Control of Black Rot in Greenhouse and Field Trials Using Organic Approved Materials, 2007

Dr. Jim Travis[1], Bryan Hed[2] , and Andrew Muza[3]

[1] Penn State Fruit Research and Extension Center, Biglerville PA 17307-1330
[2]Lake Erie Regional Grape Research and Extension Center, North East, PA 16428;
[3] Erie County Cooperative Extension; The Pennsylvania State University, Erie, PA

OBJECTIVE 1: Evaluate organic approved materials for efficacy against grape diseases (with emphasis on black rot) in greenhouse screening and field trials.
OBJECTIVE 2: Evaluate strategies to reduce over-wintering inoculum of the black rot fungus.

Objective 1:
A) Greenhouse screening on leaves and clusters of potted grapevines*:* Lime sulfur, NuFilm P, Armicarb O, Milstop, Citrex, and EF400 were applied to runoff to clusters of interspecific hybrid 'Aurore' about 6 hours before black rot inoculation (5 x 10^4 spores per ml). Check clusters were destroyed confirming very adequate challenge to the materials tested. Milstop and Armicarb O provided nearly complete control of fruit rot. Lime sulfur provided good control at 1 (75 % control) and 2 % (81-85 % control) solution. NuFilm P provided no control. EF400 at 0.375 % and Citrex at 0.2 % provided 73 and 64 % control, respectively; much improved over results in 2006 in which they provided no control on fruit. This may be attributed to the use of higher concentrations and pH adjustment of the spray water.

B) Field evaluation of greenhouse screened organic materials:
1) Cluster inoculations (Table 1): Replicated treatments were applied to individual clusters (2/shoot x 10 reps) of mature Concord vines either 10 hours or 3 days before black rot inoculation (5 x 10^4 spores per ml). Each experiment was repeated 3 times. Milstop and Armicarb O performed well when applied 10 hours before inoculation but poorly when applied 3 days before inoculation. EF400 (applied with NuFilm P, adjusted to pH 7) provided fair but significant control when applied 10 hours before inoculation, but no control when applied 3 days before inoculation. This product will be re-tested at the higher recommended 0.75 % rate in subsequent field trials. Citrex (applied with xenic and pH Plus (adjusted to about pH 5)) and NuFilm P provided little or no control. To date, field and greenhouse results suggest that although these materials have activity against the black rot pathogen, they offer little or no residual protection to developing fruit. In the third repetition of experiment 1, Neptune's Harvest (fish emulsion) was included at 5 % solution, at 10 hours + 3 days before inoculation, and provided 87 % control of fruit rot (data not shown). In experiment 2, Cueva (copper octanoate) and lime sulfur provided high levels of control when applied 10 hours before infection. Lime sulfur efficacy diminished significantly whereas Cueva remained very effective, when applied 3 days before inoculation.

Table 1: Control of black rot fruit rot[z] on inoculated Concord clusters in the field.

Experiment 1					Experiment 2				
Rate/100 gal	10 hrs	% Control[y]	3 days	% Control[y]	Rate/100 gal	10 hrs	% Control[y]	3 days	% Control[y]
Milstop 5 lb	3.7 a[x]	96	56.6 d	34	Cueva 8 qts	1.0 a[x]	98	7.2 a	89
Armicarb O 5 lb	11.3 b	87	70.6 e	17	Lime sulfur 2 % + Nufilm P 8 oz	6.1 a	88	23.2 b	35
EF400 0.375 %	28.6 c	67	79.2 f	7					
Citrex 0.2 %	72.2 e	15	85.6 g	0	Milstop 5 lb + Nufilm P 8 oz[w]			46.4 c	6
Nufilm P 8 oz			96.8 h	0					
Check	85.3 fg		85.3 fg		Check	49.2 c		49.2 c	

[z]Severity = Rotted berries/total berries x 100.
[y]Percent control = control of disease severity on berries over that of the check.
[x]Means followed by the same letter within experiments are not significantly different according to Fisher's Protected LSD ($P \leq 0.05$).

2) Whole vine field trials: Organic pesticides were applied to 3-4 vine (Concord, Vidal) or 8 vine (Niagara) plots in a replicated (4x) complete block design. In Concord and Niagara trials, treatments were not extended past early July due to the continuation of very dry conditions through 4 weeks post bloom. However, wet conditions in the second half of July (more than 4 weeks after bloom) were responsible for most black rot fruit infection in 2007, and extended coverage would likely have improved results. Black rot and powdery mildew incidence and severity were determined in late August from 50 clusters per plot.

Field trial 1(Table 2): Evaluation of organic fungicides for control of black rot and powdery mildew of Concord grapes. Fruit susceptibility to black rot commences at bloom, but cluster stem (rachis), shoot, and leaf lesions can become established earlier, supplying inoculum shortly after bloom. The presence of these pre-bloom infections has been shown to increase fruit infection (objective 2 below). However in 2007, the pre bloom and early post bloom period was dry, leaving shoot and rachis tissue nearly disease free and greatly limiting later fruit infection. In hindsight, pre-bloom sprays were probably unnecessary in 2007, and programs with pre-bloom sprays of lime sulfur, Serenade + NuFilm P, Milstop, Armicarb, and Citrex, amended to a minimal copper program (Champion/lime at 5, 6) or EF400 amended to lime sulfur (at 5, 6) did not significantly improve control of black rot over the minimal Champion/lime program alone.

All treatments except Cueva and NuFilm P reduced black rot severity over the water check. The addition of NuFilm P to Champion/lime (at 4-7) numerically increased control in all disease assessments over Champion/lime (4-7) alone, and resulted in a significant reduction in the incidence of black rot and powdery mildew on fruit when compared to the check. When comparing copper formulations (Champion, Kocide, and Cueva), black rot control generally improved numerically with increasing copper content of the application, but none of these differences were significant.

Powdery mildew disease pressure was also light. All but Champion/lime at 4-7, Cueva at 1 gal, Kocide at 1.75 lb, and NuFilm P (alone) provided significant control of powdery mildew fruit infection. Programs that included lime sulfur had less powdery mildew fruit infection than all other programs. Pre and post bloom sprays of lime sulfur and Serenade + NuFilm P amended to the minimal copper program (Champion/lime at 5, 6) significantly improved the control of powdery mildew fruit infection over that of the minimal program alone. When comparing copper formulations, there was no clear relationship between copper content of the application and control of powdery mildew fruit infection. For example, the Champion/lime application (1 lb actual copper per application) failed to provide significant control of fruit infection, whereas the 2 gal rate of Cueva (0.3 lb actual copper per application) had significantly fewer clusters with powdery mildew fruit infection than Champion/lime or the check. Pre and post bloom sprays of lime sulfur amended to a minimal copper program (Champion/lime at 5, 6) significantly reduced the severity of powdery mildew rachis infection over the minimal program alone and all other treatments tested. When comparing copper formulations applied at 4-7, control of powdery mildew rachis infection generally improved with increasing copper content of the application and there were significant differences between the high and low rates of Cueva. Concord grape is sensitive to sulfur, and an examination of clusters and leaves just before harvest (Oct 4) revealed that lime sulfur did not injure fruit but did contribute to premature deterioration and abscission of leaves at the first four nodes.

Table 2: Field control of black rot and powdery mildew on Concord grape using organic approved pesticides.

		Black rot on fruit			Powdery mildew on clusters	
Treatment and rate/A	Timing[z]	% Infected	% Area[y] infected	% Control[x]	% with Infected Fruit	% Area[w] Rachis Infected
Lime sulfur 1 % Champion WP 2 lb + Lime 4 lb…….	1, 2, 3, 4, 5, 6, 7	7.0 a[v]	0.22 a[v]	91	4.0 ab[v]	0.74 a[v]
Serenade AS 4 qts + Nufilm P 8 fl oz Champion WP 2 lb + Lime 4 lb…….	1, 2, 3, 4, 5, 6, 7	10.5 ab	0.37 ab	85	5.5 abc	1.42 bc
Milstop 2.5 lb Champion WP 2 lb + Lime 4 lb.....	1, 2, 3, 4, 5, 6, 7	17.0 abc	0.46 ab	81	8.0 abcd	1.72 cdef
Armicarb O 2.5 lb Champion WP 2 lb + Lime 4 lb.....	1, 2, 3, 4, 5, 6, 7	14.0 abc	0.84 ab	65	8.0 abcd	1.64 bcde
Citrex 0.2 % + pH Plus + Xenic Champion WP 2 lb + Lime 4 lb…….	1, 2, 3, 4, 5, 6, 7	26.0 bc	1.05 ab	57	11.5 cdef	1.91 def

EF400 48 oz + Nufilm P 8 oz	1, 2, 3, 4, 7							
Lime sulfur 1 %.....	5, 6	13.5 abc	0.69 ab	71	1.0 a		2.64	g
Champion WP 2 lb + Lime 4 lb…….	5, 6	13.5 abc	0.54 ab	78	13.0	defg	1.73	cdef
Champion WP 2 lb + Lime 4 lb…….	4, 5, 6, 7	14.0 abc	0.46 ab	81	16.0	fgh	1.24	b
Champion WP 2 lb + Lime 4 lb + NuFilm P 8 fl oz…….	4, 5, 6, 7	8.0 a	0.28 a	88	12.0	cdef	1.31	bc
Kocide 3000 0.75 lbs + Lime 1.5 lb...	4, 5, 6, 7	17.0 abc	0.80 ab	67	12.5	cdefg	2.03	ef
Kocide 3000 1.75 lbs + Lime 3.5 lb...	4, 5, 6, 7	13.0 abc	0.61 ab	75	15.5	efgh	1.64	bcde
Cueva 1 gal…….	4, 5, 6, 7	20.5 abc	1.33 abc	45	15.5	efgh	2.13	f
Cueva 2 gal…….	4, 5, 6, 7	22.0 abc	1.35 abc	44	8.5	bcde	1.56	bcd
Nufilm P 8 fl oz……..	1, 2, 3, 4, 5, 6, 7	22.0 abc	1.63 bc	33	19.5	gh	2.92	g
Water treated check……	1, 2, 3, 4, 5, 6, 7	28.5 c	2.42 c		21.0	h	2.95	g

[z] Timing. 1 = 14 May; 2 = 21 May; 3 = 29 May; 4 = 6 Jun; 5 = 14 Jun (full bloom); 6 = 22 Jun (1st post bloom); 7 = 3 Jul.
[y] Severity was rated using the Barratt-Horsfall scale and was converted to % area infected using Elanco conversion tables.
[x] Percent control = control of disease severity on berries over that of the water-treated check.
[w] Severity was rated using 1 = 1-10 % disease; 2 = 10-50 % disease; 3 = 50-100 % disease.
[v] Means followed by the same letter within columns are not significantly different according to Fisher's Protected LSD ($P \leq 0.05$).

Field trial 2 (Table 3): Evaluation of organic fungicides for control of black rot of Niagara grapes, 2007. In the upwind half of each plot, black rot was allowed to develop only from naturally occurring inoculum in wood and canes (black rot disease was severe in this vineyard the previous year). In the downwind half of each plot, black rot fruit mummies were hung from the trellis wire to increase inoculum pressure. Black rot incidence and severity were determined on 21-22 Aug from 50 clusters in each sub plot.

At higher inoculum pressure (cane inoculum plus mummies) two applications of Champion/lime alone or in a rotation with 2 % lime sulfur, and four applications of Champion/lime were the most effective treatments, significantly reducing black rot incidence (% infected). All treatments significantly reduced black rot severity (% area infected) over the check. At lower inoculum pressure (cane inoculum only) ProPhyt significantly reduced black rot incidence, and all fungicide treatments except two applications of Champion/lime (minimal copper program) significantly reduced black rot severity over the check. Early sprays of lime sulfur (1-4) were applied to prevent black rot shoot and cluster stem infections that inoculation trials have shown can contribute significantly to later fruit infections. However, the pre bloom period was relatively dry, and early sprays did not significantly improve a fruit protection program under higher or lower inoculum pressure. Four applications of 2 % lime sulfur were as effective as four applications of Champion/lime at lower inoculum pressure but significantly less effective at higher pressure. The efficacy of all lime sulfur programs and the ProPhyt program improved as inoculum pressure was lowered. Treatment applications for black rot control were not extended past early July due to the continuation of very dry conditions through 4 weeks post bloom. However, when clusters were rated it became clear that most black rot fruit infection had occurred more than 4 weeks after bloom when rainfall resumed, suggesting that programs would have performed better if coverage had been extended.

Table 3: Field control of black rot on Niagara grape using organic approved pesticides.

		Black rot on fruit					
		Cane inoculum plus mummies			Cane inoculum only		
Treatment and rate/A	Timing[z]	% Infected	% Area[y] infected	% Control[x]	% Infected	% Area[y] infected	% Control[x]
Champion WP 2 lb + Lime 4 lb Lime Sulfur 2 %	5, 6…..... 1, 2, 3, 4, 7	62.0 a[w]	7.94 ab[w]	71	31.0 ab[w]	2.28 ab[w]	40
Champion WP 2 lb + Lime 4 lb Lime Sulfur 1 %	5, 6……. 1, 2, 3, 4, 7	58.5 a	6.75 a	75	24.5 ab	0.82 a	79
Champion WP 2 lb + Lime 4 lb Champion WP 2 lb	5, 6…….	75.0 ab	13.69 ab	49	25.5 ab	1.01 a	74

+ Lime 4 lb	4, 5, 6, 7….	56.0 a	6.49 a	76	34.5 ab	1.63 a	57
ProPhyt 2.4 pt	4, 5, 6, 7….	85.5 b	12.12 ab	55	18.0 a	0.97 a	75
Lime Sulfur 2 %	4, 5, 6, 7….	70.0 ab	15.93 b	41	26.5 ab	1.96 a	49
Water-treated check	1, 2, 3, 4, 5, 6, 7….	90.0 b	26.98 c		39.5 b	3.82 b	

[z] Timing. 1 = 14 May; 2 = 21 May; 3 = 29 May; 4 = 6 Jun (immediate pre-bloom); 5 = 13 Jun (full bloom); 6 = 21 Jun (1st post-bloom); 7 = 2 Jul.
[y] Severity was rated using the Barratt-Horsfall scale and was converted to % area infected using Elanco conversion tables.
[x] Percent control = control of disease severity over that of the water-treated check.
[w] Means within columns followed by the same letter are not significantly different according to Fisher's Protected LSD ($P \leq 0.05$).

Field trial 3: Evaluation of organic fungicides for control of powdery mildew of Vidal grapes, 2007. Two pre and three post bloom applications of a Champion WP 2 lb/Lime 4 lb/Microsulf 2 lb/NuFilm P 8 oz tank mix provided 75 % control of powdery mildew fruit infection and 39 % control of leaf infection by mid September. These results demonstrate the potential for organic production of Vidal in the Lake Erie region of Pennsylvania.

In conclusion, 2007 fungicide trials continue to confirm the superiority of copper over other alternatives, for black rot control. However, there may be potential for *reducing* copper application by reducing rates, integrating formulations with lower copper content, and by the use of lime sulfur or other alternatives during lower disease and inoculum pressure and lower fruit susceptibility.

Objective 2: Strategies to reduce over-wintering inoculum of the black rot fungus.

Timing and prevention of black rot shoot infections. Black rot shoot infections can contribute to crop loss where effective organic fungicides are lacking and may be an important source of over-wintering inoculum. Shoot inoculations were conducted on Concord grape to determine the susceptibility period of the basal 5 internodes and the importance of early shoot infections to subsequent fruit rot. Shoots inoculated on 18 May (2-3 leaf stage) produced black rot leaf, shoot, rachis, and petiole lesions with pycnidia (spore producing structures) by early bloom. Internode 1 was nearly resistant and internode 3 most susceptible. All leaves were susceptible (data not shown). Shoots inoculated on 29 May (5-6 leaf stage) produced black rot leaf, shoot, rachis, and petiole lesions with pycnidia by the end of bloom. Internodes 1 and 2 were fully expanded and were resistant. Internode 3 was almost fully expanded and nearly resistant. Internodes 4-6 were expanding and susceptible. Dormant pruning of Concord grape typically retains 5 node canes. This suggests that shoot protection may need to continue through May when conditions are wet, to reduce wood borne black rot over-wintering inoculum in the trellis. Pre bloom inoculations established cluster stem infections that resulted in significant reduction of flowers and berries/cluster, and increased fruit rot (Table 4). For example, the 29 May inoculation reduced berries/cluster by 57.5 % with a subsequent 30 % loss of the remaining berries to fruit rot, for a total crop loss of about 70 %. The 3.89 % fruit rot on the non-inoculated shoots likely resulted from spread of the pathogen from lesions on nearby inoculated shoots. Infection of shoots and the subsequent crop loss was more severe from the 29 versus the 18 May inoculation and may be due to more optimal temperature during infection, greater susceptibility of the host on 29 May, or both.

Table 4: Black rot cluster stem lesion and fruit rot development on inoculated Concord clusters in the field.

	Cluster stem Incidence (12 Jun)	Cluster stem Severity (12 Jun)	Fruit rot Severity (11 Sep)	Berries/ Cluster
Inoculated (18 May)	18.8	0.44	9.63	33.9
Non-inoculated	0	0	0.40	31.1
Inoculated (29 May)	88.2 a	2.07 a	29.82 a	14.1 a
Non-inoculated	0 b	0 b	3.89 b	33.2 b

Means within columns followed by different letters are significantly different according to Fisher's Protected LSD ($P \leq 0.05$).

These results probably demonstrate a worst case scenario, but highlight the potential importance of pre-bloom black rot shoot/rachis infections in vineyards with high over-wintering inoculum loads, even in a dry year like 2007. Shoot infections represent a source of over-wintering inoculum that cannot be completely pruned out of the trellis. The epidemiology and control of early black rot shoot and rachis infection will be examined again in 2008.