APPLE (*Malus domestica*, 'Ginger Gold' 'Macoun', 'Zestar!')
Apple scab; *Venturia inaequalis*
Apple rusts; *Gymnosporangium* spp.
Frogeye leaf spot; *Botryosphaeria obtusa*
Brooks spot; *Mycosphaerella pomi*
Fruit rots; *Botryosphaeria* spp. and *Colletotrichum* spp
Sooty blotch; disease complex
Flyspeck; *Zygophiala jamaicensis*

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Field assessment of biostimulants to aid in reduction of sulfur for management of apple scab in an organic orchard, 2015.

Salicylic acid, as found in high concentrations in willow bark, and yucca extracts are used as promoters of plant defense against disease. This trial was conducted to evaluate the efficacy of biostimulants to reduce the rate of elemental sulfur applied to manage apple scab and other diseases in a certified organic apple orchard. The study was conducted at the University of Vermont Horticultural Research and Education Center (HREC) in South Burlington, VT, in a certified organic apple orchard planted in 2006. Cultivars included 'Ginger Gold', 'Macoun', and 'Zestar!' on B.9 rootstock and trained to a vertical axis system. The experimental design was completely randomized in a two-way split-plot design including spray treatment and cultivar factors with five three-tree replications for each treatment and cultivar combination. Three treatments were evaluated in the study: 1) 'Organic Standard'- elemental sulfur (Microthiol Disperss, United Phosphorous, Inc., King of Prussia, PA) at a standard rate of 10 kg/ha; 2) 'Reduced Organic' - elemental sulfur at a reduced rate of 4 kg/ha; and, 3) 'Reduced Organic + Biostimulant'- elemental sulfur at 4 kg/ha plus biostimulants including yucca extract (Yucca Ag Aide, Desert King International, LLC, San Diego, CA) applied at 2 L/ha, white willow bark extract (Stryka Botanics, Hillsborough, NJ) applied at 370 g/ha and a defoaming agent (Antifoam OR-10, Momentive Performance Materials. Columbus, OH) applied at 66 ml/ha. Treatments were applied approximately weekly during primary apple scab ascospore emergence and biweekly until mid-Jul. No negative (non-treated) control was included because of the lack of sufficient tree numbers in the experimental orchard, the expectation that non-treated trees would have almost complete incidence of scab and other diseases on foliage that would be beyond commercial standards for management, and the overall goal was to evaluate the potential for biostimulants to aid in reduction of sulfur application rate from the commercial standard of 10 kg/ha to 4 kg/ha. Treatment dates for all applications were: 4, 8, 14, 27, May; 3, 10, 17 Jun; and 9 Jul. In addition, copper (NuCop 50 DF, Albaugh, Inc., Ankeny, IA) was applied at 8 kg/ha on 16 and 23 Apr, and liquid lime sulfur (Miller Chemical and Fertilizer Corp., Hanover, PA) was applied at 14 L/ha on 21 May to aid in crop thinning. All trees received a standard organic insecticide and fertility program. Treatment sprays were applied with a hydraulic handgun sprayer calibrated to deliver 935 L/ha of spray material. Foliar disease assessment was conducted on 6-7 Aug when two vegetative terminals per tree (six per replicate) were assessed for total number of leaves with of apple scab, rust, and necrotic leaf spot lesions, and number of disease lesions per leaf. Disease severity was calculated from collected data by dividing the total number of lesions per terminal by the number of leaves with lesions for a mean number of lesions per affected leaf for each disease. At harvest, ten fruit were assessed per tree (thirty fruit per replicate) for incidence of apple scab, rust, Brooks spot, fruit rot, sooty blotch, and flyspeck symptoms. Replicate mean data were analyzed in a 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.

For all evaluated parameters except incidence of quince rust on fruit, which was low overall, there was a significant cultivar effect which will not be discussed further unless in relation to any cultivar x treatment interactions. There were few observed effects of spray treatment on assessed parameters. For incidence of foliar apple scab across all cultivars, more apple scab was observed on the Biostimulant treatment than the Organic Standard treatment. No difference was found among treatments over all cultivars for foliar apple scab severity, but a cultivar x treatment interaction was observed and the Biostimulant treatment had greater apple scab severity than the Organic Standard treatment on Ginger Gold only. The Standard Organic treatment had lower incidence of foliar rust than the Reduced Organic treatment across all cultivars, and the Biostimulant treatment differed from neither. No treatment or treatment by cultivar interaction effects were seen for frogeye leaf spot incidence or severity. On fruit, apple scab incidence was greater on Reduced and Biostimulant treatments than on the Standard treatment. No treatment or cultivar x treatment effects were observed for incidence of rust, Brooks spot, or rot on fruit. No treatment effect was observed on sooty blotch or flyspeck across all cultivars, but a treatment x cultivar effect was observed: for sooty blotch, no differences were found among treatments within cultivars after adjusting for multiple comparisons (Tukey's); for flyspeck, the Biostimulant treatment had greater incidence than the Standard treatment.

Weather conditions at the test site in 2015 were challenging both for disease development and, conversely, management. Dry spring weather through the end of May resulted in few primary apple scab infection periods (IPs): one IP occurred at green tip, two light to moderate IPs occurred between bloom and petal fall, and one IP prior to the estimated end of primary ascospore release (900 degree days base 32°F since green tip) on 28 May. Therefore, the liquid lime sulfur applied for fruit thinning 21 May did not likely affect overall apple scab incidence because limited conditions for infection had occurred . Given the dry weather during May, it is likely that ascospore maturity was well-behind the standard model used to time the end of primary ascospore release, and primary apple scab infections likely occurred into June. June and July were among the wettest months on record at the HREC, which allowed ample opportunity for disease development. For example, between the 27 May and 3 Jun treatments, 71 mm rain fell in the study orchard, another 52 mm fell before the next application on 11 Jun, and 65 mm fell before the next application on 18 Jun. Given the assumption that 25-50 mm of rain will remove fungicide coverage, it is likely that not all apple scab infection periods were adequately covered during the experiment. Because primary ascospore release was complete by the end of June and little scab was observed in the planting, spray intervals were extended to 14-21 days, and 139 mm of rain fell in the orchard before the final treatment on July 9. Very little apple scab was observed during field scouting on 16 Jul, and treatment applications were suspended in order to allow for development of disease symptoms to assess in the study. In total, thirteen primary or secondary apple scab infection periods occurred during the time when treatments were applied. Foliar scab observed during evaluation consisted primarily of younger secondary lesions that most likely established during the extended wet period that occurred from the end of treatment on 9 July and disease assessment on 6-7 Aug. Extended spray intervals in June and July provided conditions for scab infection in all treatments. Observed scab incidence on fruit and foliage in August and at harvest, respectively, were well above commercial standards. Under heavy disease pressure, the Reduced Sulfur plus Biostimulant treatment showed no benefit for disease management over the Reduced Sulfur treatment alone, and in several cases disease incidence was greater than the Standard rate sulfur treatment.

Table 1. Disease incidence (percent of leaves affected) or severity (number of lesions per affected leaf) on foliage[z]

Cultivar	Treatment[y]	Apple scab incidence	Apple scab severity	Rust incidence	Rust severity	Frogeye leaf spot incidence	Necrotic leaf spot severity
Ginger Gold	Standard, 10 kg/ha sulfur	43.0	8.2 b[x]	54.9	5.4	28.8	2.5
Ginger Gold	Reduced, 4 kg/ha sulfur	45.4	12.9 ab	68.3	6.3	27.8	2.7
Ginger Gold	Reduced + Biostimulant	59.7	14.7 a	59.0	7.4	48.4	3.2
Macoun	Standard	7.7	5.5	43.9	2.2	41.4	2.8
Macoun	Reduced	12.8	2.3	47.8	2.8	43.2	4.1
Macoun	Reduced + Biostimulant	9.2	1.7	46.8	2.5	45.5	4.2
Zestar	Standard	11.3	2.5	19.9	1.7	20.9	1.5
Zestar	Reduced	17.3	3.7	31.3	1.9	26.4	1.8
Zestar	Reduced + Biostimulant	26.2	3.6	25.5	1.8	28.5	1.6
Ginger Gold	all	49.4 a	11.9 a	60.7 a	6.3 a	35.0 b	2.8 a
Macoun	all	9.9 c	3.1 b	46.2 b	2.5 b	43.4 a	3.7 a
Zestar	all	18.3 b	3.3 b	25.6 c	1.8 c	25.3 c	1.6 b
all	Standard	20.6 b	5.4	39.5 a	3.1	30.4	2.3
all	Reduced	25.2 ab	6.3	49.1 b	3.7	32.5	2.9
all	Reduced + Biostimulant	31.7 a	6.7	43.8 ab	3.9	40.8	3.0
Cultivar p-value		<0.0001	<0.0001	<0.0001	<0.0001	0.0085	<0.0001
Treatment p-value		0.0063	0.6064	0.0346	0.1207	0.1763	0.1816
Cultivar x treatment p-value		0.158	0.041	0.8213	0.2348	0.501	0.6556

Table 2. Disease incidence (percent of fruit with symptoms) on fruit[w]

Cultivar	Treatment	Apple scab	Rust	Brooks spot	Fruit rots	Sooty blotch	Flyspeck
Ginger Gold	Standard	16.0	40.0	4.0	10.7	0.0	3.3
Ginger Gold	Reduced	34.0	36.8	2.7	20.3	0.0	10.2
Ginger Gold	Reduced + Biostimulant	39.2	36.0	6.8	21.7	0.0	4.5
Macoun	Standard	7.7	1.0	27.3	0.7	5.0	5.0 b
Macoun	Reduced	13.3	0.7	26.0	2.0	18.7	23.3 ab
Macoun	Reduced + Biostimulant	21.1	3.4	21.3	0.0	14.1	26.5 a
Zestar	Standard	0.7	3.3	37.3	8.0	0.0	3.3
Zestar	Reduced	9.3	2.0	30.3	8.0	0.0	0.0
Zestar	Reduced + Biostimulant	7.3	2.7	25.2	11.3	0.0	3.0
Ginger Gold	all	29.7 a	37.6 a	4.5 a	17.6 a	0.0 b	6.0 b
Macoun	all	14.0 b	1.7 b	24.9 b	0.9 b	12.6 a	18.3 a
Zestar	all	5.8 c	2.7 b	30.9 b	9.1 a	0.0 b	2.1 b
all	Standard	8.1 a	14.8	22.9	6.4	1.7	3.9
all	Reduced	18.9 b	13.2	19.7	10.1	6.2	11.2
all	Reduced + Biostimulant	22.5 b	14.0	17.8	11.0	4.7	11.3
Cultivar p-value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Treatment p-value		0.0012	0.4188	0.7683	0.7608	0.0783	0.0695
Cultivar x treatment p-value		0.9363	0.4975	0.6521	0.8554	0.0437	0.0048

[z] Foliar disease was rated on 6-7 Aug by examining all leaves on six vegetative terminals per replicate for presence/absence of disease symptoms and number of lesions per infected leaf.

[y] Treatment included: 'Standard'- elemental sulfur (Microthiol Disperss, United Phosphorous, Inc., King of Prussia, PA) at a standard rate of 10 kg/ha; 2) 'Reduced' - elemental sulfur at a reduced rate of 4 kg/ha; and, 3) 'Reduced + Biostimulant'- elemental sulfur at 4 kg/ha plus biostimulants including yucca extract (Yucca Ag Aide, Desert King International, LLC, San Diego, CA) applied at 2 L/ha, white willow bark extract (Stryka Botanics, Hillsborough, NJ) applied at 370 g/ha and a defoaming agent (Antifoam OR-10, Momentive Performance Materials. Columbus, OH) applied at 66 ml/ha. Treatments were applied approximately weekly during primary apple scab ascospore emergence and biweekly until mid-July. Treatment dates for all applications were: 4, 8, 14, 27, May; 3, 10 17 Jun; and 9 Jul.

[x] Values within each group followed by the same letter were not different from one another at α=0.05 after applying Tukey's adjustment for multiple comparisons.

[w] Fruit disease was rated at harvest by examining thirty fruit per replicate for presence/absence of disease symptoms.