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

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Efficacy of different sulfur rates and an intelligent sprayer on grape powdery mildew on Pinot noir, 2018.

Four sulfur rate treatments (Table 1) were arranged in a randomized complete block design in a block of 'Pinot noir' (on V. rupestris x V. riparia 101-14 rootstock) planted in 1998 on 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. Pinot noir vines were trained to a Guyot (vertical shoot position) system and pruned on 5 Mar. Shoot thinning and sucker removal by hand occurred from 10 to 20 May. Shoots were cut above the top wire on 10 June and maintained at this height throughout the growing season. Minor leaf thinning in the cluster zone was conducted on the east side of the row on 11 July (BBCH 77, berries beginning to touch). Each treatment was replicated on 4 sets of 5 vines. Rely 280 (1 fl oz/gal) was applied, using a backpack sprayer, as a band on 12 June to control weeds under vine rows. Sulfur treatments were applied every 7 to 10 days depending on phenology and disease pressure as measured by the Gubler-Thomas powdery mildew risk index. Shorter intervals (7-8 day) corresponded to bloom and times of high disease pressure and longer (10-12 day) intervals corresponded to times of fruit development and lower disease pressure.

Table 1. Treatments applied to Pinot noir vines.

Treatment[z]	**Tractor Speed (mph)**	**Sprayer Mode**
Non-treated	N/A	N/A
5#/100gal Microthiol Disperss	1.9	Automated
5#/100gal Microthiol Disperss	1.9	Standard
5#/Acre Microthiol Disperss	1.9	Standard
20#/100gal Microthiol Disperss	4.5	Standard

[z]All treatments were applied at 80psi at tractor PTO rated speed.

Treatments were applied using a Kubota M5N-111 tractor and a 50 gallon Pak-blast (Rears Mfg., Eugene, OR) axial fan air assisted sprayer with TeeJet ceramic D3 discs and DC25 cores. The sprayer was retrofitted with components of the "Intelligent Sprayer Project." The Intelligent Sprayer Project consists of a multi-discipline research team from across the USA working on improving spray application technology in specialty crops. The Pak-blast was a standard "off-the-shelf" sprayer retrofitted with a Lidar laser sensor, Doppler radar speed sensor, embedded computer, and individual pulse width modulation (PWM) solenoid valves at each sprayer nozzle. These components adjust pesticide application volume in real time to match plant canopy characteristics, with the goal of minimizing pesticide use and off target drift while keeping pest management similar to standard sprayers. A spray console wired to the system allowed use of either the intelligent spray system (ISS) components or standard operation mode. When the ISS was used it was referred to as "automated mode," and when the system was off and standard operation occurred it was referred to as "standard mode."

Leaf and cluster data was 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 22 June through 16 August 2018. The severity of powdery mildew on clusters was taken on 11 July and 1 August 2018. Treatments were also evaluated using the area under disease progress curve (AUDPC) which was calculated by multiplying the mean incidence or severity 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 severity of mildew at *ith* observation and X_i is the day of the i*th* observations) and adding together the values. AUDPCs were calculated using the agricolae package in R version 3.5.1 and a modeled with a 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. Any overdispersion was corrected for using an observational level random effect.

Spray coverage was evaluated on 22 June 2018 using water as the spray mixture on the same vines where sulfur treatments were applied. Water sensitive cards (TeeJet Technologies, Wheaton, IL) were clipped back-to-back with a sign holder (VersaGrip, Deflecto LLC, Indianapolis, IN) and attached to vines on the east and west side of the row in the cluster zone so that one card was facing east and one card was facing west. Cards that were clipped to the outside of the row were termed "outer canopy" cards, and cards that were clipped to the inside of the row were termed "inner canopy" cards. Tractor settings tested included automated at 1.9 mph, standard at 1.9 mph and standard at 4.5 mph which mirrored the settings in the sulfur trial. Spray coverage percentages were modeled using a generalized linear model. Treatment contrasts were conducted using the emmeans package. Uncertainty was estimated using asymptotic 95% confidence intervals.

Spring weather conditions for grapes were considered warm and dry with below normal rainfall. Symptoms of powdery mildew were first found on 14 May as a few individual colonies on scattered vines. (One flag shoot was also observed in a nearby Pinot Gris block.)

All sulfur treated vines had significantly lower leaf AUDPC values than non-treated vines (Figure 1). AUDPC values were lowest and not significantly different (Figure 1) for all sulfur treatments applied using the standard sprayer mode. Vines treated with 5lb/100gal Microthiol Disperss using the automated mode had a significantly higher AUDPC value than all other Microthiol Disperss treatments (Figure 1). No phytotoxicity was observed on treated vines over the course of the season.

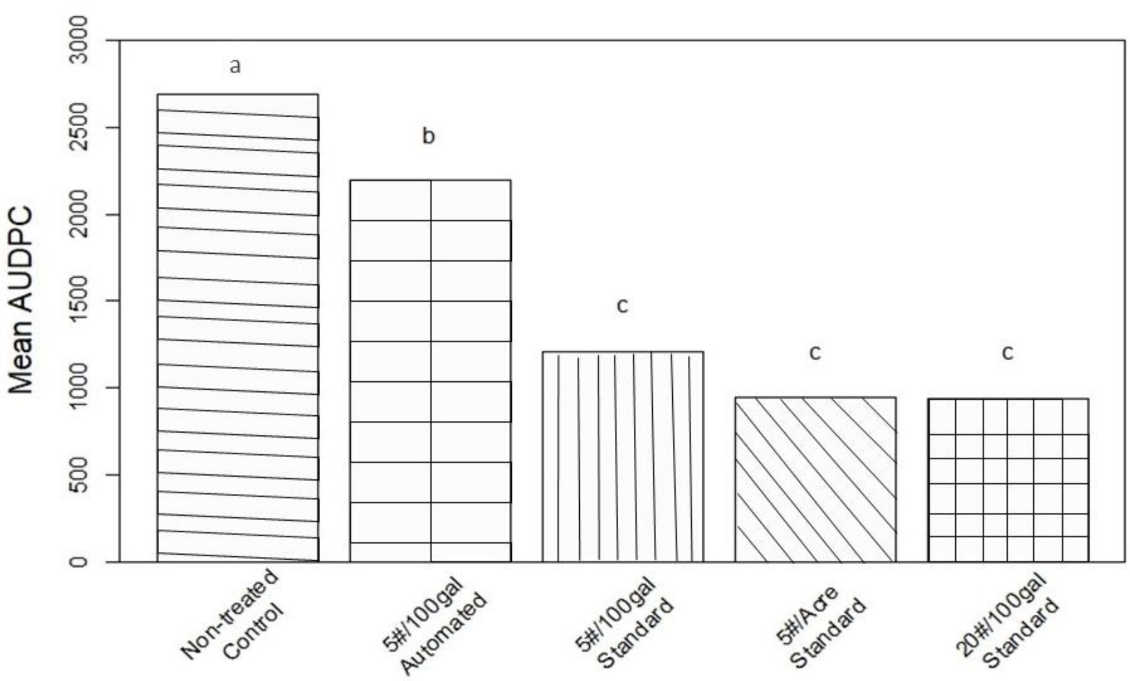

Figure 1. Leaf incidence Area Under Disease Progress Curve (AUDPC) for each treatment. Treatments with the same letter do not differ significantly based on Tukey Honest Significant Difference test ($p < 0.05$).

All sulfur treated vines had significantly lower cluster severity than non-treated vines (Figure 2). Cluster severity was lowest and not significantly different for all sulfur treatments applied using the standard sprayer mode (Figure 2). Vines treated with 5lb/100gal Microthiol Disperss applied using the intelligent sprayer system components had a significantly higher severity than all other Microthiol Disperss treated vines (Figure 2).

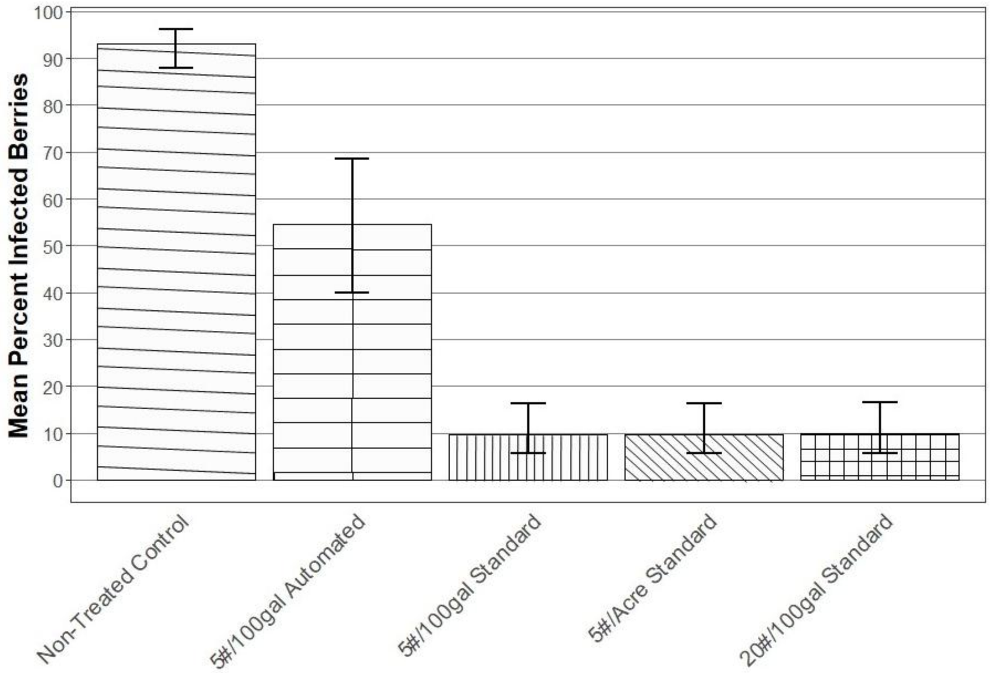

Figure 2. Cluster severity (mean percentage of infected berries) for each treatment. Error bars represent 95% confidence intervals where confidence intervals that overlap are not significantly different from each other.

Among all three tractor settings within the outer canopy group there were no significant differences in percent coverage of water sensitive cards (Figure 3). In the inner canopy group, the standard sprayer mode applied at 1.9mph resulted in significantly higher percent coverage of water sensitive cards than automated mode at 1.9mph and standard mode at 4.5mph (Figure 3).

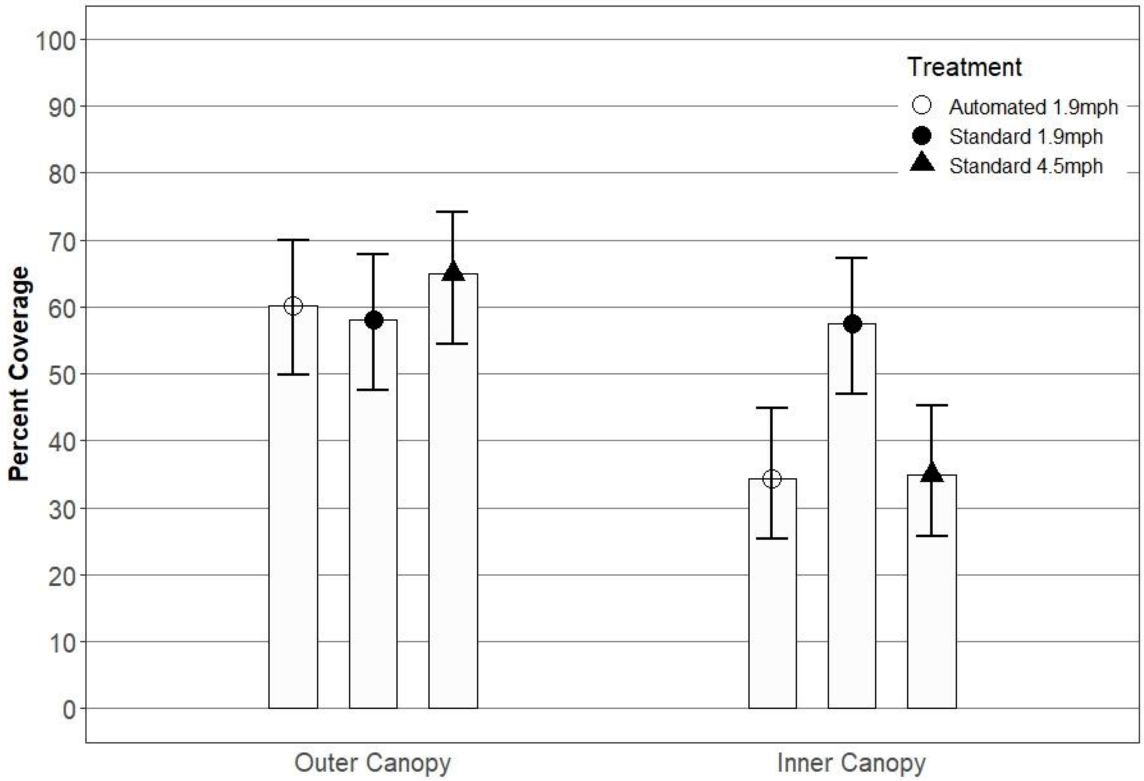

Figure 3. Percent coverage on water sensitive cards placed in the cluster zone. Error bars represent 95% confidence intervals where confidence intervals that overlap represent treatments that are not significantly different from each other.

Sulfur applications occurred on 18 May (BBCH 16), 28 May (BBCH 53), 7 June (BBCH 62, early flowering), 14 June (BBCH 64), 21 June (BBCH 71, fruit set), 29 June (BBCH 73), 10 July (BBCH 77), 19 July (BBCH 79), 30 July (BBCH 80) and 10 August (BBCH 81, beginning of veraison). Application volumes ranged from 105 to 115 gal/A in standard mode treated plots at the slower 1.9 mph speed and 46 to 47 gal/A at the higher 4.5 mph speed; volumes were much lower in automated mode and ranged from 18 to 47 gal/A (computer calculated values, Figure 4).

Note: The 20 # Microthiol Disperss treatment went out at 100 gal/A with the first application which meant it was over the labeled rate of 10 lb/A. A lower gal/A was achieved by adjusting to a faster tractor ground speed.

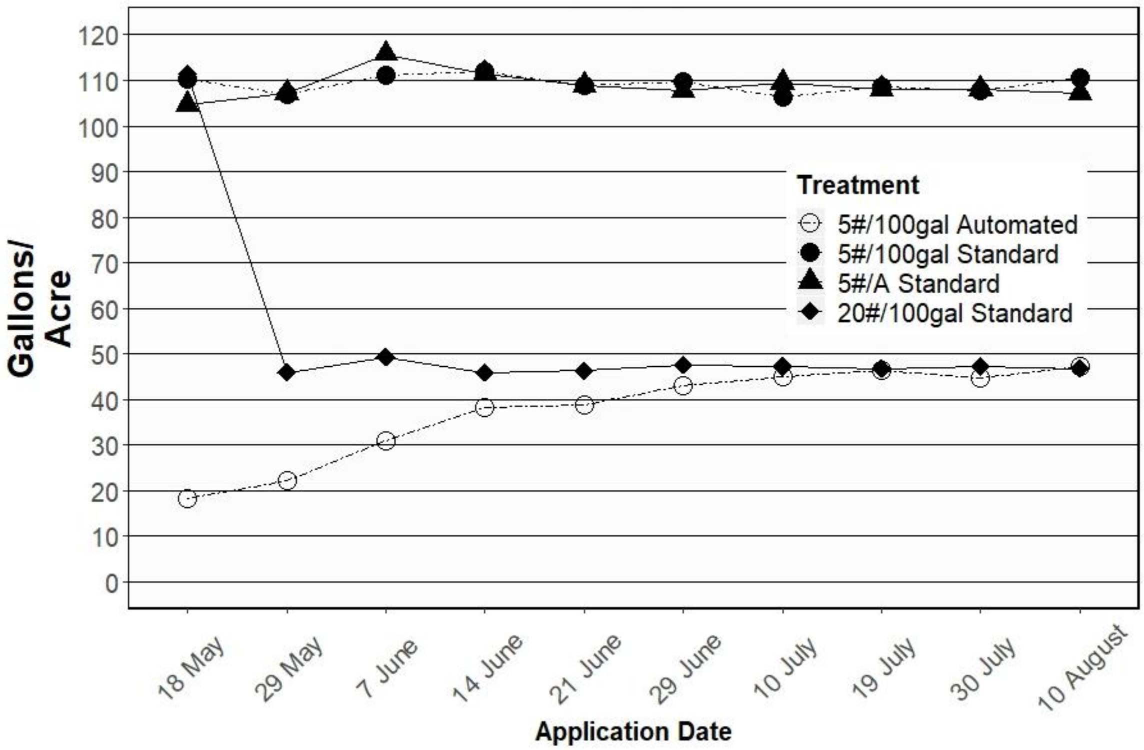

Figure 4. Volume of pesticide solution applied per acre. Values are from the embedded computer which calculates volume sprayed based on parameters in the intelligent sprayer user controls.

The amount of Microthiol Disperss applied during each application ranged from to 5.4 to 5.7 lb/A for 5#/100gal standard mode and 0.9 to 2.4 lb/A for 5#/100gal automated mode, 5.1 to 6.1 lb/A for 5#/Acre in standard mode treated plots at the slower speed and 9.3 to 9.5 lb/A for 20#/100gal standard mode at the higher speed (back calculated from computer volumes, Figure 5).

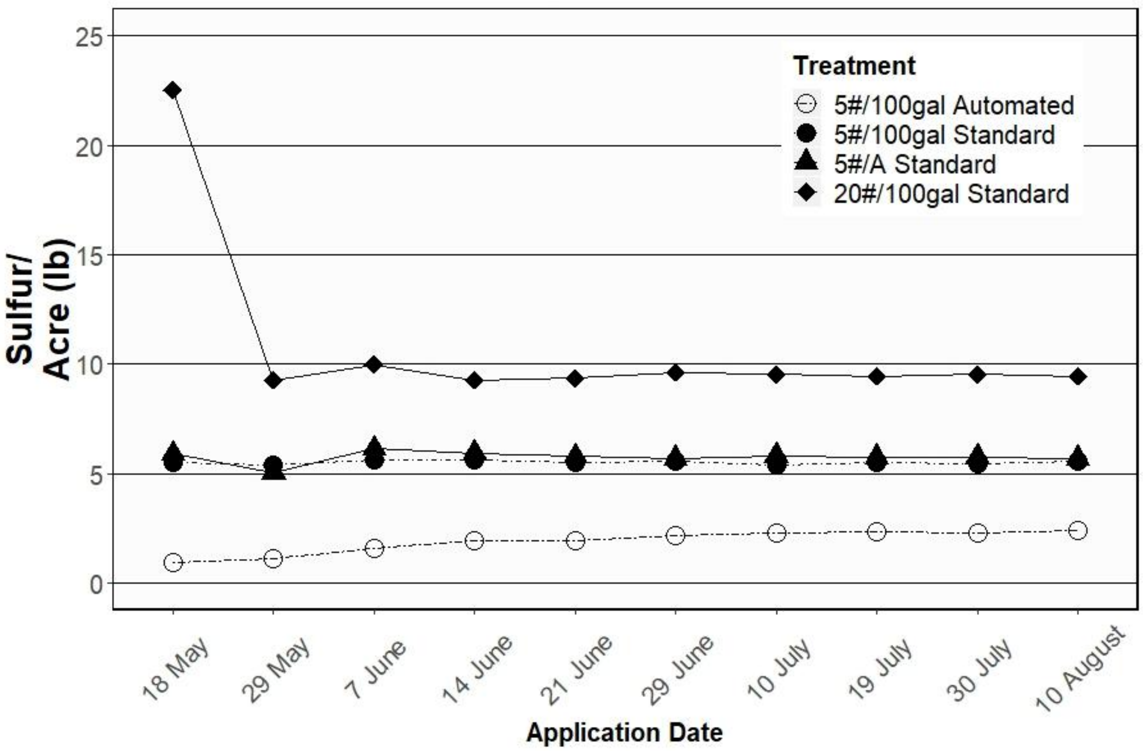

Figure 5. Mass of Microthiol Disperss applied per acre during each application. Values are back calculated from the embedded computer volumes.

Summary

The intelligent spray system did not control powdery mildew on grape as well as a standard sprayer. Factors that contributed to this result included severe powdery mildew pressure, use of the non-systemic fungicide sulfur and use of initial (out of the box – off the shelf) Intelligent Spray System (ISS) settings. Spray card coverage was not significantly different among treatments in the outer canopy group, however the standard mode 1.9mph treatment had significantly higher coverage than the automated mode 1.9mph and standard mode 4.5mph treatments in the inner canopy group. This could explain some of the higher disease levels observed in automated mode treated plots, however mildew levels in the standard mode 4.5mph treated plots was significantly lower than the automated treatment plots. The coverage trial in combination with the disease data indicate that a main factor leading to higher disease levels in automated treated plots was low spray volume (not enough sulfur/A) applied with the ISS. In this study the ISS was set to apply a spray volume of 0.06 fl oz/ft^3, corresponding to a low duty cycle on the PWM valves. Future trials should test higher PWM duty cycles by setting the spray volume higher, such as 0.12 fl oz/ft^3. Additionally, spray coverage should be more rigorously evaluated at critical times for fungicide use in grapes such as pre-bloom and/or boom as well as mid-season.