GRAPE (*Vitis vinifera* 'Chardonnay')
Powdery Mildew; *Erysiphe necator*

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Efficacy of tank mixing biological fungicides with sulfur for management of grape powdery mildew, 2022.

Tank mixes of biological fungicides and sulfur were used for grape powdery mildew (GPM) management of Chardonnay vines at the Botany and Plant Pathology Field Laboratory in Corvallis, Oregon. The treatments focused on evaluating whether tank mixes of each of three different biological fungicides and a low rate of Microthiol Disperss (MD) micronized sulfur would provide better control than using the low rate of MD alone (Table 1).

Treatments (Table 1) were arranged in a randomized complete block design. A 50 gallon Pak-blast air blast sprayer (Rears Mfg., Coburg, OR) was used to apply the treatments and operated using a Kubota M5N-111 tractor and the nozzles in the sprayer were TeeJet ceramic D3 discs and DC25 cores. The blocks used consisted of 'Chardonnay' planted in 1998 on V. rupestris x V. riparia 101-14 rootstock with 7x8 ft spacing. A single buffer rootstock vine was trained between each set of treatment vines and a buffer row of rootstock vines separated each varietal row, which helped minimize plot-plot interference. Vines were trained to a Guyot (vertical shoot position) system and pruned by 24 Feb. Shoot thinning by hand occurred from 9 May to 10 Jun and sucker removal by hand was continuous throughout the season. Shoots were cut above the top wire on 21 Jun and maintained at this height throughout the growing season. Fungicide treatments were applied every 7 to 10 days. Each treatment was replicated on 4 sets of 5 vines.

Table 1. Biological fungicide treatments applied to Chardonnay vines in 2022.

Treatment[xy]
Non-treated control
MD 2 lb/A alone
Aviv (30 fl oz/100gal) + MD 2 lb/A
Lifegard (4.5 oz/100gal) + MD 2 lb/A
Theia (3lb/A) + MD 2 lb/A

[x]Treatments applied at 80psi at approx. 430 PTO rpm and 3mph.
[y]MD = Microthiol Disperss.

Spring weather conditions were very wet resulting in the second wettest spring on record. A frost event on 14 Apr hit bud breaking Chardonnay hard all over western Oregon resulting in a delayed of vine development and injured or killed 60 to 70% if the primary buds. Signs of powdery mildew were first found on 23 May on longer shoots (~7in) from primary buds that were not killed in the Apr frost. The 2022 season was generally observed to be a high pressure GPM year, as noted by the high severity observed on non-treated vines and throughout Willamette Valley commercial vineyards, compared to 2021. Bloom took place from 22 Jun to 5 Jul with most caps detaching from 27 Jun to 2 Jul.

Leaf and cluster data were taken on the middle three vines of each experimental plot by randomly examining either 25 clusters or leaves on both the east and west side of the row for a total of 50 units examined per plot. The incidence of powdery mildew on leaves was recorded weekly from 21 Jun through 16 Aug. The severity of powdery mildew on clusters was taken on 16 Aug. Leaf incidence data was analyzed by calculating the area under disease progress curve (AUDPC) which was calculated by multiplying the mean incidence from two observation dates by the number of days between observations ($\Sigma[Y_{i+1} + Y_i)/2][X_{i+1}-X_i]$ where Y_i is incidence of mildew at i*th* observation and X_i is the day of the i*th* observations) and adding together the values. AUDPCs were calculated using the agricolae package and modeled with a generalized least squares linear model. Cluster severity percentages were modeled using a generalized linear mixed model with block fitted as a random effect. Cluster severity treatment contrasts were conducted using the emmeans package and model fit was checked with the DHARMa package. Uncertainty was estimated using asymptotic 95% confidence intervals. All data was analyzed in R version 4.0.3.

Table 2. Area under disease progress curve (AUDPC, leaf disease) and percent infected berries from the Chardonnay biological fungicide and MD tank mix trial at the Botany and Plant Pathology field lab in 2022.

Treatment[v]	AUDPC[w]	Percent Infected Berries[w]
Non-treated control	2632 (2537-2726) A	99.4 (98.7-99.7) A
MD 2 lb/A alone	1719 (1421-2016) BC	84.7 (74.2-91.4) B
Aviv (30 fl oz/100gal) + MD 2 lb /A	1612 (1396-1827) BC	84.3 (73.7-91.2) B
Lifegard (4.5 oz/100gal) + MD 2 lb/A	1781 (1730-1832) B	85.4 (75.3-91.8) B
Theia (3lb/A) + MD 2 lb/A	1558 (1357-1758) C	54.1 (38.0-69.3) C

[y]All treatments were applied at 80psi at approx. 430 rpm PTO. MD = Microthiol Disperss
[z]Estimates are followed by asymptotic 95% confidence intervals in parentheses. Treatments followed by different letters are significantly different than each other, marginal means contrast ($p<0.05$) with p values adjusted using Tukey method.

AUDPC values were significantly higher for non-treated vines than any of the fungicide treated vines. Among fungicide treatments, the vines treated with a mixture of Theia + MD resulted in the lowest observed AUDPC value that was significantly lower than the Lifegard + MD treatment, but not the MD alone or the Aviv +MD treatment (Table 2). The lowest cluster severity was observed in Theia + MD treated plots, with all other fungicide treatments resulting in approximately 30% more cluster severity on average, representing a significant difference. The non-treated vines resulted in 99.4% cluster severity, which was significantly higher than any of the fungicide treated vines.

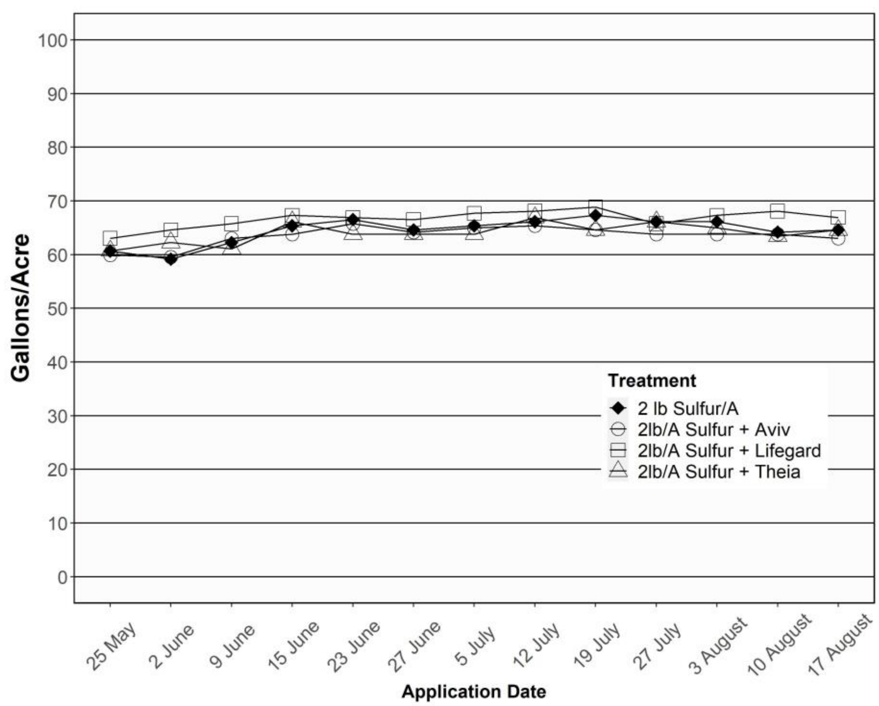

Figure 1. Spray volumes applied to vines in the Chardonnay tank mix trial.

Spray volume applied for fungicide treatments was relatively consistent and ranged from around 60 GPA to almost 70 GPA at times during the growing season (Figure 1). The amount of Aviv applied over the course of the season ranged from a low of 18.6 fl oz/A to 19.7 fl oz/A, which was within the label recommended range of 15 fl oz/A to 25 fl oz/A. The amount of Lifegard applied over the course of the season ranged from a minimum of 2.8 oz/A and maximum of 3.1 oz/A which are both within the label recommended rate range of 1 oz/A to 4.5 oz/A (Figure 2A). The amount of Theia applied over the course of the season ranged from 3.4 lb/A to 4.2 lb/A, which was all well within the label rate range of 1.5 lb to 5 lb/A for control of GPM (Figure 2A). For all fungicide treated vines the amount of MD applied in the tank mixes was fairly consistent, ranging from 2.3 lb/A to 2.9 lb/A (Figure 2B).

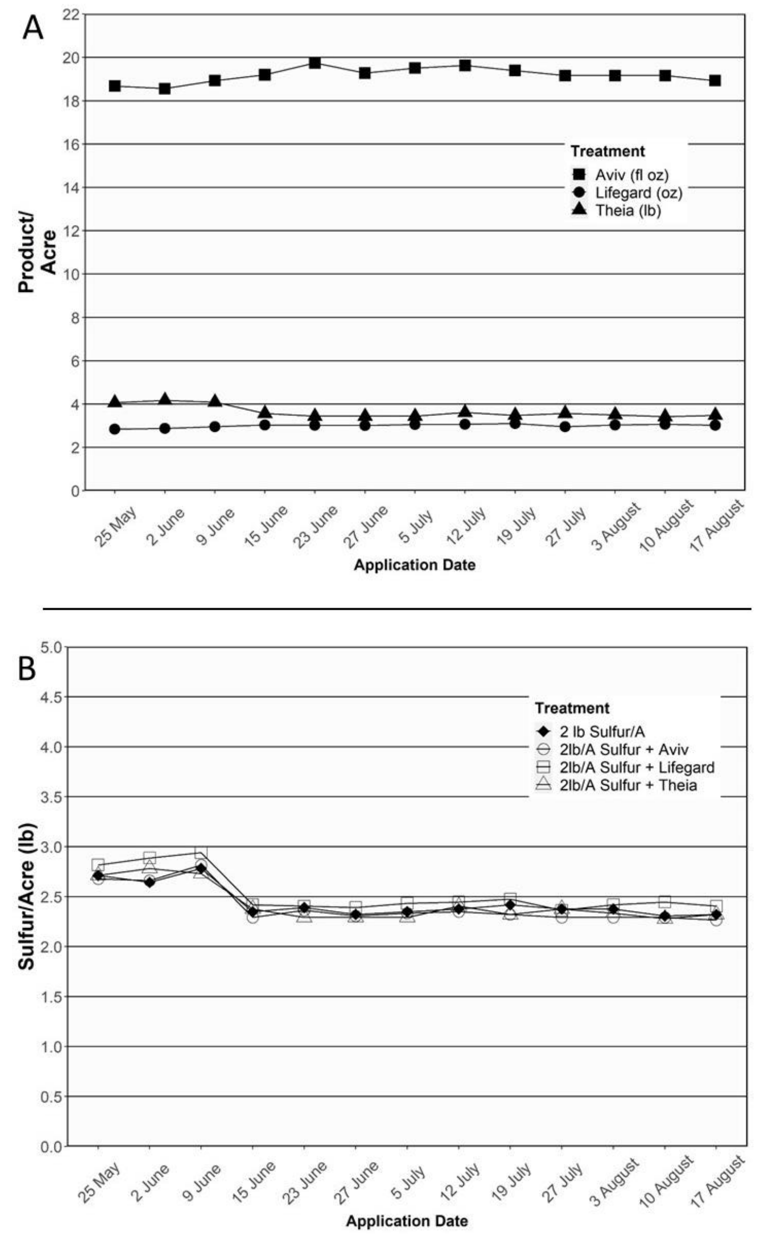

Figure 2. The amount of biological fungicide (A) and Microthiol Disperss (B) applied Chardonnay vines during each application.

The tank mix containing Theia resulted in the lowest observed AUDPC and cluster severity. While the AUDPC for the Theia tank mix was the lowest observed, it was not significantly different than the MD alone or the Aviv tank mix. Theia is a *Bacillus* bacterium with a mode of action that is described as production of anti-microbial compounds, competition for space on the plant, and activation of plant defenses through the systemic acquired resistance (SAR) response. The lower observed AUDPC and cluster severity values indicate that the addition of Theia augmented the control of GPM over MD alone. Aviv has the same three modes of action as Theia and uses a different strain of the same organism (*Bacillus subtilis*) while Lifegard is a different species of *Bacillus* (*Bacillus mycoides*) that is described as only activating the SAR plant defense system. None of the three products used in the study have tank mixing restrictions so the better performance of Theia is likely due to higher efficacy of inhibiting GPM than the other two products.

In this study Aviv and Lifegard were applied at their highest label rate, while Theia was applied at a rate in the middle of its range (1.5 lb/A to 5lb/A). The amount of active bacteria in each product is measured by colony forming units (CFU), which is a quantification of the number of live bacteria in a given sample size of the product, usually a gram or milliliter depending on if the product is a solid or liquid. While the CFU numbers vary between the products ($1x10^7$/ml for Aviv, $3x10^{10}$/g for Lifegard, $1x10^9$/g for Theia), Theia is composed of 100% of the active ingredient bacterium, whereas Lifegard and Aviv contain 40% and 0.08%, of their active ingredient bacterium in the product formulation, respectively. It is unknown what exactly composes each product formulation. Given that the Theia formulation is entirely composed of its active bacterium, there may be a higher amount of anti-fungal compounds already present in the formulation, whereas the active ingredient bacteria in Lifegard and Aviv may need to establish themselves on the plant before producing the bulk of their anti-fungal or plant-activating compounds. Fungicide applications were initiated in this study upon discovery of GPM lesions on grape shoots. There may have been active GPM colonies already present throughout the Chardonnay rows, which Lifegard and Aviv were less able to control than Theia.

In general biological fungicides are considered contact fungicides that should be applied in a preventative manner. In large part this may be because biological fungicides many times work by colonizing plant tissue and excluding pathogens, or by producing anti-fungal compounds. Thus it is a common practice to tank mix with a different fungicide that is known to have curative activity on the target pathogen when applying biological fungicides to provide curative activity for any active infections on the plant. All three products used in this study are described as being tank-mix compatible with a wide range of fungicides, with nothing mentioned about the active ingredient bacteria being incompatible with sulfur. All three of the products contain live bacteria that colonize leaf tissue, so if any of the bacteria were compromised by being tank mixed with sulfur this may have resulted in less effective control of GPM. Plating of the tank mixes to determine if viability of the active ingredient bacteria was not done in this study but could be done to elucidate if there was an effect of tank mixing and spraying on the active ingredient bacteria.

Future trials could evaluate the viability of the active ingredient bacteria of biological fungicides in the course of tank mixing and/or application. In addition, evaluation of different rates, other biological fungicides, or other tank mixing partners may further elucidate efficient methods of use biological fungicides to control GPM in the Willamette Valley.