SRSFC Project 2022-R-16: Techniques to improve and expand efficacy of fungicides against powdery mildew of grape

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Abstract: The objectives of this project were: (1) to review surfactants that can be added to sulfur products to safely control powdery mildew under the hot conditions observed in the Southeast, and (2) to review the relative efficacy of DMI fungicides at high rates to determine the most effective DMIs to utilize where *Erysiphe necator* resistance has occurred. For both objectives, fungicides were tested for their performance in controlling DMI-tolerant grapevine powdery mildew (PM) on *Vitis vinifera* L. cv. 'Chardonnay' at the University of Georgia Mountain Research and Education Center in Blairsville, GA. Resistance to both quinone outside (QoI) and demethylation inhibitor (DMI) fungicides have been confirmed at this research site, and similar resistance issues are observed in commercial grape vineyards throughout Georgia. With numerous untreated vines scattered throughout the vineyard, powdery mildew levels were extremely high. In addition, by initiating the trial after bloom, mildew was already observed in most vines as the trial started. Therefore, any treatment that provided disease suppression would be considered especially efficacious. Microthiol Disperss sulfur did reduce powdery mildew as expected, but also as expected, the level of control was poor based on the overwhelming inoculum levels provided. Only one of the tested surfactants added to the efficacy of Microthiol Disperss – that being Hi-Wett. The Hi-Wett surfactant, when added to Microthiol Disperss, decreased the level of mildew on both the leaves and fruit. Aprovia, an SDHI fungicide performed well, also as expected. Mettle, Revus Top, and Cevya grouped together relative their efficacy – generally outperforming Elite, Rally, and Procure for mildew management on leaves and fruit. However, the level of disease observed on fruit was overwhelming due to the later start of applications, as evidenced by both incidence and severity. Additional trials with surfactants and sulfur will be conducted in 2023, as this line of research has proven to be of value. As the efficacy of DMIs are reduced due to resistance, the DMIs are also challenged by regulatory issues. As a result, any means of increasing the efficacy of sulfur will be critical to future grape production in the Southeast and elsewhere.

Objectives: (1) Review surfactants that can be added to sulfur products to safely control powdery mildew under the hot conditions observed in the Southeast; (2) Review the relative efficacy of DMI fungicides at high rates to determine the most effective DMIs to utilize where *Erysiphe necator* resistance has occurred.

Description and Justification: The southeastern wine grape industry is still relatively young and fragile. Economical losses from powdery mildew (*Erysiphe necator*) are significant and threaten to reduce productivity on a yearly basis. Indeed, losses have been significant enough that no wine is produced in some locations. Powdery mildew is particularly aggressive as a pathogen of *V. vinifera* grapes, but it can attack hybrids as well. Damage to berries can result in additional rot development and poor wine quality; leaf damage results in reduced photosynthesis and premature defoliation (Fig. 1). To minimize powdery mildew losses, grape growers spray fungicides throughout the season and even after harvest (to protect leaves and reduce overwintering inoculum). As a result, growers may employ thirteen to seventeen fungicide sprays in a season. As a result, resistance to QoI and DMI fungicide classes have recently been confirmed in *E. necator* populations. Sulfur does not develop resistance, and it does have well-researched efficacy against powdery mildew. However, when using sulfur in the Southeast, hot temperatures can result in phytotoxicity, and sulfur is also not as efficacious as many of the systemic fungicides – the ones that readily develop resistance through point mutations. This presents a dilemma for producers relative fungicide selection and resistance management. One solution may be to simply add surfactants with sulfur, but some surfactants are known to exacerbate phytotoxicity. Information is not available as to how sulfur plus surfactants will perform under the hot, humid conditions of the Southeast; however, if growers can increase sulfur's efficacy through mixing with surfactants, this would be helpful, as they design their spray programs for both efficacy and resistance management. In addition, we have determined that cross-resistance is not complete among the DMI fungicides applied to grape, with some providing good to excellent efficacy while some provide virtually no disease control at all. As a result, we would like to test many of the most commonly utilized DMI fungicides for comparison in the presence of a DMI-resistant *E. necator* population.

Figure 1. Powdery mildew of grape on fruit and leaves.

Procedures:

Surfactants and sulfur trial. Five surfactants, when tank-mixed with sulfur, were tested for their performance in adding to the control of grapevine powdery mildew (PM), as compared to sulfur alone. The trial was conducted at the University of Georgia Mountain Research and Education Center in Blairsville, GA. The experimental design utilized a randomized complete block with five replications per treatment; single plants were utilized for each replicate unit. Unsprayed buffer rows allowed for increased powdery mildew disease pressure. Treatments were applied with a CO_2 backpack sprayer equipped with one TT11002 (TeeJet Technologies, Wheaton, IL) nozzle, and rates were calculated to correspond with a 50 gal per acre total spray volume; applications were made four times (1 Jun, 14 Jun, 28 Jun, 11 Jul). Cultural practices mimicked those observed in commercial vineyards. Treatments and active compounds were as follows: (1) untreated control; (2) Microthiol Disperss (sulfur); (3) Microthiol Disperss + Bond Max; (4) Microthiol Disperss + LI 700; (5) Microthiol Disperss + Vintre; (6) Microthiol Disperss + Hi-Wett; and (7) Microthiol Disperss + Trend 90. Fruit clusters (five per plant) were rated for PM incidence (% of clusters infected) and severity (% of cluster covered by powdery mildew) on 29 Jun and 22 Jul. On the same date, 25 leaves were collected from each vine and assessed for powdery mildew incidence (% leaves infected) and severity (% leaf area with powdery mildew). JMP Pro 16 was utilized for data analysis, and Student's t was utilized for treatment means separation.

DMI comparisons trial. Seven demethylation inhibitor (DMI) fungicides were tested for their performance in controlling DMI-tolerant grapevine powdery mildew (PM) on *Vitis vinifera* L. cv. 'Chardonnay' at the University of Georgia Mountain Research and Education Center in Blairsville, GA. The experimental design utilized a randomized complete block with five replications per treatment; single plants were utilized for each replicate unit. Unsprayed buffer plants allowed for increased powdery mildew disease pressure. Treatments were applied with a CO_2 backpack sprayer equipped with one TT11002 (TeeJet Technologies, Wheaton, IL) nozzle, and rates were calculated to correspond with a 50 gal per acre total spray volume; applications were made four times (1 Jun, 14 Jun, 28 Jun, 11 Jul). Cultural practices mimicked those observed in commercial vineyards. Treatments and active compounds were as follows: (1) untreated control; (2) Elite 45WP (tebuconazole); (3) Rally 40WSP (myclobutanil); (4) Procure 480SC (triflumizole); (5) Mettle 125 ME (tetraconazole); (6) Cevya (mefentrifluconazole); (7) Revus Top (difenoconazole + mandipropamid); and (8) Aprovia (an SDHI fungicide) as a positive control. Fruit clusters (five per plant) were rated for PM incidence (% of clusters infected) and severity (% of cluster covered by powdery mildew) on 22 Jul. On the same date, 25 leaves were collected from each vine and assessed for powdery mildew incidence (% leaves infected) and severity (% leaf area with powdery mildew). JMP Pro 16 was utilized for data analysis, and Student's t was utilized for treatment means separation.

Results and Discussion:

Surfactants and sulfur trial. With numerous untreated vines scattered throughout the vineyard, powdery mildew levels were extremely high at this site. In addition, by initiating the trial after bloom, mildew was already observed in most vines as the trial started. Therefore, any treatment that provided disease suppression would be considered especially efficacious. Microthiol Disperss sulfur did reduce powdery mildew as expected, but also as expected, the level of control was poor based on the overwhelming inoculum levels provided (Tables 1 and 2). Only one of the tested surfactants added to the efficacy of Microthiol Disperss – that being Hi-Wett. The Hi-Wett surfactant, when added to Microthiol Disperss, decreased the level of mildew on both the leaves and fruit. Resistance to both quinone outside and demethylation inhibitor fungicides has been confirmed at this research site, and similar resistance issues are observed in commercial grape vineyards throughout Georgia. Therefore, sulfur is a critical component of spray programs and it must be optimized in its use. Though surfactants are often touted as providing increased efficacy, limited trials are conducted with the multitude of surfactants that are commercially available to grape producers. As observed in this trial, many surfactants do not provide increased efficacy; indeed, some have been reported to increase disease in some systems. If Hi-Wett will consistently increase the efficacy of sulfur for powdery mildew control under the rainy conditions often observed in Georgia, this would be of great value. Additional research is required to confirm the consistency of the results observed here, but the results were encouraging for the Hi-Wett surfactant product.

Table 1. Performance of Microthiol Disperss and various surfactants for control of leaf powdery mildew.

Treatment and amount/A	Application timing *	Leaf powdery mildew incidence 29 Jun**	Leaf powdery mildew incidence 22 Jul **	Leaf mildew severity 29 Jun**	Leaf powdery mildew severity 22 Jul **
Untreated	---	100.0 a	100.0 a	40.8 a	43.2 a
Microthiol Disperss 10 lb	ABCD	89.6 ab	31.2 b	21.9 bcd	4.4 b
Microthiol Disperss 10 lb + Bond Max 1.5 fl oz	ABCD	85.6 b	20.8 bc	19.1 d	2.1 b
Microthiol Disperss 10 lb + LI 700 0.25 pt	ABCD	89.6 ab	27.2 b	19.4 cd	3.2 b
Microthiol Disperss 10 lb + Vintre 16 fl oz	ABCD	98.4 a	28.8 b	29.6 b	2.3 b
Microthiol Disperss 10 lb + Hi-Wett 9.5 fl oz	ABCD	85.6 b	10.4 c	13.7 d	0.6 b
Microthiol Disperss 10 lb + Trend 90 4 fl oz	ABCD	96.0 ab	27.2 b	29.4 bc	2.5 b

*Treatment dates: A = 1 Jun (post bloom), B = 14 Jun (first cover), C = 28 Jun (bunch closure), D = 11 Jul (second cover)
**Powdery mildew incidence (% infected leaves) and severity (% of leaf covered by powdery mildew) were calculated from 25 leaves per treated plant. Means followed by the same letter are not significantly different when comparing each pair using Student's t test statistic ($P \leq 0.05$).

Table 2. Performance of Microthiol Disperss and various surfactants for control of fruit powdery mildew.

Treatment and amount/A	Application timing *	Fruit powdery mildew incidence 29 Jun**	Fruit powdery mildew incidence 22 Jul	Fruit powdery mildew severity 29 Jun	Fruit powdery mildew severity 22 Jul
Untreated	---	100.0 a	100.0 a	70.5 a	99.6 a
Microthiol Disperss 10 lb	ABCD	86.0 a	85.0 ab	22.4 bc	43.5 c
Microthiol Disperss 10 lb + Bond Max 1.5 fl oz	ABCD	88.0 a	84.0 ab	34.0 bc	48.4 c
Microthiol Disperss 10 lb + LI 700 0.25 pt	ABCD	92.0 a	96.0 a	31.4 bc	66.8 bc
Microthiol Disperss 10 lb + Vintre 16 fl oz	ABCD	88.0 a	90.0 ab	68.8 a	74.0 b
Microthiol Disperss 10 lb + Hi-Wett 9.5 fl oz	ABCD	45.0 b	75.0 b	10.0 c	18.2 d
Microthiol Disperss 10 lb + Trend 90 4 fl oz	ABCD	84.0 a	100.0 a	40.4 b	60.0 bc

* Treatment dates: A = 1 Jun (post bloom), B = 14 Jun (first cover), C = 28 Jun (bunch closure), D = 11 Jul (second cover)
**Powdery mildew incidence (% infected clusters) and severity (% of cluster covered by powdery mildew) was calculated from 5 clusters per treated plant. Means followed by the same letter are not significantly different when comparing each pair using Student's t test statistic ($P \leq 0.05$).

DMI comparisons trial. Powdery mildew levels were exceptionally high in this trial for several reasons. The Y136F mutation in the 14α-demethylase (CYP51) gene, associated with DMI tolerance but not complete DMI resistance, is prevalent in the *E. necator* population at this site. In addition to being surrounded by untreated vines, this trial was initiated immediately after bloom, allowing for active powdery mildew development in all vines prior to the first treatment date. Aprovia, an SDHI fungicide performed well, as expected. Mettle, Revus Top, and Cevya grouped together relative their efficacy – generally outperforming Elite, Rally, and Procure for mildew management on leaves and fruit (Table 3). However, the level of disease observed on fruit was overwhelming due to the later start of applications, as evidenced by both incidence and severity. In past trials, we have utilized minimum labeled rates for each product. In this trial, maximum labeled rates were utilized, so this trial is representative of the best efficacy that these products can provide under these severe disease conditions. Whether due to better intrinsic efficacy of Cevya, Revus Top, and Mettle or an innate ability of these products to overcome DMI resistance, these three products have consistently outperformed Elite, Rally, and Procure at this site. The moderate increase in efficacy of Rally and Procure in this trial, as compared to Elite in past trials, may be due to the increased rates of these DMIs in this trial.

Table 3. Performance of various DMI fungicides for control of leaf powdery mildew.

Treatment and amount/A	Application timing *	Leaf powdery mildew incidence 22 Ju1**	Leaf powdery mildew severity 22 Jul **	Fruit powdery mildew incidence 22 Jul***	Fruit powdery mildew severity 22 Jul***
Untreated	---	95.2 a	42.7 a	100.0	99.6 a
Elite 45WP 4 oz	ABCD	96.0 a	30.1 b	100.0	99.4 a
Rally 40WSP 5 oz	ABCD	88.0 a	12.5 c	100.0	92.4 ab
Procure 480SC 8 fl oz	ABCD	87.2 a	14.0 c	100.0	67.6 c
Mettle 125 ME 5 fl oz	ABCD	51.2 b	3.4 d	88.0	53.6 cd
Cevya 4 fl oz	ABCD	44.0 bc	2.6 d	100.0	71.6 bc
Revus Top 7 fl oz	ABCD	47.2 b	2.6 d	84.0	36.4 de
Aprovia 10.5 fl oz	ABCD	27.2 c	1.5 d	88.0	26.8 e

* Treatment dates: A = 1 Jun (post bloom), B = 14 Jun (first cover), C = 28 Jun (bunch closure), D = 11 Jul (second cover)
**Powdery mildew incidence (% infected leaves) and severity (% of leaf covered by powdery mildew) were calculated from 25 leaves per treated plant. Means followed by the same letter are not significantly different when comparing each pair using Student’s t test statistic ($P \leq 0.05$).
***Powdery mildew incidence (% infected clusters) and severity (% of cluster covered by powdery mildew) was calculated from 5 clusters per treated plant. Means followed by the same letter are not significantly different when comparing each pair using Student’s t test statistic ($P \leq 0.05$).

Impact: Resistance to both quinone outside and demethylation inhibitor fungicides has been confirmed in the Southeast. Therefore, sulfur, which does not develop resistance, is a critical component of spray programs and it must be optimized in its use. Though surfactants are often touted as providing increased efficacy, limited trials are conducted with the multitude of surfactants that are commercially available to grape producers. As observed in this trial, many surfactants do not provide increased efficacy. However, Hi-Wett did increase the control of powdery mildew by sulfur. If Hi-Wett will consistently increase the efficacy of sulfur for powdery mildew control under the rainy conditions often observed in Georgia, this would be of great value. Additional trials with surfactants and sulfur will be conducted in 2023, as this line of research has proven to be of value. Any means of increasing the efficacy of sulfur will be critical to future grape production in the Southeast and elsewhere. We were also able to confirm the efficacy rankings of DMIs commonly utilized for powdery mildew control. As the efficacy of DMIs are reduced due to resistance, the DMIs are also challenged by regulatory issues. Maximizing new DMIs with reduced environmental or human toxicity concerns is critical, and this research will be useful to that end.