Evaluation of the efficacy of dormant applications of lime sulfur and fixed copper to control Phomopsis cane and leaf spot of grape

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Introduction

Phomopsis cane and leaf spot is a disease of grape caused by the fungus *Phomopsis viticola*. Various tissues of the vine, such as leaf, cane, rachis, and fruit can be infected by *P. viticola*. Infected leaves show small irregular, or round, pale green-to-yellow spots with dark centers (**Figure 1A**). Brown to black necrotic irregular shaped lesions develop on the infected canes and rachises (**Figure 1B**). Infected fruits appear as brown shriveled berries near harvest (Pezet et al. 1983; Pearson and Goheen 1988). Infections on the cane and rachis weakens the plant and may cause premature fruit drop. Up to 30% loss of the crop has been reported in Southern Ohio grape growing regions (Erincik et al. 2001).

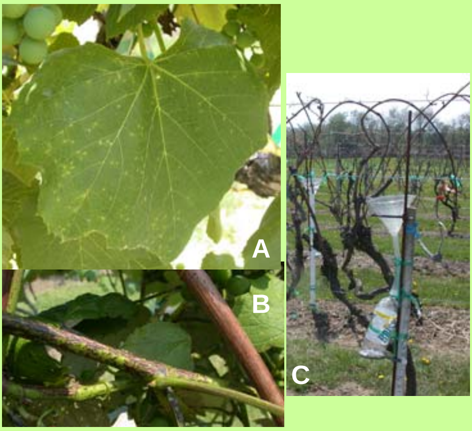


Figure 1 A) Typical leaf symptoms caused by *Phomopsis viticola* on grape, **B)** Typical cane symptoms, **C)** Spore traps under grape canopy (cultivar 'Concord')

The fungus survives winter in grape cane tissues that were infected in precious years. In spring, the pathogen on infected canes produces numerous pycnidia. Conidia are splashed by rain onto new growth where they infect the plant tissues. Typically, protective fungicide applications are used to control the disease. Grape growers apply fungicide, such as mancozeb or captan, on a 7-10 day calendar based schedule. Research has indicated that the fungus becomes active early in the growing season when only 2.5-5 cm of the new growth of the grape are present . It may not be practical to apply fungicides at this time because the target plant tissue area is very small. However, if this window of infection is missed, disease intensity could be high no matter how many fungicide applications are made afterwards. Under favorable weather conditions, the fungus could already be established in grape tissues where standard protectant fungicides have no effect. The use of dormant application of fungicides that may aid in controlling this very early season infection needs to be studied.

The purpose of this study was to evaluate the efficacy of dormant (pre-growth) sprays of two different fungicides, liquid lime sulfur (calcium polysulfide) and fixed copper (copper oxychloride sulfate) for control of Phomopsis cane and leap spot.

Materials & Methods

A 35-year old vineyard of a 'Concord' (*Vitis labrusca*) located in Wooster, OH, was used for the experiment. Calcium polysulfide (liquid lime sulfur) and copper oxychloride sulfate (fixed copper COCS) were applied to dormant vines in: the fall (after leaf drop and after formation of periderm of canes, early-November); in the spring (at bud swell, mid-April); or both. Lime sulfur was applied at 95 L and COCS was applied at 3.4 kg per ha in 379L of water. Treatments were applied using a handgun sprayer at a pressure of 689 kPa. Experimental design was a completely randomized block design, replicated four times. Each replication consisted of three vines, and the center vine was assessed for disease.

Levels of disease were assessed during late June or early July. The five basal internodes and 5 basal leaves on 10 shoots per vine were rated. Direct estimation of percentage of diseased area was used for internode disease assessments. Disease severity of leaves was assessed by estimating the number of lesions on each leaf using a scale with seven levels (0 = no spots, 6 = more than 100 spots [=lesions]). Data were transformed using an angular transformation ($\arcsin\sqrt{\%/100}$) for internode severity, or a square-root transformation for leaf lesion counts, then back-transformed after the analysis to obtain means for each treatment. Data were analyzed using a mixed linear model analysis of variance (ANOVA).

To assess the effects of treatments on subsequent sporulation, three infected canes per vine were collected at the end of the growing season (after formation of periderm tissues of cane; early-November). Each cane was cut into 10-cm sections, and then placed in a moist chamber at ~20 $^{\circ}$ C for 2 wk to induce sporulation. Sporulation of *P. viticola* was assessed by counting the number of pycnidia with cirrhi per square centimeter of cane. A total of nine 1-cm^2 sections per treatment were assessed.

Table 1 Disease incidence and severity of Phomopsis cane and leaf blight for different dormant applications of fungicides

2003		Incidence		Severity	
		Leaf	Node	Leaf	Node
Treatment[a]	Timing	%	%	#[b]	%
LS	Fall	77.3 a	77.3 ab	4.8 a	1.4 ab
LS	Spring	37.5 bc	47.1 bc	1.7 bc	0.4 c
LS	both	47.1 c	36.4 c	1.2 c	0.4 c
COCS	Fall	58.4 ac	92.8 a	3.2 ac	1.9 ab
COCS	Spring	66.1 c	54.6 bc	1.7 bc	0.8 bc
COCS	Both	37.5ab	92.8 a	4.0 ab	2.0 a
Control	N/A	53.3 ac	93.6 a	2.9 ac	2.3 a

2004		Incidence		Severity	
		Leaf	Node	Leaf	Node
Treatment[a]	Timing	%	%	#[b]	%
LS	Fall	91.1 ab	95.0 ab	6.3 ab	4.0 ab
LS	Spring	70.0 b	74.9 bc	2.9 b	1.4 bc
LS	both	71.2 b	66.1 c	3.2 b	0.8 c
COCS	Fall	81.9 ab	98.4 ab	5.8 ab	3.6 ab
COCS	Spring	76.1 b	93.6 ac	3.6 b	2.6 ac
COCS	Both	91.1 ab	98.8 a	8.4 a	4.0 ab
Control	N/A	97.5 a	99.8 a	9.6 a	5.8 a

[a] Lime sulfur (LS) was applied at rate of 94.7 L/ha and fixed copper (COCS) was applied at 3.4 kg/ha

[b] # = mean the number of lesions per leaf.

In addition, spore traps, consisting of a 20-cm funnel attached to a 2-L plastic bottle, were placed under the center vine during bud-break to the end of bloom to determine sporulation and dispersal in the field (**Figure 1C**). A trap was placed in each replication of treatments receiving both spring and fall applications of lime sulfur and the untreated control. Rainwater in the container was collected and number of conidia was counted after each rain event. Collected water was mixed constantly with a magnetic stir plate and six 20-μl samples per replication were assessed using a hemocytometer. Square-root transformation was used for spore/ml per rain episode, and data were analyzed with a linear mixed model.

Results

Effects on disease development*:** Spring application of both liquid lime sulfur (LS) and fixed copper (COCS) provided significant (P<0.05) level of control of Phomopsis cane and leaf spot (**Table 1**). In 2003, leaf disease incidence was decreased by 30% in both LS and COCS treatments, and internode incidence was decreased by 50% and 42% with LS and COCS, respectively. Leaf severity was decreased by 42% with both fungicides, and internode severity was decreased by 84% and 64% with LS and COCS, respectively. In 2004, there was higher disease intensity, and reductions in disease intensity were lower, especially with COCS, but the trend was similar. ***Sporulation on cane pieces*:** There were significant reductions (P<0.05) in number of mature pycnidia at the end of the season with lime sulfur applications (**Table 2**). Reductions in number of mature pycnidia were about 55% compared to the control, regardless of timing of application. Fixed copper treatments did not show a significant reduction compared with the control. ***Spores collected in the spring: In 2003, the peak of spore discharge was relatively early (mid-April) in the field, while in 2004, the peak was around mid-May (**Figure 2**). In 2003, the control had a significantly higher mean than treated vines in the first month after spring application, but not in the second month. In 2004, overall mean spores trapped under treated vines were significantly less than that of untreated vines, but the effect of treatment did not depend on time (**Table 3**).

Table2 Number of mature pycnidia with cirrhi of *Phomopsis viticola* per cm^2 of grape cane after the growing season of 2003

Treatment[a]	Timing	Pycnidia/cm^2 #[b]	
LS	Fall	5.29	bcd
LS	Spring	4.93	cd
LS	Both	4.62	d
COCS	Fall	8.70	ab
COCS	Spring	7.84	a cd
COCS	Both	8.41	ab
Control	N/A	11.63	a

[a] Lime sulfur (LS) was applied at rate of 94.7 L/ha and fixed copper (COCS) was applied at 3.4 kg/ha

[b] # = mean number of mature pycnidia with cirrhi per cm^2

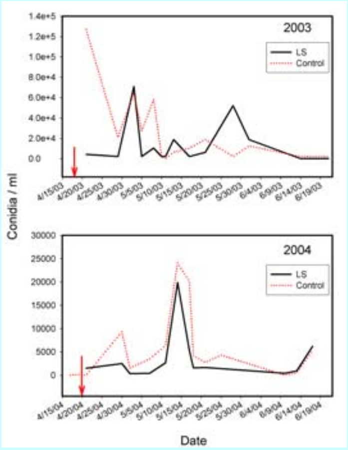
Discussions and Conclusions

Liquid lime sulfur application tended to suppress the disease better than fixed copper applications when applied in the spring (**Table 1**). But in some cases there were no significant differences between the treatments, and both treatments were generally significantly different from the control. Fall applications of both chemicals did not show significant effects on the disease control (**Table 1**). For unknown reasons, applications of fixed copper in the fall and spring resulted in higher disease intensity than application just in the spring.

Table 3 Mean number of spores per ml of splashed rain per rain event in the first and second month after applications of dormant fungicides in spring

2003	Mean spores					
	Time					
Treatment	**Month 1**		**Month 2**		**Mean**	
Lime sulfur	3056	b	3426	b	3194	
Control	9744	a	1542	b	6178	
All	6161		2434		4654	
2004						
Treatment	**Month 1**		**Month 2**		**Mean**	
Lime sulfur	4130		1637		3071	a
Control	9029		2800		6750	b
All	6580	a	2183	b	4776	

Figure 2 Spores of *Phomopsis viticola* trapped in splashed rain under a grape canopy treated in the fall and spring with Lime sulfur (LS) and untreated (Control). Red arrows indicate date of spring dormant fungicide application



One explanation for the positive effect of dormant application of lime sulfur or fixed copper is in reduction of spores that can potentially infect new tissues. This was observed during spore sampling in the spring, where significantly fewer conidia were collected in treated vines compared to the control. However, the effect on sporulation decreased over time, and there was still a substantial amount of spore release even with dormant fungicide applications (**Table 3**).

A potential longer term effect of dormant application of fungicides could be seen in lowered inoculum density on canes after the growing season, which could impact infections during the next season. Line sulfur treatments significantly reduced the number of mature pycnidia with cirrhi, compared with the control (**Table 2**). However, our data suggests that copper fungicides are less effective in dormant applications compared with lime sulfur.

Our results indicate that, although dormant fungicide applications do not provide complete control of the disease, there may be a benefit in applying lime sulfur early in the spring. Because frequent rains in the spring can prevent the timely application of protective fungicides, an application of a dormant fungicide can provide some level of protection during this critical period when plant tissues would be otherwise unprotected. Also, a dormant fungicide application in combination with a standard protective fungicide program may lead to better control of Phomopsis cane and leaf spot of grape. The economics of using dormant applications of fungicides relative to the amount of disease control needs to be studied. Dormant applications of fungicide may have greater potential in organic grape production systems where alternative fungicides are currently not available. Lime sulfur, as well as fixed copper, is registered for use with organic production of grapes.

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