Annual Report 2011: Organic Wine Grapes
Carol Miles, Walter Mahaffee, Michelle Moyer, Jonathan Roozen, David Wheeler, Gale Sterrett, Esther Nielsen, and Jacqueline King
WSU Mount Vernon NWREC
16650 State Route 536, Mount Vernon, WA 98273
Tel. 360-848-6131 Email *milesc@wsu.edu*
http://maritimefruit.wsu.edu/

TITLE: Management of powdery mildew (*Erisiphe necator*) in organic wine grapes in western Washington

PERSONNEL: Carol Miles, Vegetable Extension Specialist, WSU Mount Vernon NWREC
Walter Mahaffee, Research Plant Pathologist, USDA-ARS, Corvallis, OR
Jonathan Roozen, Associate in Research, WSU Mount Vernon NWREC
Michelle Moyer, Viticulture Extension Specialist, WSU Prosser IAREC
David Wheeler, Graduate Student, WSU Mount Vernon NWREC
Gale Sterrett, Technical Assistant, WSU Mount Vernon NWREC
Esther Nielsen, Technical Assistant, WSU Mount Vernon NWREC
Jacqueline King, Technical Assistant, WSU Mount Vernon NWREC

PRINCIPAL INVESTIGATORS:
Carol Miles, Vegetable Horticulture Specialist, WSU Mount Vernon NWREC, 16650 State Route 536, Mount Vernon, WA 98273; (360) 848-6150, milesc@wsu.edu.
Michelle Moyer, Viticulture Extension Specialist, WSU Prosser IAREC; 509- 786-9234; michelle.moyer@wsu.edu
Walter Mahaffee, Research Plant Pathologist, USDA-ARS, 3420 NW Orchard Avenue, Corvallis, OR 97330; (541) 738-4036, Walt.Mahaffee@ars.usda.gov

INTRODUCTION:
Organic wine grape production is expanding in western Washington due to increased demand for local organic wine. Growers in the region report serious problems in controlling grape powdery mildew (GPM) (*Erisiphe necator*). Sulfur is the most commonly used fungicide for GPM control, regardless of whether management is based on conventional or organic approaches. Sulfur applications can have negative impacts on wine making and efficacy of biological control. In order to avoid sulfur residues on grapes many growers use other fungicides post fruit set; however, for organic production there are few alternative fungicides and none are as economical or effective as sulfur when used as the sole source of GPM management. In this study we evaluated four organic fungicides, Serenade, Sonata, Regalia, and Sulfur in combination with fruit zone leaf removal, a cultural disease management technique, to determine if it is possible to enhance the efficacy of fungicide applications for GPM management.

ACCOMPLISHMENTS: A survey of the organic grape vineyard at WSU Mount Vernon NWREC on April 27, 2011 revealed significant vine damage; approximately 20% of plants were either dead or weak and needed to be replaced. Remaining plants were not of sufficient size to carry out the proposed spray trial. Plant loss was due to vine health deterioration caused by a late application of nitrogen in July-August 2010 followed by vine pruning in August that resulted in new growth that did not fully acclimate, and high grape powdery mildew (GPM; *Erysiphe necator)* disease pressure. These effects reduced vine cold hardiness, exacerbating the effects of a cold event that occurred in November. Due to these complications we redesigned this study to fit into a newly identified commercial vineyard in Whatcom County (Siper Vineyard) that has been managed organically.

Siper Vineyard is 3 acres planted in 2008, and includes *Vitis vinifera*'Madeleine Angevine', a common white wine variety grown in western Washington. The planting was cane-pruned to 5-7 buds per cane, plus a 2-bud spur was retained for next year's renewal canes. The research design was a randomized complete block with split plot treatments where the main plot treatment was fungicide and the split plot treatment was leaf removal. The main plot was 1 row wide and 30 plants long (180 feet) with 5 feet between plants. Main plot treatments were:

1) Serenade MAX + adjuvant (7-day);
2) Regalia + adjuvant (7-day);
3) Sonata + adjuvant (7-day);
4) Kumulus DF (standard organic sulfur) + adjuvant (14-day);
5) Water control (7 day);
6) Water control + adjuvant (14 day);
7) Water control + adjuvant (7 day); and
8) Water control (14 day).

The split plot was 5 plants long (25 feet), and fruit-zone leaf removal treatments were:

1) Pre-bloom;
2) Fruit at pea size;
3) Bunch closure; and
4) None (control).

The first application of main plot treatments was when grape shoots were 6 in. long (June 6, 2011), and the final application was at fruit set (August 16, 2011). Fungicide application intervals (7 or 14 days) were set according to manufacturer's recommendations. All fungicides were mixed with the same adjuvant, Pronatural. Table 1 presents each product used in this study, its active ingredient and its mode of action, the rates and intervals used, the cost per application for each, and the total cost of the spray regime for the 2011 study period. Table 2 presents spray dates for each treatment throughout the 2011 season. For the split plot treatment, leaves were removed from the base of the shoot to the node above the top-most cluster (Table 3). Vines were thinned on June 23, 2011 to approximately 3 shoots per foot, and clusters were thinned to 2 clusters per shoot on June 23 and July 1, 2011. The number of clusters removed per vine was recorded for one row (Row 18, vines 3-40).

Incidence of powdery mildew on leaves was monitored weekly by examining 10 leaves from each data plant in each subplot. Severity of leaf infection (% leaf surface area, combined from upper and lower leaf surfaces) was estimated from 10 leaves per data vine in each subplot at bloom (July 1), berry touch (August 23), and véraison (August 31). In addition, 20 clusters per subplot were visually examined for disease incidence at fruit set (August 16) and berry touch (August 23). At harvest (October 18-19), percent severity was determined for 30 clusters; in addition, botrytis incidence was rated and individual cluster weight recorded. Temperature and relative humidity were measured and recorded at the site from June 27 through harvest, using Hobo™ sensors attached to a post in the center of the vineyard (Figure 1).

Spray coverage was evaluated using water sensitive paper (Syngenta Crop Protection AG); a paper (approximately 3 in. x 2 in.) was attached to a shoot within the vine canopy and recovered following the fungicide treatment application. This evaluation was performed in water-sprayed plots with no leaf removal and in water-sprayed plots with leaves removed when berries were pea size. Spray coverage was measured in plots on August 17 and August 24, approximately 1 and 8 days post leaf pulling. The papers were then scanned with a business card scanner (ScanShell 800NR, Card Scanning Solutions, Culver, CA) and quantified using DepositScan (Zhu *et al.* 2011). This program allowed for fast determination of spray dot distribution, numbers of spray dots and percent spray coverage.

Post-trial fungicides were applied to the plot on September 13 (Nordox 75 WP @ 1.5lbs per 100 gallons), September 23 (Kaligreen 3lb/A and Regalia 2.5 quarts/A + organic sticker), September 29 (Kaligreen 12 lbs/ 250 Gallons of water), and October 13 (Serenade MAX) to maintain GPM control through the end of the season (Table 2). Phenology ratings at Siper Vineyard over the course of this study are presented in Table 4.

A greenhouse study was initiated to verify *E. necator* virulence from inoculum collected from the spray study vineyard and to further evaluate the efficacy of the biological fungicides evaluated in the field study. Grape seeds were germinated and inoculum collected. Due to extenuating circumstances in labor, this portion of the study was not completed.

RESULTS:

Spray Coverage. The percent coverage differed due to leaf removal on both sample dates ($P < 0.0001$ and $P = 0.0003$, respectively). Spray coverage was 42-56% for the leaf-removal treatment and was 9-11% for the non-leaf removal treatment (Table 5). The area deposits per area did not differ by treatment, but the volume of the depositions did differ on both dates ($P < 0.0063$ and $P = 0.0101$, respectively), and was approximately 50-80 $\mu L/cm^2$ for thinned and 1-2 $\mu L/cm^2$ for non-thinned plots.

Foliar Powdery Mildew. The timing of fruit-zone leaf removal did not significantly influence disease incidence or severity on leaves, while all four fungicide regimes significantly reduced incidence (Figure 2) and severity (Figure 3) on leaves. This is likely due to overall poor spray coverage (<45%, Table 5). Disease progression, expressed as either change in incidence or severity, were also not significantly different among the four main fungicide treatments ($P = 0.98$ and $P = 0.87$, respectively). All fungicide treatments had significantly lower overall disease levels than the water controls. Lack of variation between the fungicide treatments and canopy powdery mildew is likely due to: (i) the cool spring where temperatures often went below 10^oC prior to bloom; and (ii) the use of Kumulus during bloom thru set for all treatments. Moyer et al. (2010) have shown disease development is severely limited when temperatures are periodically below 10^oC for even a few hours.

Fruit Powdery Mildew. The timing of leaf removal had no effect on powdery mildew incidence or severity of fruit at harvest (Tukey's HSD, significance set at $P = 0.05$), regardless of fungicide or control application. There was a significant reduction in incidence and severity associated with the fungicide regimes as compared to water (Figures 4 and 5). The Serenade Max and Sonata treatments had lower incidence levels of powdery mildew compared to Kumulus and Regalia but had the same disease severity. This indicates that while fewer clusters may have had initial infections, those displaying symptoms in the Serenade Max and Sonata treatments had overall higher individual severity levels (i.e., in order to get the same average severity when those treatments had higher proportions of clusters with no incidence, the clusters with disease had to be more severely infected).

The difference in disease incidence among fungicide treatments was likely due to the shorter spray interval of the non-Kumulus applications, and increased environmental favorability (Figure 6) for later-stage infections before the complete onset of ontogenic resistance in all clusters in the vineyard (which would have occurred at the end of August; within-vineyard cluster phenology was asynchronous as seen in Table 3). Kumulus applications were made every 14 days prior to bloom, while the other products were applied every 7 days (Table 2).

The lack of difference in disease severity among fungicide treatments was likely due to the application of Kumulus in all four fungicide regimes from bloom through set. This period has been shown to be the most susceptible period for fruit infection (Gadoury, 2003; Ficke 2003; Ficke 2004). Since the application of Kumulus during this period provided commercially acceptable levels of control in this trial, and there are numerous reports of inconsistent performance of the other products in various other studies (Table 6), the use of sulfur from bloom thru pea size berries should be seriously considered in organic management programs. This is especially true considering the cost of the products (Table 1).

Fruit zone leaf removal and canopy architecture. Leaf-removal treatments, as expected, significantly impacted the fruit-zone canopy architecture. Post-bloom treatments (Fruit Set and Pea Size Berries; Table 7), had significantly fewer interior (shaded) leaves and interior (shaded) clusters, and significantly more canopy gaps than the control or prebloom timing. All fruit-zone leaf removal treatments had reduced leaf layer number, relative to the control. The lack of an effect of leaf removal on disease development is likely due to the young age of the vineyard and relatively limited canopy development. Even the no leaf-removal control had a canopy architecture similar to the recommended ideal canopy (Smart and Robinson 1991). This young vineyard was also improperly managed the year before, and since it is cane-pruned, appropriate shoot positioning was not ideal for the current growing season due to lack of shoot development control the prior year. There was also significant primary bud damage (noted by a high number of secondary shoot emergence). This was likely due to high disease pressure the previous year and overall vineyard neglect. There have been a few reports that bud infection by the powdery mildew fungus can reduce bud cold hardiness, and severe canopy infections can also reduce overall vine health. Those factors likely contributed to a reduction in cold hardiness. An unsual cold event occurred in November 2010, and while the minimum temperatures were not at thresholds for damage of healthy grapes, the aforementioned combined factors likely resulted indamage.

PUBLICATIONS AND PRESENTATIONS:

Wheeler, D.L., and C. Miles. 2011. Powdery mildew management in the organic vineyard. Presentation, Puget Sound Wine Growers' Association 7th Annual Cool Climate Viticulture Conference, August 8, 2011, WSU Mount Vernon NWREC.

Wheeler, D.L. 2011. Organic management of powdery mildew (*Erysiphe necator*) in wine grapes (*Vitis vinifera* ' Madeleine Angevine') in Western Washington. Poster presented at 2011

Agriculture & Northwest Ecosystems Symposium, October 27, 2011, WSU Mount Vernon NWREC.

REFERENCES:

Zhu, H., M. Salyani, and R.D. Fox. 2011. A portable scanning system for evaluation of spray deposit distribution. Computers and electronics in agriculture 76:38-43.

Table 1. Products used in 2011 grape powdery mildew trial, the active ingredient in each and its mode of action, and the rates and intervals used and the product cost per application for each fungicide.

Products	Active ingredient	Mode(s) of Action	Rates and intervals	Cost per application	Total No. Apps.[1]	Total Cost[2]
Serenade MAX	*Bacillus subtillus*	Penetrates cell membrane; strengthens plant immunity	2 lbs/A 7-day	$29/A	6 (+ 4 Kumulus)	$214/Acre
Sonata	*Bacillus pumillus*	Disrupts cell metabolism; resists establishment of pathogens	4 qts/A 7-day	$24/A	6 (+ 4 Kumulus)	$184/Acre
Regalia	Plant extract (*Reynoutria sachalinenesis*)	Activates defense responses	4 qts/A 7-day	$72/A	6 (+ 4 Kumulus)	$472/Acre
Kumulus DF	Sulfur	Unknown	5 lbs/A 14-day	$10/A	7	$70/Acre
Adjuvant *Pronatural*	Soapbark	Disperses + adheres product to plant tissues	4 oz/100 gal of mix	--	--	--

[1]Total applications refer to the testing period, and does not include fungicide costs that were common to all programs after 24 Aug.

[2]Total costs do not include the cost of ProNatural Spreader, which was included in all program applications.

Table 2. Fungicide program for the organic management of grape powdery mildew (*Erysiphe necator)* on *Vitis vinifera* 'Madeleine Angevine' at Siper Vineyard (Whatcom County, Washington) in 2011.

	Date													
Treatment[a]	6-Jun	13-Jun	20-Jun	27-Jun	7-Jul	18-Jul	28-Jul	8-Aug	17-Aug	24-Aug	13-Sep	23-Sep	29-Sep	13-Oct
Kumulus [1,2]	X		X						X		Post Trial Treatment: Nordox 75 WP (1.5lb/100 gallons)	Post Trial Treatment: Kailgreen (3lbs/Ac) + Pronatural (2oz/Ac)	Post Trial Treament: Kailgreen (12lbs in 250Gal total)	Post Trial Treatment: Serenade Max
Regalia [1,2]	X	X	X	X	All corresponding treatments switched to Kumulus + Pro Natural Spreader				X	X				
Sonata[1,2]	X	X	X	X					X	X				
Serenade Max[1,2]	X	X	X	X					X	X				
Water + Pro Natural[1] (14d)	X		X		X	X	X	X	X					
Water + Pro Natural[1] (7d)	X	X	X	X	X	X	X	X	X	X				
Water (14d)	X		X		X	X	X	X	X					
Water (7d)	X	X	X	X	X	X	X	X	X	X				

[a] All products rates were applied in 31.7 gal/acre for the Jun applications. At 7 Jul and thereafter, products rates were applied in 63.4 gal/acre.

[1]Products mixed with Pro Natural Spreader. Pro Natural Spreader used at a rate of 4 oz/100gal

[2]Product rates as follows: Kumulus (5lbs/acre); Regalia (4qts/acre); Sonata (4 qts/acre); Serenade Max (2lbs/acre)

Table 3. Timing of subplot fruit-zone leaf removal treatments on *Vitis vinifera* 'Madeleine Angevine' at Siper Vineyard (Whatcom County, Washington) in 2011.

Treatment	Date
None	No fruit-zone leaf removal completed; Control
Prebloom	*21 Jun*; all leaves from base of shoot to top inflorescence were removed
Pea Size Berries	*16 Aug*; all leaves from base of shoot to top inflorescence were removed
Bunch Closure	*23 Aug*; all leaves from base of shoot to top inflorescence were removed

Table 4. Phenology ratings for *Vitis vinifera* 'Madeleine Angevine' at Siper Vineyard (Whatcom County, Washington) in 2011.

30-Jun	6 to 12 separated leaves and inflorescence separating (EL 13-17)
5-Jul	8 to14 separated leaves, compact inflorescences to flower caps fading color but still attached (EL 15-18)
13-Jul	12 separated leaves and inflorescence separating to10% cap fall (EL 17-20)
20-Jul	14 separated leaves, flower caps fading color but still attached to Cap fall complete (EL 18-26)
26-Jul	50% Cap fall-Fruit set to bunches begin drooping (EL 23-28)
2-Aug	Fruit set to pea size berries. (EL 27-30)

[1] Corresponding EL numbers indicate the growth stages as represented in the modified Eichhorn and Lorenz (1977) growth charts.

Table 5. Evaluation of impact of leaf removal on spray patterns using water sensitive paper in 2011 grape powdery mildew trial.

Date	Leaf Removal	% Coverage	Droplet Density (drops cm^{-2})	Deposition ($\mu L/cm^2$)
17-Aug	Berries at pea size	42.30 a	41.06	49.69 a
	None	10.99 b	37.08	2.11 b
	Significance	*<0.0001*	*NS*	*0.0063*
24-Aug	Berries at pea size	55.99 a	36.97	79.93 a
	None	8.72 b	41.89	1.03 b
	Significance	*0.0003*	*NS*	*0.0101*

Table 6. Previous fungicides trials that include at least one of the currently tested products. Reports can be found at: http://www.plantmanagementnetwork.org

Select Plant Disease Management Report Titles
Plant Disease Management Reports 5:SMF030. 2011. Evaluation of fungicides, a bio-fungicide, and fungicide programs for grape powdery mildew management, 2010"
Plant Disease Management Reports 4:SMF011. 2010. "Fungicide control of grape powdery mildew, trials II and III, 2009"
Plant Disease Management Reports 4:SMF014. 2010. "Evaluation of synthetic fungicides and Regalia for management of grape powdery mildew, 2009"
Plant Disease Management Reports 2:STF015. 2008. "Grape powdery mildew control, Prosser, WA 2007"
Plant Disease Management Reports 2:SMF053. 2007."Bacterial Control of Grape Powdery Mildew"
F&N Tests Vol 60:SMF024. 2005. "Control of grape powdery mildew, 2004"
F&N Tests Vol 59:SMF014. 2004. "'Soft' grape powdery mildew control measures, Prosser, WA, 2003"

Table 7. Impact of fruit-zone leaf removal on basic canopy and fruit-zone architecture.

	Point Quadrat Analysis Measurements[1]			
Leaf Removal Timing	**% Canopy Gaps**	**Total Leaf Layer Number**	**% Interior Leaves**	**% Interior Clusters**
None (Control)	7.78 a[1]	2.13 a	22.91 a	53.93 a
PreBloom	12.15 ab	1.78 b	19.83 a	41.81 a
Fruit Set	20.98 bc	1.08 c	8.81 b	13.01 b
Pea Size	22.22 c	1.09 c	10.45 b	8.70 b
Ideal Canopy **(Smart and Robinson 1991)**	20-40	1.0-1.5 or less	<10%	<40%

[1]Values in the same column with different letters are statistically different at the $p \leq 0.05$ (Tukey's HSD).

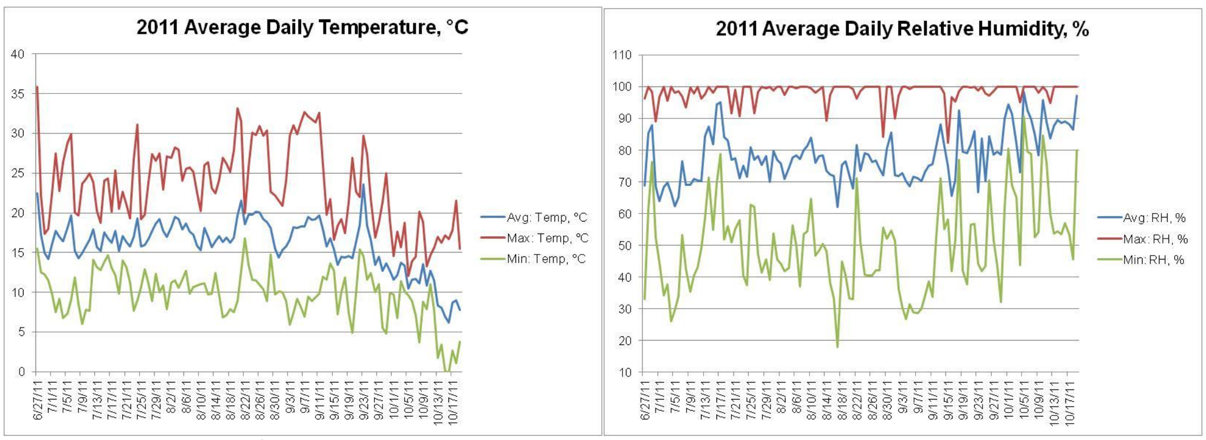

Figure 1. Temperature (°C) and relative humidity (%) at Siper Vineyard June 27 through October 17, 2011.

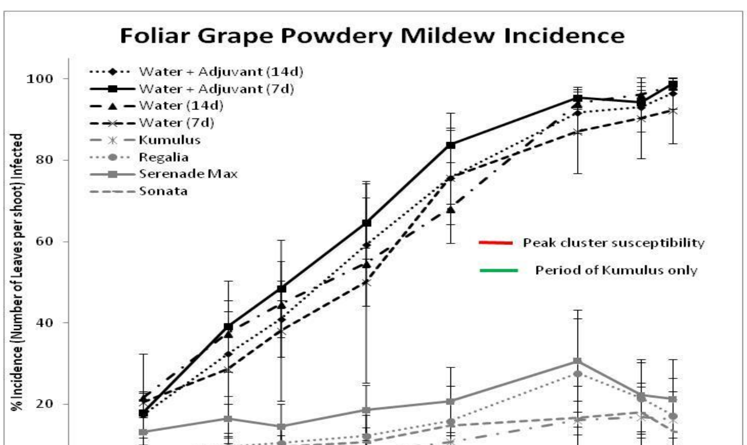

Figure 2. Mean main plot (fungicide treatment) seasonal progression of foliar powdery mildew incidence (number of leaves per shoot displaying symptoms) on *Vitis vinifera* 'Madeleine Angevine'. Error bars are standard error of the mean. Period of peak cluster susceptibility corresponds to the time frame of immediate pre-bloom to three weeks post-fruit set (Gadoury et al. 2003).

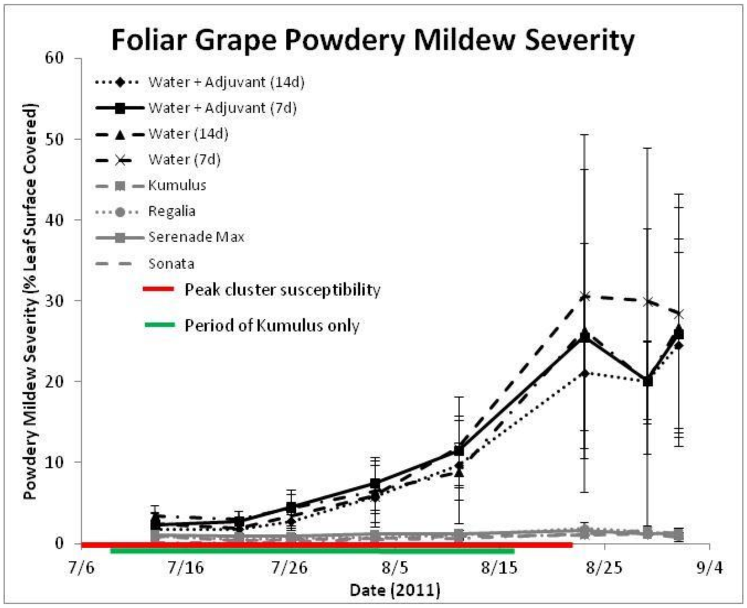

Figure 3. Mean main plot (fungicide treatment) seasonal progression of foliar powdery mildew severity (total surface area of each leaf on per shoot displaying symptoms) on *Vitis vinifera* 'Madeleine Angevine'. Error bars are standard error of the mean. Period of peak cluster susceptibility corresponds to the time frame of immediate pre-bloom to three weeks post-fruit set (Gadoury et al. 2003).

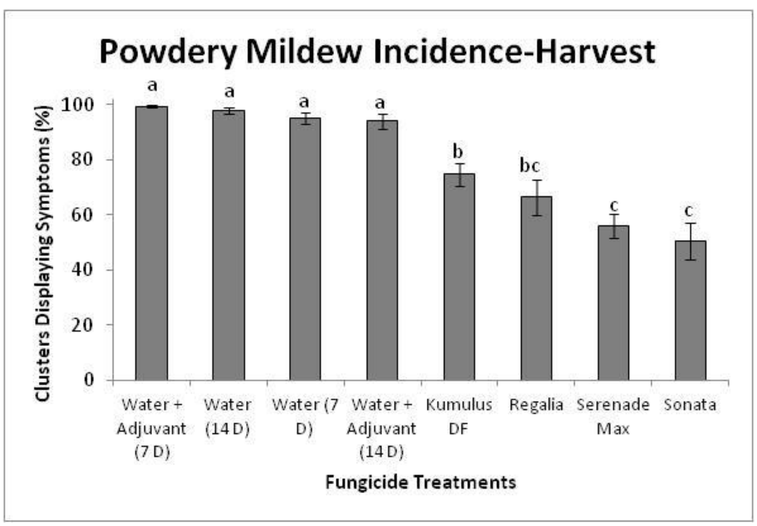

Figure 4. Final grape powdery mildew incidence on grape clusters at the time of harvest. All fungicide treatments (except water) received three 10-day interval applications of Kumulus during the period of peak cluster susceptibility to powdery mildew. Error bars represent standard error. Letters above bars denote mean significance differences a $P = 0.05$ (Tukey's HSD).

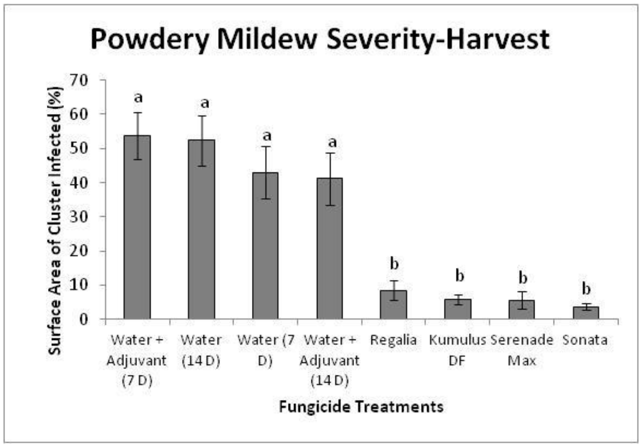

Figure 5. Final grape powdery mildew severity on grape clusters at the time of harvest. All fungicide treatments (except water) received three 10-day interval applications of Kumulus during the period of peak cluster susceptibility to powdery mildew. Error bars represent standard error. Letters above bars denote mean significance differences a *P* = 0.05 (Tukey's HSD).

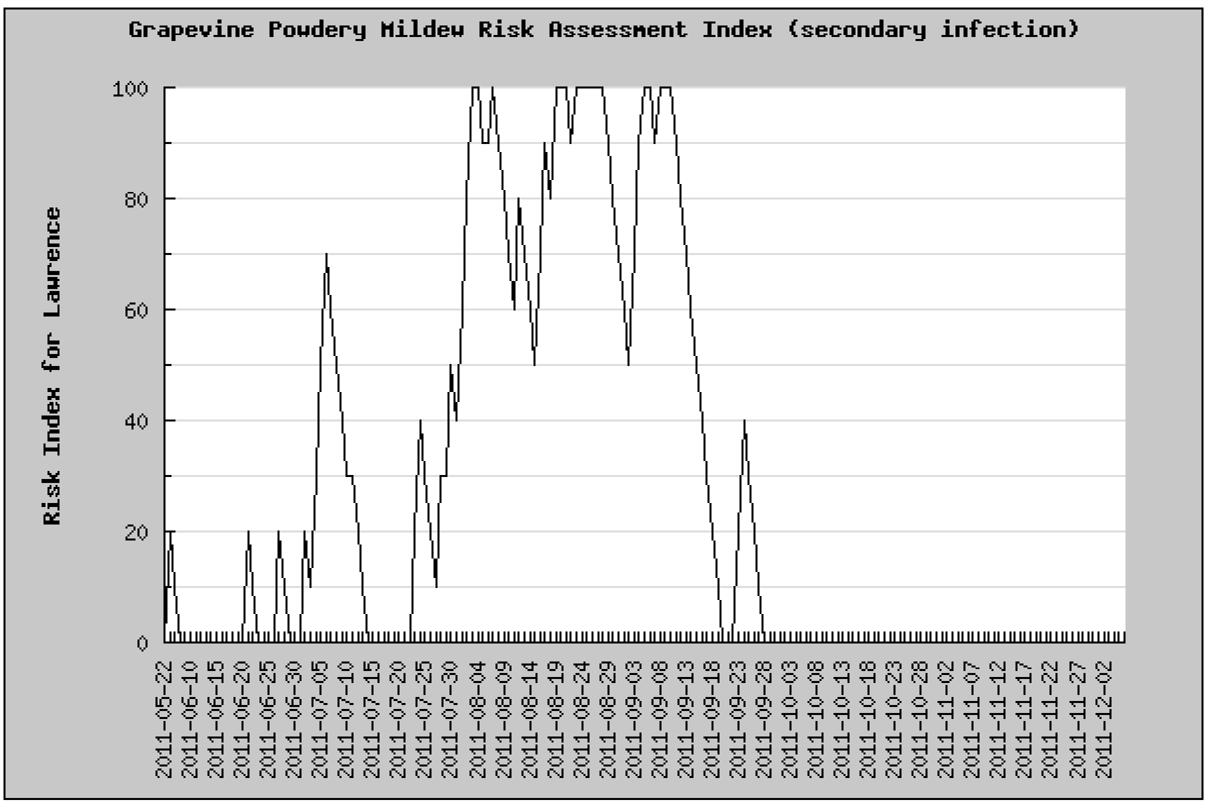

Figure 6. The Grape Powdery Mildew Risk Index, as powered by AgWeatherNet. The station selected is Lawrence, located approximately 1 mile from the research site. When the risk index is 60 or greater conditions are considered highly conducive for disease, and short spray intervals are recommended. When risk is at 30 or less, long spray intervals are recommended. Risk accumulation is based on temperatures falling within the favorable range for pathogen development, and is based on the UC-Davis Grape Powdery Mildew Risk Index.