Use of Petroleum Derived Spray Oils in Washington Grapevine Powdery Mildew Management Programs

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Abstract
The effects of petroleum-derived spray oils (PDSO) on powdery mildew control and selected berry characteristics were evaluated in vineyards in eastern Washington during 2001 and 2002. Up to seven PDSO applications were made during each growing season between the 15-to-30-cm shoot stage and veraison. The use of oil decreased total soluble solids (TSS) at harvest by 0.17% per application but had no significant effects on berry weight, pH, or titratable acidity. Because of their documented eradicant and antisporulant properties, PDSO were also utilized as the initial treatment in fungicide treatment sequences initiated upon the first visual detection of powdery mildew signs in the vineyard. When used in this fashion very early in powdery mildew epidemics, PDSO helped to reduce fungicide usage and input costs without compromising disease control.

Introduction
Powdery mildew, caused by *Erysiphe (=Uncinula) necator* Schwein. (2), is the primary fungal disease of viniferous grapes in eastern Washington (9). Despite the availability of numerous effective control materials, management of powdery mildew entails significant expenditures for fungicides, fuel, and labor. The standard approach to disease management in the region involves the intensive use of sterol demethylation-inhibiting (DMI), quinone outside inhibitor (QoI), and (more recently) quinoline fungicides. Sulfur usage has declined in the region due to concern about deleterious affects on populations of beneficial insects (12). The documented resistance of *E. necator* populations to the DMI (5,10) and QoI (17) compounds in other grape-producing regions accentuates the urgency of adopting sound fungicide-resistance management strategies. Some basic guidelines for managing resistance to fungicides are recommended by the CropLife International’s Fungicide Resistance Action Committee (3). These include (but are not limited to) the incorporation (through alternation or tank mixing) of multiple fungicide modes of action in disease management programs, limiting the number of applications of resistance-prone classes of compounds per growing season, and limiting the number of sequential applications of compounds in resistance-prone classes. In general, effective resistance management involves the mixing and/or alternation of a resistance-prone compound with compounds shown to offer lower resistance risks.

Potassium bicarbonate, monopotassium phosphate, *Bacillus subtilis*, hydrogen dioxide, sulfur, and petroleum spray oils (PDSO) are some of the powdery mildew fungicides currently available with reportedly low risk of resistance development. However, limitations accompany the use of each group. Sulfur is fungicidal over a narrow temperature range and can damage vines if applied at temperatures > 32°C. Excessive sulfur usage can have detrimental effects on beneficial arthropod populations (12), and applications made late in the season can interfere with fermentation and impart undesired flavors to wine. Potassium bicarbonate has effects on beneficial insects similar to those of sulfur...
and, under the growing conditions in eastern Washington, appears to provide very limited protective activity. *Bacillus subtilis* (Serenade) is reasonably effective as a replacement for sulfur (13) but is relatively expensive. The results of regional efficacy trials using milk products have been mediocre (13).

During the last decade, PDSO have been evaluated for use as stand-alone powdery mildew fungicides and as companion products for use in DMI and strobilurin resistance management programs. PDSO provide protective (pre- and post-lesion) eradicant, and antisporeulant effects against *E. necator* (16). They provide the added benefit of efficacy against some insect pests and their residues have no documented deleterious effects on fermentation (4). These characteristics, in conjunction with benign environmental risks and relatively low cost, make them an attractive fungicide choice for the grape grower.

However, the inhibition of total soluble solid (TSS) accumulation in berries has been documented in other cool-climate viticulture regions (7,15). Locally, grower concerns about depressed TSS values at harvest have precluded the widespread incorporation of PDSO into grapevine powdery mildew management programs. However, several organic growers in eastern Washington have used PDSO at rates of 0.5 and 1.0 % (v:v) in their disease management programs and have reported no deleterious effects on fruit quality at harvest.

Perennation of *E. necator* in the region occurs as cleistothecia, and epidemics are initiated during rain events that occur between bud burst and bloom (9). At present, fungicide applications in the region are made according to vine phenology or the calendar without regard for weather conditions or disease pressure. The initial fungicide application is typically made at the flat leaf and 15-cm (6-inch) shoot stages in high- and moderate-pressure vineyards, respectively. If the pathogen is absent or environmental conditions are not conducive for primary infection and subsequent disease development, season-long use of this management approach may be unnecessary. A possible means of reducing fungicide usage and input costs is to exploit PDSO postinfective and antisporeulant activities against primary mildew colonies, thereby slowing the rate of disease increase or halt further disease development. This approach would be initiated in the early stages of actual, rather than predicted or assumed, disease development. The timely use of PDSO as post-infective fungicides may also offer the producer a means of eliminating early sprays and lowering input costs without favoring development of fungicide-resistant pathogen populations that can result from applications of DMI and QoI compounds to active mildew colonies.

**Effects of Sequential PDSO Applications on Selected Fruit Characteristics and Disease Severity**

A 3-ha vineyard comprised of 10-year-old self-rooted ‘Chardonnay’ grapevines planted on a 3.0×1.8-m spacing was used for this study. Individual fungicide treatments were applied to four three-vine replications arranged in a randomized complete block design. Applications began at 15- to 30 cm shoot growth and continued at 14-day intervals through veraison. Treatments were applied using a handgun sprayer calibrated to deliver 1868 liters/ha at 1.1 kg/cm² (1.39 × 10³ kPA). The full-season PDSO program consisted of six (2001) and seven (2002) (Table 1) sequential applications of 1% (v:v) JMS Stylet Oil (JMS Flower Farms, Vero Beach, FL). Other treatments consisted of stepwise replacement of PDSO treatments with a tank mix of fenarimol (6.3 g ai/ha) and micronized sulfur (6.4 kg ai/ha). Untreated controls were included during both years of the study. Fungicide effects on berry weight, total soluble solids, titratable acidity, and pH were evaluated using fruit samples collected on 17 and 12 October 2001 and 2002, respectively. One hundred berries arbitrarily selected from the center vine of each replication were weighed and used for subsequent fresh berry analyses. Pectinase enzyme (Rohapect D5-L, Scott Laboratories, San Rafael, CA) was added at the rate of 1 ml of enzyme per kg of fresh berries. Juice was extracted in a Squeezo-Strainer (Lemra Products, Boca Raton, FL), centrifuged at 4080 × G for 10 min in a Sorval RC-5 Hi-speed centrifuge (DuPont Corp, Newton, CT). The supernatant was filtered through fluted filter paper (No. 588, Schlechter and Schuell, Keene, NH). The filtrate was
used for determination of percent soluble solids, pH, and titratable acidity. Percent soluble solids was measured using a temperature-compensating Abbe refractometer (Model 10450, American Optical Corp., Buffalo, NY). The pH was measured with a pH meter (Model 455, Corning Inc., Kennebunk, ME) calibrated to pH 7.0 and 4.0. Titratable acidity was determined by titrating 5 ml of juice diluted with 100 ml of boiling distilled water to pH 8.2 with 0.1 N NaOH and was expressed as g tartaric acid per liter. TSS (%), berry weight (g), titratable acidity, and pH were regressed on the number of oil applications using JMP Statistical Analysis Software. The number of oil applications had significant effects on TSS (Fig. 1) but no other fruit quality parameters during both years of the study. Because an F-test (14) indicated that the TSS data from 2001 and 2002 were not significantly different, analysis was conducted on the pooled data. Results of the regression analyses are presented in Table 1.

![Graph](image.png)

**Fig. 1.** Effect of number of sequential oil applications on total soluble solids (TSS) in 'Chardonnay' berries at harvest in 2001 and 2002. Pooled data are shown because an F-test indicated that results from 2001 and 2002 were not significantly different.

**Table 1. Regression of number of oil applications on total soluble solids, 2001 and 2002.**

<table>
<thead>
<tr>
<th>Year</th>
<th>$r^2$</th>
<th>$b_0$ (intercept)</th>
<th>$b_1$ (regression coefficient)</th>
<th>$F$</th>
<th>Prob &gt; $F$</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>0.25</td>
<td>23.7</td>
<td>-0.21</td>
<td>11.32</td>
<td>0.0019</td>
<td>0.062</td>
</tr>
<tr>
<td>2002</td>
<td>0.18</td>
<td>23.1</td>
<td>-0.20</td>
<td>7.47</td>
<td>0.009</td>
<td>0.071</td>
</tr>
<tr>
<td>Combined data*</td>
<td>0.16</td>
<td>23.3</td>
<td>-0.17</td>
<td>12.96</td>
<td>0.0006</td>
<td>0.048</td>
</tr>
</tbody>
</table>

* See text.

The equation from the combined data:

\[
\text{predicted TSS} = 23.3 - 0.17 \cdot \text{(no. of oil applications)}
\]

indicated that each additional oil application will depress TSS at harvest by an additional 0.17%. However, the coefficient of determination ($r^2 = 0.16$) indicated that only 16.0% of the variability is TSS values were accounted for by the number of oil applications.

On 9 September 2001 and 10 October 2002, foliar mildew severity ratings were taken by arbitrarily selecting 25 leaves on the center vine in each replicate plot and visually determining the per cent leaf area affected. There was no fruit infection in 2001. In 2002, fruit mildew severity was rated by visually evaluating
the area infected on 10 arbitrarily-selected clusters per plot. Regression analysis was used to describe the impact of the relationship between the number of oil applications and foliar and fruit (2002 only) disease severity. Foliar disease increased significantly with increasing numbers of oil applications substituting for fenarimol + sulfur applications in 2001, but not in 2002; the relative number of oil applications also had no significant effect on fruit disease severity in 2002. In 2001 the relationship between substituted oil applications and disease severity was described by the equation:

\[
\text{predicted foliar disease severity} = 10.1 + 2.64 (\text{no. of oil applications})
\]

with a coefficient of determination \((r^2)\) of 0.28 \((F = 13.1; P > 0.0009)\).

**Utilizing the Postinfective Properties of PDSO**

The approach used for this portion of the study was to compare the industry-standard vine phenology-based fungicide program with one initiated upon initial observation of powdery mildew signs. The new program was intended to take advantage of the eradicative properties of PDSO to treat young powdery mildew colonies at, or very shortly after, disease onset in order to slow epidemic progress. Therefore, the initial oil treatment was made only if primary infection was observed. A 0.3-ha vineyard comprised of 30-year-old self-rooted 'Lemberger' grapevines planted on a 3.0-×-1.8-m row spacing was used for this portion of the study. Individual plots consisted of three vines replicated four times in a randomized complete block design. Because early symptoms and signs of ascosporic infections typically appear on leaves closest to trunks and cordons (5), the basal two leaves of each of eight shoots per cordon were examined weekly for evidence of infection (Fig. 2). A total of 100 vines were assessed every 3 to 4 days beginning at bud burst. The initial PDSO (Omni Oil; Helena Chemical Co., Collierville, TN) application was made at 1.0% v/v within 24 h of the first observed signs of infection by *E. necator*. In 2001, sulfur (6.4 kg ai/ha) or triflumizole (280 g ai/ha) were applied at 7- and 14-day intervals, respectively, following the initial oil treatment. These oil-initiated treatments were compared to a standard phenology-based program that was initiated using sulfur (6.4 kg ai/ha) at the flat-leaf stage and continued using a rotation of triflumizole (280 g ai/ha) and trifloxystrobin (70 g ai/ha) at 14-day intervals. In 2002 the initial oil application was followed by sulfur applied at 7-day intervals or alternate applications of fenarimol (6.3 g ai/ha) and trifloxystrobin (70 g ai/ha) at 14-day intervals. The industry standard program utilized in 2001 was included for comparison in 2002.

Fungicides were applied to drip with a handgun sprayer calibrated to deliver 1868 liters/ha at 14. 1 kg/cm\(^2\) \((1.39 \times 10^3\) kPA). As described above, foliar mildew severity was assessed on 10 and 12 September 2001 and 2002, respectively, and fruit mildew severity ratings were also taken at harvest in early October. Severity data were subjected to analysis of variance, and means were...
separated according to Tukey-Kramer HSD at $P = 0.05$. Total soluble solids were evaluated at harvest using the methods described above. During both years, disease severity resulting from the disease sign-driven management approach was similar to that obtained using the full season, phenology-based program (Table 2). The single PDSO application had no effects on fruit quality parameters at harvest in 2001 and 2002.

Table 2. Effect of postinfective fungicide applications on severity of foliar and fruit powdery mildew on 'Lemberger' grapevines.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Timing of initial application</th>
<th>Initial application</th>
<th>Disease severity: foliage</th>
<th>Disease severity: fruit</th>
<th>Total applications</th>
<th>Powdery mildew management (costs per ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Untreated</td>
<td>--</td>
<td>--</td>
<td>54.8 c</td>
<td>0.0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2001</td>
<td>PDSO, then micronized sulfur</td>
<td>Initial signs, then 7-day intervals</td>
<td>12 July (pea-sized berries)</td>
<td>11.4 ab</td>
<td>0.0</td>
<td>5</td>
<td>$927.80</td>
</tr>
<tr>
<td></td>
<td>PDSO, then triflumizole</td>
<td>Initial signs, then 14-day intervals to veraison</td>
<td>12 July</td>
<td>12.0 ab</td>
<td>0.0</td>
<td>2</td>
<td>$446.00</td>
</tr>
<tr>
<td></td>
<td>Micronized sulfur, then triflumizole/trifloxystrobin alternation</td>
<td>Industry standardb</td>
<td>17 May</td>
<td>9.7 ab</td>
<td>0.0</td>
<td>7</td>
<td>$1488.78</td>
</tr>
<tr>
<td></td>
<td>Micronized sulfur, then triflumizole/trifloxystrobin alternation</td>
<td>Industry standardb</td>
<td>17 May</td>
<td>9.7 ab</td>
<td>0.0</td>
<td>7</td>
<td>$1488.78</td>
</tr>
<tr>
<td>2002</td>
<td>Untreated</td>
<td>--</td>
<td>--</td>
<td>48.0 b</td>
<td>22.8 b</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PDSO, then micronized sulfur</td>
<td>Initial signs, then 7-day intervals to veraison</td>
<td>16 June (late bloom)</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>7</td>
<td>$1270.26</td>
</tr>
<tr>
<td></td>
<td>PDSO, then fenarimol/trifloxystrobin alternation</td>
<td>Initial signs, then 14-day intervals to veraison</td>
<td>16 June</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>5</td>
<td>$1045.53</td>
</tr>
<tr>
<td></td>
<td>Fenarimol/azoxystrobin alternation</td>
<td>Industry standard</td>
<td>23 May</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>7</td>
<td>$1451.82</td>
</tr>
<tr>
<td></td>
<td>Micronized sulfur, then fenarimol/trifloxystrobin alternation</td>
<td>Industry standard</td>
<td>23 May</td>
<td>0.0 a</td>
<td>0.0 a</td>
<td>7</td>
<td>$1400.85</td>
</tr>
</tbody>
</table>

Summary and Recommendations

Effects of PDSO applications on selected fruit characteristics and disease. The suppression of TSS in wine grapes by PDSO has been documented previously (7,15). In our fruit quality study, an inhibitory effect was observed on
the accumulation of TSS, but the effect of each application was a depression of percent TSS (at harvest) by 0.17%. However, our experimental protocol did not permit differentiation of the effects of early- versus late-season applications. TSS values increase rapidly in the relatively hot weather that characterizes the veraison-to-harvest time period in eastern Washington. For this reason, most Washington winemakers consider a 0.1-to-0.5% depression in total soluble solids as insignificant, particularly in earlier varieties. Some may even consider slight depressions in TSS as beneficial because some excessive sugar is a primary problem for the winemaker. The extent of oil usage in the mildew management program in eastern Washington should therefore be a decision to be made between the grower and winemaker. However, the levels of TSS suppression reported here could be problematic in cooler grape-producing regions or locally during exceedingly cool growing seasons. We must emphasize that the levels of TSS suppression described herein occurred under summer growing conditions characterized by high solar radiation and temperature. In viticulture regions receiving less solar radiation, conditions for photosynthesis may be less conducive and the suppressive effects of PDSO on TSS accumulation more pronounced. The effects of oil usage may also be more deleterious in Washington vineyards with a high incidence of grapevine leafroll, a viral disease that has been shown to slow fruit maturation (8).

There was a significant correlation between foliar disease severity levels and the number of sequential oil applications (substituted for the fenarimol/sulfur tank mix) in 2001 but not 2002. The reason for the difference between years is unclear. One reason for increased disease severity with increased number of PDSO substitutions may be due to photodegradation (11) of oils under the intense solar radiation that characterizes summer climatic conditions in eastern Washington. In this case, photodegradation may have compromised PDSO fungicidal activity. We also speculate that high temperatures also may have contributed to the degradation of oils in the phyllosphere during July and August of 2001, which was significantly warmer than the corresponding time period in 2002. For example, the number of heat units (base 60°F) accumulated between bud burst and veraison in 2001 and 2002 was 2346 and 1582, respectively.

Use of post-infective characteristics of PDSO in mildew management programs. The initiation of the fungicide program at the first visible signs of powdery mildew offer a potential means of reducing input costs without compromising foliar disease control. For example, in 2001 the phenology- and sign-driven programs resulted in 7 and 2 fungicide applications respectively. The sign-driven PDSO:triflumizole program resulted in about $236 U.S. per ha reduction in chemical costs alone. The reduction of the application costs associated with fungicide applications would result in further cost savings of $796.50 U.S. per ha (1) which (when added to chemical costs) amounts to a total savings of $1032.80 U.S. per ha in annual mildew management costs. While the sign-driven program could be adopted with minimal risk in nonbearing or retrained vineyards, on bearing vines it has several inherent risks. The immediate pre-bloom to 4-week post-bloom period is the most critical period of fruit susceptibility (6). If primary infection has not occurred prior to the standard pre-bloom fungicide application, the safest approach would be to supplement the sign-driven program with protection during bloom. A fungicide application early in the bloom period would provide needed protection of fruit with only a moderate increase in disease management costs. Because of their documented eradicant/antisporulant properties and relatively low cost, only PDSO was evaluated as the initial treatment in all sign-driven iterations described herein. Other fungicide classes should be evaluated as the initial treatment in sign-driven disease management programs. For example, disease management costs could be lowered even further were sulfur demonstrated to be equally effective in this role.

The results of this study suggest that PDSO has an appropriate place in the grapevine powdery mildew management programs in eastern Washington and that their judicious use does not pose unnecessary risk to developing fruit. Because of high summer temperatures, relatively high levels of solar radiation,
and the concomitant risk of PDSO-induced phytotoxicity (11), Washington growers are encouraged to confine PDSO usage to earlier in the season when temperatures are less conducive for oil-induced phytotoxicity. Restricting PDSO usage to the relative cool period between bud burst and bloom would (by limiting the number of applications) also limit the magnitude of TSS suppression. These results also indicate that the exclusive reliance on 1% PDSO at the application intervals reported herein would not provide consistently satisfactory control of powdery mildew if used on a full-season basis. PDSO may perform better as a stand-alone fungicide if applied at higher rates or shorter spray intervals. However, either alternative could further depress TSS at harvest and increase chemical and labor costs. The primary uses for PDSO in eastern Washington therefore appears to be as an early-season replacement for sulfur, as a companion product for DMI, QoI, and quinoline resistance management, and as a potential tool for use in sign-driven management programs.

**Literature Cited**


