APPLE (*Malus domestica*, 'Crimson Crisp', 'Crimson Gold', 'Crimson Topaz', 'Florina Querina', 'Galarina', 'Liberty', 'William's Pride', and 'Winecrisp')

Apple rusts; *Gymnosporangium* spp.
Brooks spot; *Mycosphaerella pomi*
Fruit rots; *Botryosphaeria* spp. and *Colletotrichum* spp.
Sooty blotch; disease complex

T.L. Bradshaw[1], A. Hazelrigg[2],
J. Foster[1], S.L. Kingsley-Richards[1]
[1]Department of Plant and Soil Science
[2]UVM Extension
University of Vermont,
Burlington VT 05405

Biological disease management of *Vf*-gene scab resistant organic apples, 2015.

This research was conducted to evaluate biological and 'low-dose' copper fungicide effects on disease incidence on *Vf*-resistant, organically-managed apples. The study orchard was located at the University of Vermont Horticultural Research and Education Center in South Burlington, VT, in a certified organic apple orchard planted in 2011. The orchard was planted in a randomized complete block design with single-tree replications per plot of eight scab-resistant cultivars ('Crimson Crisp', 'Crimson Gold', 'Crimson Topaz', 'Florina Querina', 'Galarina', 'Liberty', 'William's Pride', and 'Winecrisp') on M.26 rootstock at 1.2 x 4.6 m spacing. All cultivars within a replicate plot received the same treatment, with five replicates per treatment. Treatment materials included three biological fungicides (Actinovate AG, active ingredient *Streptomyces lydicus* strain WYEC 108; Double Nickel 55, a.i.: *Bacillus amyloliquefaciens* strain D747; and Serenade MAX, a.i.: *Bacillus subtilis* strain QST713), an organically-acceptable non-biopesticide material (Cueva, a.i.: copper octanoate), and a non-treated (NTC, water only applied) control. Each biopesticide was evaluated alone (i.e., in each spray treatment during the season) and in alternation with Cueva (i.e. application 1= biopesticide, application 2= Cueva…) which resulted in a total of eight treatments. Treatment timing was designed to manage rusts, fruit rots, and other summer diseases on fruit. Treatments were applied seven times from 8 May – 9 Jul with a hydraulic handgun sprayer calibrated to deliver 935 L/ha of spray material in a water carrier. All plots received standard organic insecticide and foliar mineral sprays as well as a single application of lime sulfur (Miller Chemical & Fertilizer Corp., Hanover, PA, 13.75 L/ha) to aid with crop thinning. Foliar disease assessment was conducted on 27 Jul - 5 Aug; and five vegetative terminals per tree were assessed for total number of leaves with rust lesions. At harvest, ten fruit were assessed per tree for incidence of rust, Brooks spot, fruit rot, sooty blotch, and flyspeck symptoms. Replicate mean data were analyzed using two-way ANOVA by spray treatment and cultivar using Tukey's adjustment for multiple comparisons if the overall F-test was significant (α=0.05). All proportional data underwent arcsine square-root transformation prior to analysis. Cultivar effect was significant for all parameters; for this report, spray treatment results are presented.

Weather was dry through the end of May, although 26 mm rain on 10-12 May led to reapplication of treatments made on 8 May. June was wet with 221 mm rainfall and another 125 mm rain fell in July. Late summer weather conditions were dry overall. Foliar rust incidence ranged from 31.3-43.5% across all cultivars, and all treatments which included Cueva had lower rust incidence than the NTC. Treatment differences on individual cultivars were observed only on 'Liberty' and 'Florina Querina'. On 'Liberty', all biocontrol + Cueva treatments had lower rust incidence than the NTC; on 'Florina Querina', only Serenade + Cueva and Cueva alone had lower rust incidence than NTC. Incidence of rust on fruit ranged from 7.9 - 21.6% across all cultivars, and Cueva alone and in alternation with biofungicides had lower incidence than NTC. On 'Winecrisp', Double Nickel 55 + Cueva had lower fruit rust incidence (6.3%) than NTC, Actinovate, and Serenade MAX alone (38.0, 38.8, 41.7%, respectively). Fruit rots were assessed for all rots and not separated by causal organism. Across all cultivars, Actinovate + Cueva had lower incidence of fruit rot than Double Nickel alone. Only on 'Crimson Topaz' were differences among treatments observed, and Actinovate alone had higher fruit rot than Cueva, Double Nickel, Actinovate + Cueva, and Serenade + Cueva. Among all cultivars, all treatments that included Cueva had lower incidence of sooty blotch on fruit than NTC and Serenade Max alone, and Actinovate and Double Nickel alone had lower incidence than NTC. For Brooks spot across all cultivars, all treatments which included Cueva and all biopesticide treatments except Serenade alone had lower incidence on fruit than NTC. Differences among spray treatments were observed on 'Crimson Gold', 'Crimson Topaz', 'Liberty', and 'Florina Querina', and for each of those cultivars, the Cueva treatment and Cueva + biopesticide treatments had varying levels of efficacy against the disease. Russet incidence on fruit was greatest on Cueva treatment, with 61.9% of fruit russeted, followed by the three biopesticide + Cueva treatments (41.0-45.1%), and then by the biopesticide-only treatments which were also not different from the NTC (15.4-22.3%). 'Winecrisp' had numerically higher russet incidence than all other cultivars (80.0-100.0%) and no differences among treatments, which likely skewed overall russet incidence in the pooled dataset higher than observed on most other cultivars. However, russet incidence was affected by spray treatment on 'Crimson Gold', 'Crimson Topaz', 'Galarina', 'Liberty', and 'Florina Querina', and resulted in very similar ranking of russet incidence as on the pooled data (Cueva>Cueva + biopesticides>NTC & biopesticides) was observed on all of those cultivars.

Overall, Cueva was relatively effective in managing the disease parameters assessed in this study, but fruit finish problems may limit its use as a summer fungicide. However, changes in application rate or dilution rate may reduce fruit russeting. Care was not necessarily taken to optimize copper application by applying in fast drying conditions or to dry foliage, and every application was made 6:00-8:00 am when dew was likely to be present on leaves and fruit. Furthermore, handgun application resulted in very good spray coverage but may have saturated leaf and fruit surfaces and extended drying time, thus increasing phytotoxicity. A copper-based fungicide program may be useful in a processing orchard where fruit finish is less of a concern than in a fresh market orchard. The biopesticide materials in this study were relatively ineffective against apple diseases when applied alone, with a few exceptions. However, most biopesticides when applied in rotation with Cueva were effective in reducing disease incidence compared to NTC and fruit russeting compared to Cueva alone. Further research on specific materials to use against particular diseases and different rates, formulations, and application techniques for copper fungicides is warranted.

Table 1. Percent of leaves with visible rust infection symptoms [z]

		Cultivar [y]								
Treatment and amount/ha	Timing [x]	All	CC [x]	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	43.5 a [w]	43.3	49.2	58.3	28.3	55.6 a	25.1 a	22.1	65.8
2. Cueva 18.7 L	1-7	31.3 b	43.7	44.2	41.3	20.6	18.1 c	9.0 b	21.2	53.1
3. Actinovate 0.84 kg	1-7	39.2 ab	39.2	48.7	58.4	26.1	37.7 abc	17.5 ab	21.2	67.4
4. Double Nickel 55 7.0 L	1-7	39.9 ab	44.2	48.0	58.2	28.7	43.0 ab	20.2 ab	26.4	60.6
5. Serenade Max, 3.36 kg	1-7	38.6 ab	40.2	48.0	51.3	24.6	41.6 ab	18.6 ab	21.6	58.3
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	31.7 b	33.6	35.2	50.6	21.8	27.1 bc	12.4 ab	22.3	51.0
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	34.8 b	36.6	44.5	44.6	27.5	25.4 bc	18.5 ab	21.6	57.5
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	31.6 b	36.1	38.5	48.9	20.0	25.8 bc	9.8 b	21.4	47.6
Treatment (p) [v]		0.0001	0.3067	0.0323	0.3704	0.6257	0.0001	0.0213	0.9636	0.1268

z- Mean values of all leaves assessed on five vegetative terminals per replicate, n=5.

y- Cultivar codes: All= Treatment mean across all cultivars; CC= 'Crimson Crisp', CG= 'Crimson Gold', CT= 'Crimson Topaz', GL= 'Galarina', LB= 'Liberty', QR= 'Florina Querina', WP= 'William's Pride', WC= 'Winecrisp'

x- Timing: 1= 8 May; 2=11 May; 3=14 May; 4=29 May; 5=3 Jun; 6=17 Jun; 7= 9 Jul

w- Means followed by the same letter do not differ at α=0.05 after applying Tukey's adjustment for multiple comparisons.

v- P=value for overall F-test for two-way ANOVA with cultivar and spray treatments.

Table 2. Percent of fruit at harvest with incidence of disease or russet symptoms [z]

	Rust	Cultivar [y]								
Treatment and amount/ha	Timing [x]	All	CC [x]	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	22.1 a [w]	22.2	24.0 a	54.0	14.0	16.7	8.0	0.0	38.0 a
2. Cueva 18.7 L	1-7	8.7 c	5.4	6.7 a	21.3	8.8	7.5	3.8	0.0	13.8 ab
3. Actinovate 0.84 kg	1-7	20.3 ab	33.3	26.7 a	50.0	11.3	5.8	1.6	0.0	38.8 a
4. Double Nickel 55 7.0 L	1-7	17.4 bc	20.2	21.3 a	55.0	23.8	3.3	2.5	0.0	30.0 ab
5. Serenade Max, 3.36 kg	1-7	21.6 a	35.0	13.8 a	48.8	21.3	9.2	2.5	0.0	41.7 a
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	10.3 bc	15.0	4.0 a	24.0	8.9	4.0	4.0	0.0	22.4 ab
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	10.2 bc	7.1	16.3 a	36.3	3.8	1.4	9.2	0.0	6.3 b
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	7.9 c	10.8	2.5 a	30.0	5.0	0.0	2.5	0.0	8.8 ab
Treatment (p) [v]		0.0001	0.5018	0.0053	0.1790	0.5861	0.3088	0.7479	na	0.0035
	Fruit rot	Cultivar								
Treatment and amount/ha	Timing	All	CC	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	4.2 ab	0.0	0.0	8.0 ab	8.0	0.0	12.0	2.0	2.0
2. Cueva 18.7 L	1-7	1.6 ab	3.6	0.0	0.0 b	5.0	0.0	3.8	0.0	0.0
3. Actinovate 0.84 kg	1-7	5.1 ab	0.0	0.0	18.8 a	7.5	0.0	7.2	0.0	5.0
4. Double Nickel 55 7.0 L	1-7	5.2 a	5.6	0.0	0.0 b	10.0	3.7	10.0	0.0	9.6
5. Serenade Max, 3.36 kg	1-7	3.7 ab	5.0	0.0	5.0 ab	11.3	0.0	5.0	0.0	1.7
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	1.0 b	0.0	0.0	2.0 b	0.0	0.0	4.0	2.0	0.0
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	3.4 ab	7.1	2.5	6.3 ab	3.8	0.0	0.0	0.0	9.2
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	2.2 ab	1.8	2.5	1.3 b	6.3	1.3	3.8	0.0	0.0
Treatment (p)		0.0357	0.6865	0.5530	0.0050	0.5664	0.3000	0.6605	0.8070	0.1064

Table 2, continued

	Sooty blotch				Cultivar					
Treatment and amount/ha	Timing	All	CC	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	38.8 a	41.7	64.0	48.0 a	46.0	6.0	44.0 ab	0.0	62.0
2. Cueva 18.7 L	1-7	12.6 c	7.1	41.7	12.5 ab	0.0	0.0	11.3 b	0.0	32.5
3. Actinovate 0.84 kg	1-7	22.3 bc	4.2	48.3	26.3 ab	20.0	15.0	27.8 ab	0.0	38.8
4. Double Nickel 55 7.0 L	1-7	24.4 abc	25.8	53.8	30.0 ab	12.5	3.3	20.0 ab	0.0	48.3
5. Serenade Max, 3.36 kg	1-7	38.1 ab	38.3	60.0	45.0 ab	31.6	16.9	48.8 a	0.0	60.0
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	12.9 c	8.3	26.0	0.0 b	16.9	8.0	14.0 ab	0.0	30.2
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	18.5 c	7.1	37.5	17.5 ab	22.5	6.7	11.7 ab	0.0	39.2
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	29.3 ab	30.4	50.0	36.3 ab	16.3	5.5	35.0 ab	0.0	46.3
Treatment (p)		0.0001	0.3502	0.2196	0.0406	0.0709	0.7697	0.0080	na	0.5817

	Brooks spot				Cultivar					
Treatment and amount/ha	Timing	All	CC	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	21.8 a	13.9	20.0 a	30.0 a	35.0	28.0 ab	34.0 a	0.0	10.0
2. Cueva 18.7 L	1-7	3.5 d	0.0	0.0 b	2.5 b	15.0	0.0 c	5.0 b	3.3	1.3
3. Actinovate 0.84 kg	1-7	11.6 bc	0.0	5.0 ab	18.8 ab	20.0	16.7 abc	19.1 ab	0.0	8.8
4. Double Nickel 55 7.0 L	1-7	12.6 bc	0.0	20.0 a	12.5 ab	10.0	33.0 abc	11.3 ab	5.0	7.5
5. Serenade Max, 3.36 kg	1-7	17.2 ab	12.5	20.0 a	17.5 ab	16.3	34.2 a	23.8 ab	1.7	5.0
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	7.1 cd	0.0	0.0 b	14.0 ab	8.9	8.0 abc	12.0 ab	0.0	14.0
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	5.1 cd	14.3	3.8 ab	5.0 b	2.5	1.4 bc	13.8 ab	2.5	2.5
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	7.2 cd	0.0	2.5 ab	15.0 ab	16.3	3.9 abc	10.0 ab	5.0	3.8
Treatment (p)		0.0001	0.0775	0.0105	0.0172	0.0904	0.0029	0.0228	0.3819	0.4299

	Russet				Cultivar					
Treatment and amount/ha	Timing	All	CC	CG	CT	GL	LB	QR	WP	WC
1. Non-treated control	1-7	19.5 c	30.6	20.0 b	0.0 c	0.0 c	4.0 d	8.0 b	2.0	96.0
2. Cueva 18.7 L	1-7	61.9 a	53.6	80.0 a	48.8 a	31.3 a	83.3 a	85.0 a	3.3	100.0
3. Actinovate 0.84 kg	1-7	22.3 c	12.5	16.7 c	16.3 abc	3.8 abc	8.3 cd	12.2 b	5.0	100.0
4. Double Nickel 55 7.0 L	1-7	20.4 c	9.1	15.0 c	10.0 abc	2.5 abc	5.2 cd	16.3 b	5.0	85.4
5. Serenade Max, 3.36 kg	1-7	15.4 c	23.3	15.0 c	0.0 c	0.0 c	9.6 cd	7.5 b	0.0	80.0
6. Actinovate 0.84 kg	1,3,5,7									
Cueva 18.7 L	2,4,6	41.0 b	46.7	82.0 a	22.0 abc	9.7 abc	32.0 bc	24.0 b	14.0	97.8
7. Double Nickel 55 7.0 L	1,3,5,7									
Cueva 18.7 L	2,4,6	45.1 b	78.6	66.3 b	20.0 abc	20.0 abc	61.4 ab	31.5 b	2.5	97.5
8. Serenade	1,3,5,7									
Cueva 18.7 L	2,4,6	44.8 b	43.1	56.3 b	33.8 ab	10.0 ab	58.9 ab	26.3 b	15.0	100.0
Treatment (p)		0.0001	0.3662	0.0001	0.0026	0.0001	0.0001	0.0001	0.5314	0.2236

z- Mean values of all leaves assessed on five vegetative terminals per replicate, n=5.

y- Cultivar codes: All= Treatment mean across all cultivars; CC= 'Crimson Crisp', CG= ‘Crimson Gold’, CT= ‘Crimson Topaz’, GL= ‘Galarina’, LB= ‘Liberty’, QR= ‘Florina Querina’, WP= ‘William’s Pride’, WC= ‘Winecrisp’

x- Timing: 1= 8 May; 2=11 May; 3=14 May; 4=29 May; 5=3 Jun; 6=17 Jun; 7= 9 Jul

w- Means followed by the same letter do not differ at α=0.05 after applying Tukey's adjustment for multiple comparisons.

v- P=value for overall F-test for two-way ANOVA with cultivar and spray treatments.