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

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Efficacy of biological fungicides using an Intelligent and airblast sprayer on grape powdery mildew, 2020.

In 2020 biological fungicides were applied for powdery mildew management to Chardonnay vines at the Botany and Plant Pathology Field Laboratory in Corvallis, Oregon. The treatments focused on evaluating two unique biological -fungicides using a standard air blast sprayer, while also examining the applications of those same products using the Intelligent Spray System (ISS). The sprayer used (50 gallon Pak-blast, Rears Mfg., Coburg, OR) was a standard "off-the-shelf" sprayer retrofitted with a Lidar laser sensor, Doppler 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 ISS components or standard constant-rate operation mode. When the ISS was used it was referred to as "intelligent mode," and when the system was off and standard operation occurred it was referred to as "standard mode." The sprayer was operated using a Kubota M5N-111 tractor and the nozzles in the sprayer were TeeJet ceramic D3 discs and DC25 cores.

Treatments (Table 1) were arranged in a randomized complete block design. 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 1 March. Shoot thinning by hand occurred from 1 to 10 May and sucker removal by hand was continuous throughout the season. Shoots were cut above the top wire on 15 June and maintained at this height throughout the growing seasons. Fungicide treatments were applied every 7 days. Each treatment was replicated on 4 sets of 5 vines.

Approximately half of the normal rainfall fell during the winter and spring weather conditions were considered normal to wet with high powdery mildew pressure. Signs of powdery mildew were first found on 13 May as a few scattered lesions on vines and a flag shoot was found on 26 May and removed promptly. A string of rain events occurred during bloom (approx. 8-15 June), resulting in below average fruit set and millerandage (hens and chicks) on the majority of clusters.

Table 1. Treatments applied to Chardonnay vines during the 2020 season.

Tractor speed (mph)	Sprayer mode[x]	Treatment[yz]
N/A	N/A	Non-treated
1.9	Intelligent	Actinovate, 12oz/Acre
	Standard	
	Intelligent	Stargus, 4qt/Acre
	Standard	

[x]Intelligent treatments applied at spray rate of 0.12 fl oz/ft^3 of grape canopy.
[y]All treatments were applied at 80psi at tractor PTO rated speed.
[z]Treatments were calculated to be applied at their respective rates in standard mode, in intelligent mode less material was applied per acre due to the variable spray rate.

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 17 June through 12 August. The severity of powdery mildew on clusters was taken on 8 and 29 July. 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 severity 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 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. All data was analyzed in R version 3.5.1

Table 2. Leaf incidence area under disease progress curve (AUDPC) and percent infected clusters from the Chardonnay biological fungicide Intelligent Sprayer trial at the Botany and Plant Pathology field lab.

Treatment[x]	**AUDPC**[y]	**Cluster severity (8 July)**[y]	**Cluster severity (29 July)**[y]
Non-treated	2780 (2758-2802) A	94.1 (86.3-97.6) AB	99.8 (99.2-99.9) A
Actinovate Standard	2775 (2754-2797) AB	87.6 (73.6-94.7) BC	99.5 (98.2-99.8) AB
Actinovate Intelligent[z]	2776 (2754-2797) AB	96.2 (90.7-98.5) A	99.8 (99.4-99.9) A
Stargus Standard	2733 (2711-2754) B	79.9 (61.1-91.0) C	98.3 (94.7-99.5) B
Stargus Intelligent[z]	2756 (2735-2778) AB	89.0 (76.1-95.3) BC	99.5 (98.3-99.8) AB

[x]All treatments were applied at 80psi at tractor PTO rated speed.
[y]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.
[z]Treatment applied at spray rate of 0.12fl oz/ft^3 of grape canopy.

On 8 July cluster severity was the highest in the Actinovate intelligent treatment, with the non-treated control having slightly lower although not significantly different cluster severity (Table 2). Stargus standard resulted in the lowest cluster severity although Actinovate standard and Stargus intelligent both had intermediate cluster severity that was not significantly different than Stargus standard or the non-treated (Table 2). On 29 July cluster severity was above 99% and not significantly different from each other for all treatments except for the Stargus standard treatment where cluster severity was 98.3% (Table 2). For the AUDPC analysis, the non-treated resulted in the highest AUDPC and the only other treatment that had a significantly lower AUDPC was Stargus standard.

Cluster and leaf disease levels among all treatments in the study were well above what would be commercially acceptable, and as seen in both the AUDPC and cluster analyses, were comparable to not spraying at all, as in the non-treated control. While the Stargus standard treatment had significantly lower AUDPCs and cluster severity across all three analyses, the differences were practically insignificant with all fruit unfit for harvest and leaves fully covered with powdery mildew. The highest label rates of both Actinovate and Stargus were used, as well as the tightest application interval (7 days), suggesting that if either of these products played a primary role in a powdery mildew management program, effective control would not be achieved.

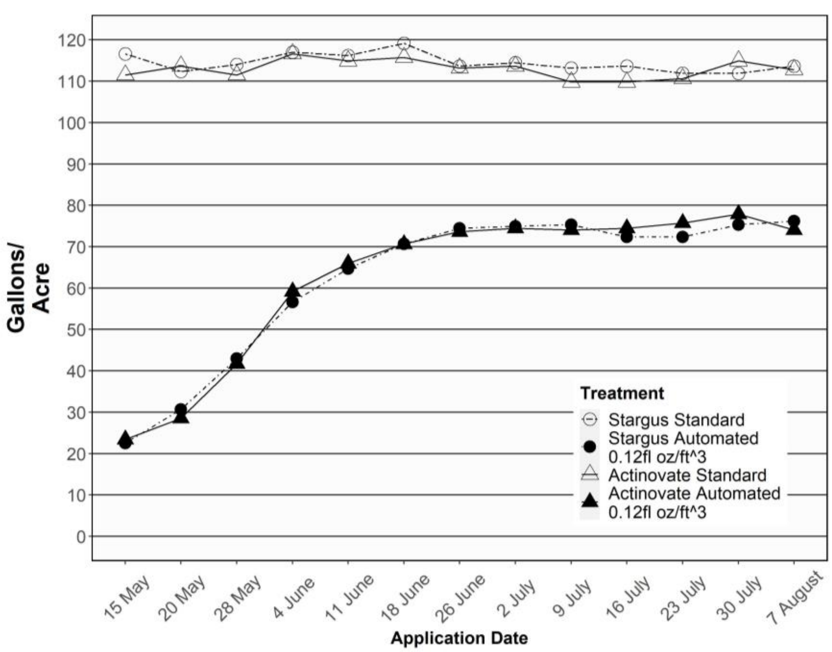

Figure 1. Gallons per acre applied at each application in the Chardonnay biological fungicide trial.

While poor disease control was achieved using both Actinovate and Stargus, when the products were applied using the ISS, the results were not significantly different in all cases than those of the same product applied in standard mode. In intelligent mode, less spray and product is applied than in standard mode (Figs. 1 & 2), as the sprayer automatically adjusts the rate to accommodate for gaps in the canopy and less dense parts of the canopy. Since disease levels were not significantly different between the standard and intelligent mode treatments on both leaves and clusters, it suggests that in intelligent mode the sprayer was distributing spray around the canopy as effectively as when the sprayer was in standard mode, with less spray used (Figure 1). The spray volume settings used in this study in intelligent mode were such that the sprayer applied 0.12 fl oz of pesticide spray per cubic foot of canopy

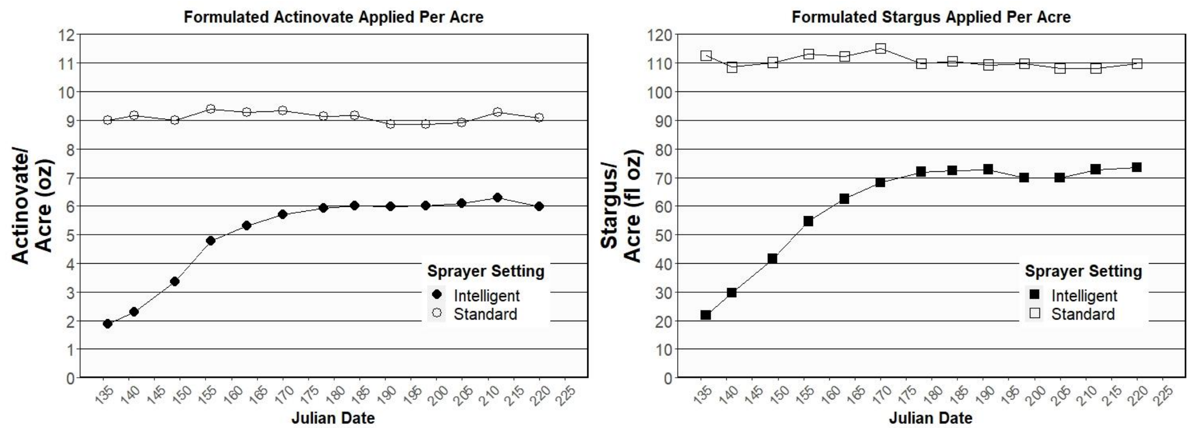

Figure 2. Quantities of formulated biological fungicides applied at each application in the Chardonnay biological fungicide trial.

volume. Other studies using ISS technology used spray rates of 0.06 – 0.12 fl oz/ft^3 and achieved good pest or disease control, depending on the products that were used (see ISS report in 2019 Fruit and Ornamental Disease Management Program Booklet).

Another possibility for the poor performance of the two biological fungicides used in this study is that the biological viability of the microorganisms in the products was harmed in the course of their application. Both biological fungicides used in this study contain viable bacteria that are supposed to colonize the plant parts they are applied to and outcompete the target pathogen for space on the plant. If the viability of the bacteria in the products was compromised they could have had less of an ability to colonize the grapevine canopy. While this is a possibility, the label instructions of both products were followed and allowed the application practices used in this trial.

Future trials could investigate the use of different nozzles or lower spray pressures, in combination with plating and biological viability tests to examine if the viability of the microorganisms is harmed in the course of their application. In addition, other biological-based fungicides should be tested to find effective regimes for grape powdery mildew control using biological fungicides.