2	Volume water/acre	Volume water/treatment	Volume water/treatment (including additional 10%)
	100 gallons	2.3 gallons	2.6 gallons

B. Experimental chronology

Date	Activity
13 August 2007	Seeds planted.
16 August	Crop first irrigated.
31 October	Spraying completed.
1-7 November	Disease evaluated in trial I.
2-6 November	Disease evaluated in trial II.

C. Experimental treatments

Trial I

Host: *Cucurbita pepo*, Merlin variety

Product	Flag	Interval (d)	FP/Acre	FP/Treatment*
Unsprayed control	Pu+Br	none	none	none
Topguard	K	14-17	10.0 fl oz	5.1 ml
Topguard	Br+Br	14-17	14.0 fl oz	7.0 ml
Procure + Silwet L-77	Pu	14-17	8.0 fl oz + 0.03%	4.1 ml + 2.9 ml (150 gal)
Procure + Quintec + Silwet L-77	R	14-17	4.0 fl oz + 4.0 fl oz + 0.03%	2.0 ml + 2.0 ml + 2.9 ml (150 gal)
Quintec alt Procure + Silwet L-77	G+K	14-17	6.0 fl oz alt 8.0 fl oz + 0.03%	3.1 ml alt 4.1 ml + 2.9 ml (150 gal)
Pristine	Br	12	15.0 oz	7.3 g
LEM 17 20EC	K+W	12	2.0 oz ai	4.8 ml
LEM 17 20EC	G	12	3.5 oz ai	8.5 ml
LEM 17 20EC	K+K	12	5.0 oz ai	12.1 ml
LEM 17 20SC	W	12	2.0 oz ai	4.8 ml
LEM 17 20SC	K+K+G	12	3.5 oz ai	8.5 ml
LEM 17 20SC	B	12	5.0 oz ai	12.1 ml
SilverDYNE	R+K	7	0.1%	9.6 ml

Notes: * These quantities include an extra 10% of product to account for unsprayed residual liquid left in tanks. FP = formulated product; alt = alternated with.

Trial II

Host: *Cucurbita pepo*, Wee-Be-Little variety

Product	Flag	Interval (d)	FP/Acre	FP/Treatment*
Unsprayed control	B	none	none	
Water control	Y	7	-	Water only: 2.6 gallons
Sporan + Silwet L-77	R+R	14	4 pt 0.03 %	48.4 ml + 2.9 ml (100gal)
Sporan + Silwet L-77	P+B	14	6 pt 0.03 %	72.5 ml + 2.9 ml (100gal)
Actinovate	Y+R	7	3 oz	2.2 g
Actinovate	Y+Y	7	6 oz	4.4 g
Companion	Y+B	7	3 qt	72.5 ml
Companion + Quintec	W	7	3 qt + 3 fl oz	72.5 ml + 2.3 ml
Quintec	R	7	3 fl oz	2.3 ml

Notes: * These quantities include an extra 10% of product to account for unsprayed residual liquid left in tanks. FP = formulated product; alt = alternated with.

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.

D. Fungicide applications

Trial I

	Dates of application																																	
	September							October							November																			
Treatment	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	31	DISEASE EVALUATION		
SilverDYNE, 0.1%							X							X																	X			
Topguard, 10 fl oz			X												X																	X		
Topguard, 14 fl oz			X												X																	X		
Pristine, 15 oz			X												X																	X		
Procure, 8 fl oz			X												X																	X		
Procure + Quintec			X												X																	X		
Quintec, 6 fl oz alt			X												X																	X		
Procure, 8 fl oz																X																		
LEM17 SC, 2 oz ai			X													X																	X	
LEM17 SC, 3.5 oz ai			X													X																	X	
LEM17 SC, 5 oz ai			X													X																	X	
LEM17 EC, 2 oz ai			X													X																	X	
LEM17 EC, 3.5 oz ai			X													X																	X	
LEM17 EC, 5 oz ai			X													X																	X	

Plants in
flower;
fruits
developing

Some plants
flowering

Trial II

Treatment	Dates of application																																											
	September										October										November																							
	20	21	22	23	24	25	26	27	28	29	30		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Water control							X															X																			X			
Sporan, 4 pt							X															X																						
Sporan, 6 pt							X															X																						
Actinovate, 3 oz/acre							X															X																				X		
Actinovate, 6 oz/acre							X															X																				X		
Companion, 3 qt/acre							X															X																				X		
Companion + Quintec							X															X																				X		
Quintec, 3 fl oz							X															X																				X		
																																												Plants in flower; some with fruit
																																												Some plants in flower
																																												Plants not yet in flower

E. Trial maps

Trial I

Trial II

Block 1	Pu+Br	K	Br+Br	Pu	R	B	Y	Y+R	Y+Y	Y+B	W+B	Block 1
	-	G+K	Br	K+W	G	P	O+B	R	W	R+R	P+B	
Block 2	K+K	W	K+K+G	B	R+K	Y	R+R	O+B	Y+R	B	Y+Y	Block 2
	-	K+K+G	B	R	K	P	W	Y+B	P+B	W+B	R	
Block 3	G	Br+Br	Pu+Br	R+K	Pu	Y+B	Y+R	P+B	O+B	P	W	Block 3
	Br	G+K	K+K	K+W	W	R+R	B	W+B	Y+Y	R	Y	
Block 4	W	G	B	K+W	Pu	Y+R	R+R	Y	Y+B	O+B	Y+Y	Block 4
	K+K+G	Br+Br	Pu+Br	R	G+K	W+B	P+B	R	P	W	B	
Block 5	K	-	K+K	Br	R+K	B	Y+R	R+R	W	P	P+B	Block 5
	Pu+Br	G+K	Pu	-	K+W	Y+B	O+B	R	Y	W+B	Y+Y	
Block 6	R	Br	R+K	B	K+K	Y+Y	O+B	W+B	Y	R	Y+R	Block 6
	W	G	K+K+G	K	Br+Br	B	P+B	P	R+R	Y+B	W	
Block 7	R+K	K+K+G	K	R	-	P+B	Y+R	P	Y+Y	O+B	W	Block 7
	K+W	G	B	G+K	Br	R	B	W+B	Y+B	R+R	Y	
Block 8	W	Br+Br	K+K	Pu	Pu+Br	R+R	Y+B	R	P+B	O+B	B	Block 8
	-	K+W	B	Br	Br+Br	P	W+B	Y+Y	W	Y	Y+R	
Block 9	Pu	K	R	K+K+G	W	R	B	P	Y+Y	W	Y	Block 9
	Pu+Br	K+K	G	R+K	G+K	P+B	Y+B	R+R	W+B	Y+R	O+B	

F. Disease evaluation and statistical analysis

Field evaluation of disease	Approximately 15-30 (usually about 30) haphazardly-collected leaves were rated for disease incidence in each plot (incidence is defined as the proportion of leaves with at least one mildew colony present). Disease severity was also assessed on about 10 leaves per plot and estimated as colony density (mean number of colonies per cm ²) by placing small paper quadrats on the leaf, centered over the upper lobe. Incidence and severity estimates were collected on both upper and lower leaf surfaces.
Statistical evaluation	Raw data is presented as means with 90% confidence intervals. Additionally, treatment effect sizes (ES) were determined for each fungicide relative to the unsprayed control in for severity data in each trial. ES were calculated using Hedges Response Ratio, $L = \ln(m_{\text{trt}}/m_{\text{control}})$ where m_{trt} and m_{control} are treated and control population means (Hedges et al. 1999). Larger negative values of L correspond with greater reductions in disease severity by a given treatment. (In most ES calculations, mean to standard error ratios were less than three for the smaller member of a pair of means, suggesting that L may have a small bias [Hedges et al. 1999]).

III. Results and discussion

Following 6 weeks of fungicide application, powdery mildew colonies were ubiquitous in both trials. Disease development, however, seemed to be faster in Merlin plants than in the Wee-Be-Little variety, appearing soon after the initiation of fungicide treatments. In both pumpkin varieties, powdery mildew colonies were present on both the upper and lower surface of leaves (Figure 1).

Trial I. Disease incidence across the trial was high, with 90% of leaves in untreated plots showing at least some colony presence (Figure 2). The upper surface of leaves in several fungicide treatments showed at least 50% disease incidence, but infection dropped to 10-20% in the best treatments (Procure, Procure + Quintec and LEM17 EC). In many treatments, disease incidence was higher on the lower leaf surface, although substantial overlap in confidence intervals suggests these differences were not statistically significant. The generally good performance of Procure and Quintec treatments (and somewhat more modest performance of Topguard applications) agrees well with results obtained during fall 2006 with similar fungicide treatments (Janousek et al. 2006).

Disease severity (measured as the density of colonies on the leaf surface) was also high in untreated plants (Figure 3). Upper leaf surface disease severity was greatly reduced in all fungicide treatments except SilverDYNE applied at 0.1%. Leaves treated with Procure + Quintec showed disease had zero colony density (the ~10% frequency of disease incidence observed in this treatment occurred because colonies appeared outside of the upper lobe of the leaf where severity was measured, or on the additional leaves that were not evaluated for severity).

Effect size data on disease severity also suggested that all treatments (except SilverDYNE) showed significantly less disease than control plots (Figure 4). Importantly, the ES data better elucidate differences among fungicide treatments, suggesting that for the upper leaf surface, most LEM17 treatments and both Procure treatments resulted in the lowest density of pathogen colonies.

Trial II. Disease incidence in the Wee-Be-Little pumpkins approached 80% on the upper leaf surfaces of unsprayed plants and exceeded 50% on the upper leaf surface of most treatments (Figure 5). Like the Merlin variety, disease incidence generally appeared to be greater on the lower surfaces of leaves. Quintec applied alone or with the biofungicide Companion, greatly reduced disease incidence and markedly outperformed other biofungicides and organic products.

Severity data suggested that all biofungicide and oil treatments reduced colony density relative to the control at least by a factor of three (Figure 6). Nevertheless, leaf-to-leaf variation in severity was high, resulting in large confidence intervals. Quintec and Companion + Quintec treated plants showed the greatest reduction in disease severity. However, ES data also suggested that for upper leaf surfaces, reduction of disease severity was significantly different from zero for both Sporan treatments, Companion, and Actinovate applied at 3 oz/acre (Figure 7). Companion (*Bacillus subtilis*) appeared to be the best organic product.

Overall, ES estimates were much larger for most synthetic fungicides in trials I and II relative to the organic products in trial II suggesting that synthetic products generally outperform organic materials. Companion gave the best control of the organic materials tested and it disease reduction approximately matched that of Topguard (compare Figures 4 and 7).

Figure 1. Powdery mildew colonies on leaves of Merlin (left) and Wee-Be-Little (right) varieties.



Figure 2. Powdery mildew incidence on upper and lower leaf surfaces in trial I treatments (means \pm 90% confidence intervals).

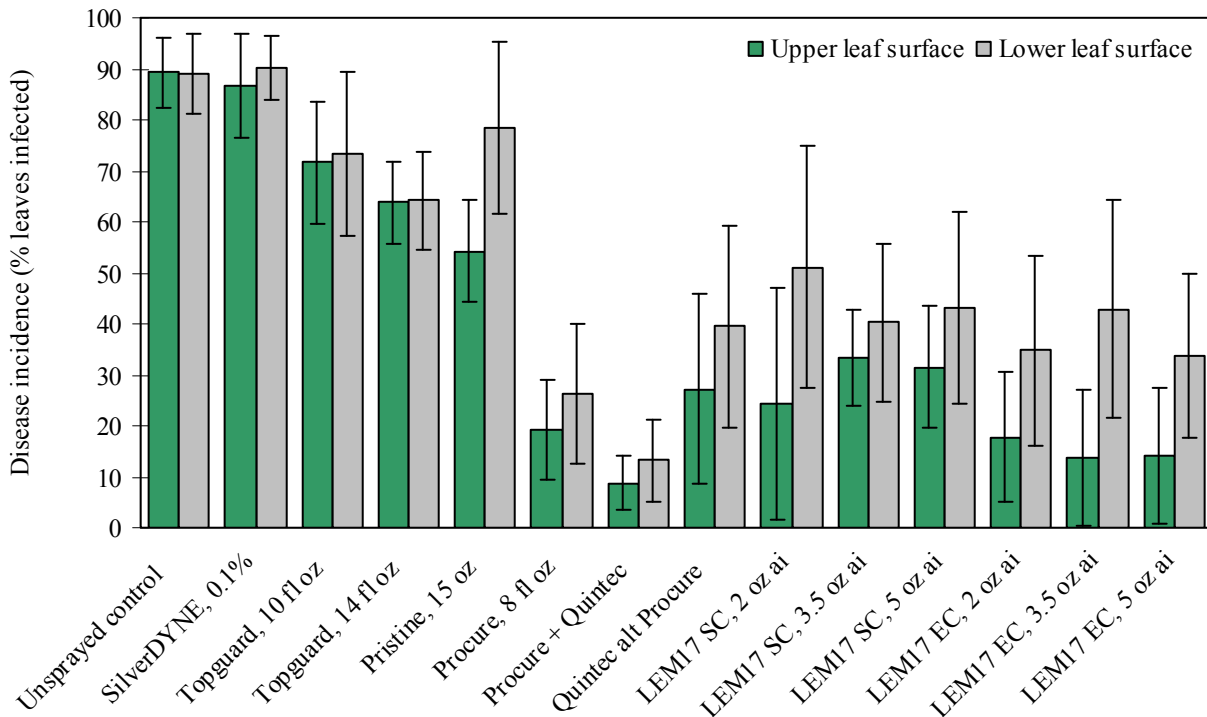


Figure 3. Disease severity (colony density per cm²) on upper and lower leaf surfaces in trial I treatments (means ± 90% confidence intervals).

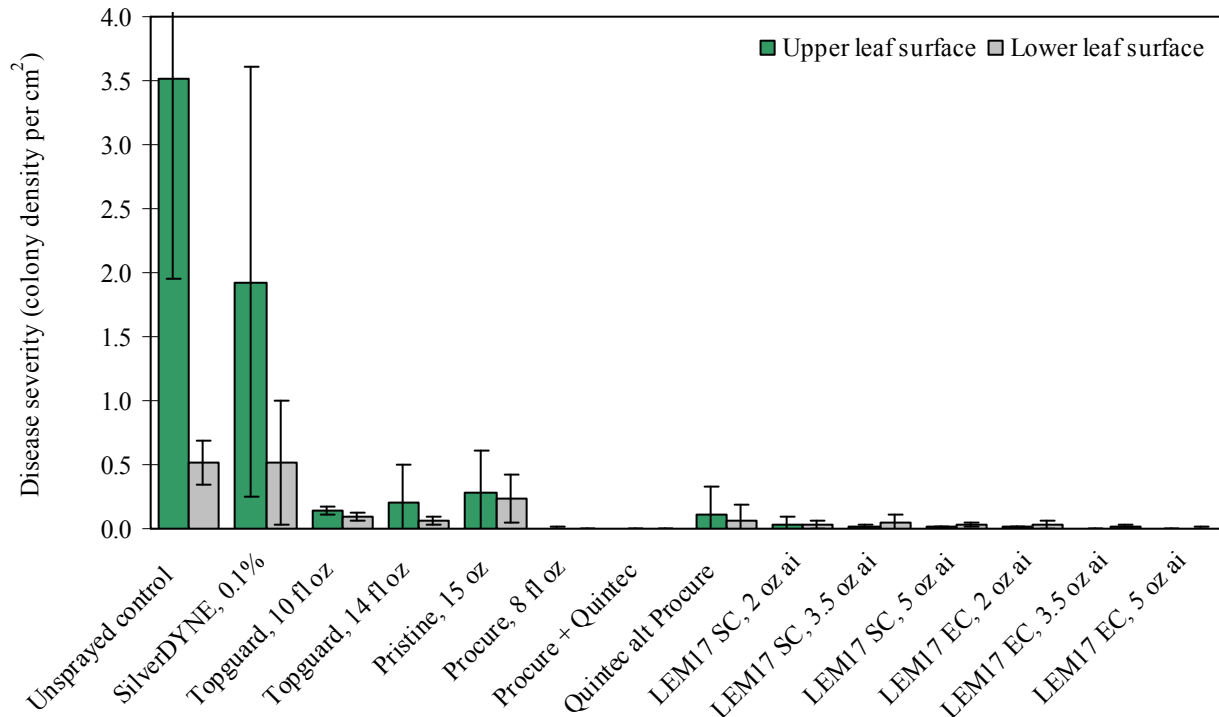


Figure 4. Effect size estimates (*L*) for trial I treatments on upper and lower leaf surfaces (± 90% confidence intervals). Increasingly negative ES estimates show greater reductions in powdery mildew severity compared with untreated leaves. No estimate of *L* was possible for the disease severity on the upper and lower leaf surfaces of the Procure + Quintec treatment because severity was 0.

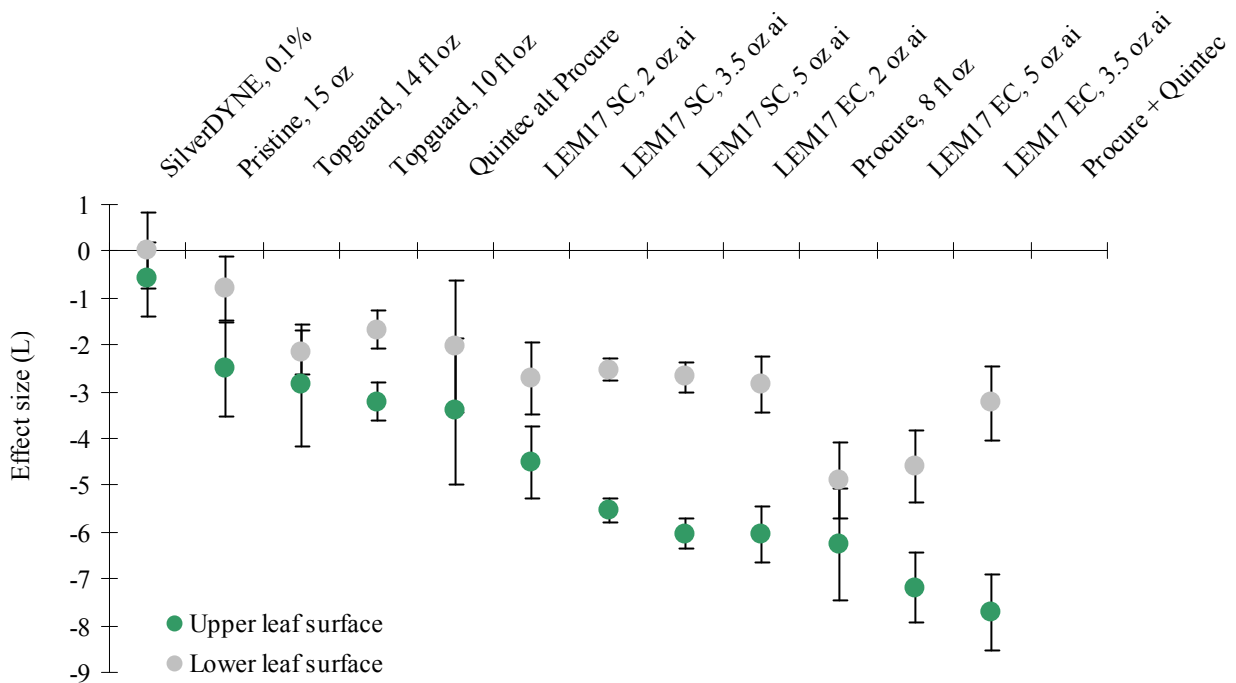


Figure 5. Powdery mildew incidence on upper and lower leaf surfaces in trial II treatments (means \pm 90% confidence intervals).

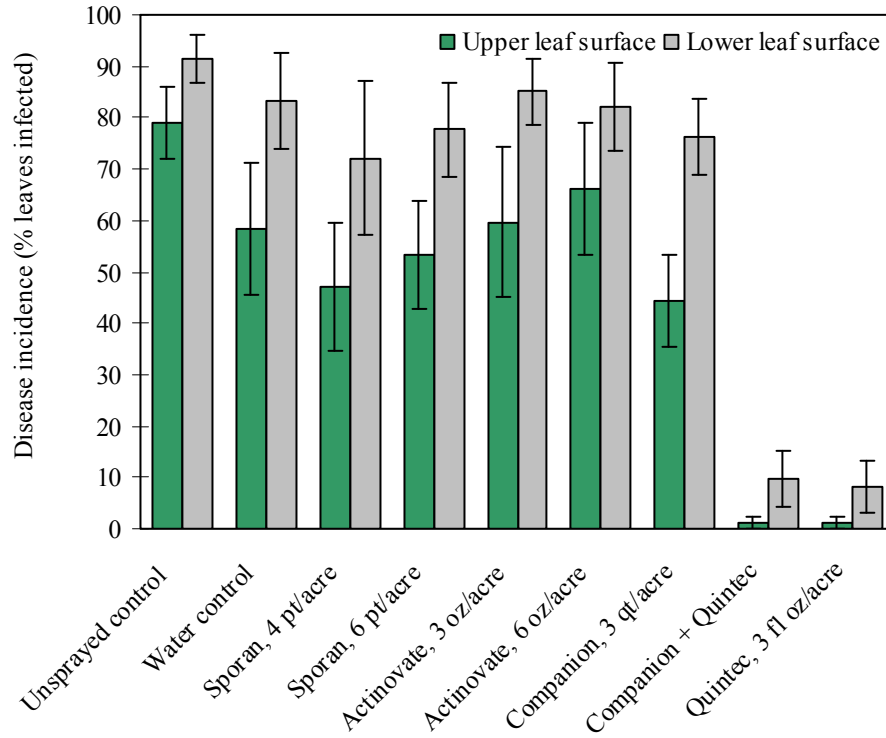


Figure 6. Powdery mildew severity (colony density per cm^2 of leaf surface) on upper and lower leaf surfaces in trial II treatments (means \pm 90% confidence intervals).

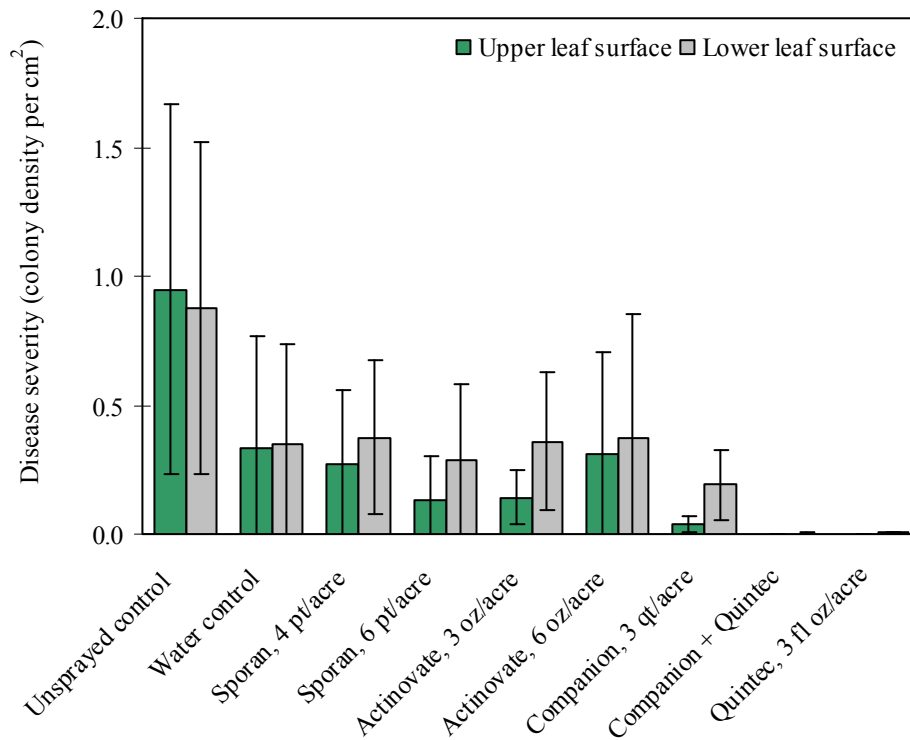
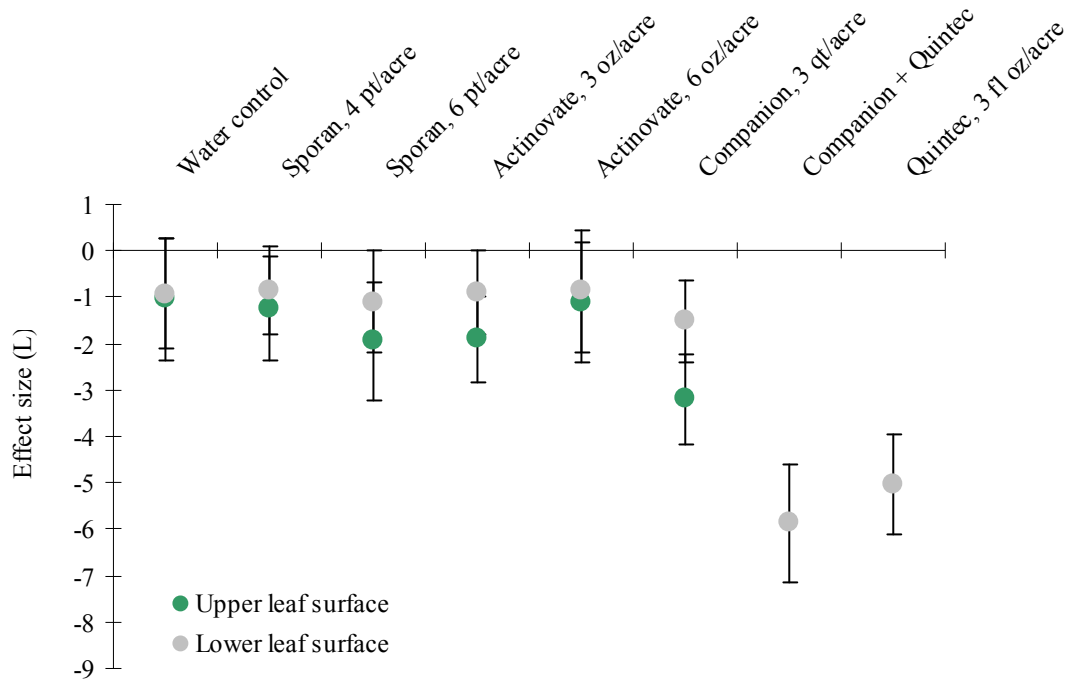


Figure 7. Effect size estimates (L) for trial II treatments (magnitude of treatment reduction of powdery mildew severity) on upper and lower leaf surfaces ($\pm 90\%$ confidence intervals). No estimate of L was possible for the disease severity on the lower leaf surface of Quintec and Quintec + Companion treatments because severity was 0.



IV. Acknowledgements

We thank P. Backup, R. Herche, J. Jertberg, R. Kaur, T. Kaur, P. Parikh, and J. Weant for assistance with disease evaluation. UCD farm staff assisted with planting and maintenance of the field.

V. References

- Bost, S.C., C.A. Mullins, G. Evans, R.A. Straw and K.E. Johnson. 1991. Pumpkin cultivar performance under fungicide treated and non-treated conditions. *Biol. Cult. Tests* 6:28.
- Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Lawrence Erlbaum Associates, Hillsdale, NJ, 567 pp.
- Hedges, L.V., J. Gurevitch, and P.S. Curtis. 1999. The meta-analysis of response ratios in experimental ecology. *Ecology* 80:1150-1156.
- Jahn, M., H.M. Munger and J.D. McCreight. 2002. Breeding cucurbit crops for powdery mildew resistance. In: *The Powdery Mildews. A Comprehensive Treatise*. APS Press, St. Paul, MN, p.239-248.
- Janousek, C.N., K.C. Asay and W.D. Gubler. 2006. Fungicide control of pumpkin powdery mildew: results of the 2006 trial. Published on-line at: <http://plantpathology.ucdavis.edu/ext/gubler/fungitrials2006/file/cucurbitreport-2006.pdf>

McGrath, M.T., H. Staniszewska, N. Shishkoff and G. Casella. 1996. Fungicide sensitivity of *Sphaerotheca fulginea* populations in the United States. *Plant Disease* 80:697-703.

Paris, H.S. 2001. History of the cultivar-groups of *Cucurbita pepo*. *Hort. Rev.* 25:71-170.

Robison, R.W. and D.S. Decker-Walters. 1997. *Cucurbits*. CAB International, Wallington, UK, 226 pp.

VI. Appendix: materials

Chemical products

Product	Active ingredient and concentration
LEM17 20EC	penthiopyrad (20%)
LEM17 20SC	penthiopyrad (20%)
Pristine 38WDG	boscalid (25.2%) + pyraclostrobin (12.8%)
Procure 480SC	triflumizole (480 g/L)
Quintec 2.08SC	quinoxifen (300 g/L)
SilverDYNE	colloidal silver (0.39%)
Silwet L-77	trisilicone ethoxylate (>97%)
Sporan	clove oil (10%) + rosemary oil (18%) + thyme oil (10%)
Topguard SC	flutriafol (125 g/L)

Biological products

Product	Organism and concentration
Actinovate	<i>Streptomyces lydicus</i> (1 x 10 ⁷ cfu/g)
Companion	<i>Bacillus subtilis</i> GB03 (2.7 x 10 ⁷ cfu/ml)

Appendix references: 1. Pscheidt, J.W. and C. M. Ocamb (editors). 2006. *2006 Pacific Northwest Plant Disease Management Handbook*. Oregon State University. 607 pp. 2. www.agraquest.com 3. www.growthproducts.com