Non-target Impacts of Agricultural Biostimulants Compared with Sulfur-based Fungicides on Pest and Beneficial Arthropods in a Certified Organic Apple Orchard in Vermont, USA

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INTRODUCTION

Apple scab (*Venturia inaequalis*) is the most challenging disease to manage in Vermont apple orchards (MacHardy, 2000). Although the use of scab-resistant cultivars can virtually eliminate the need for fungicide sprays for this pathogen, there are many other economically important fungal diseases that require management to produce a marketable crop of apples. Sulfur and liquid lime sulfur remain the standard organic fungicides used to manage apple scab and other fungal diseases. However, given the negative effects of sulfur and lime sulfur fungicides on tree health and the potential impacts to predatory mites, growers and researchers are searching for suitable alternatives for disease control in the orchard. Agricultural biostimulants, used alone or in combination with fungicides, may offer new, low environmental-impact options for disease management. The objective of this research was to evaluate the non-target effects of an organic disease management system containing biostimulants compared with two sulfur-based systems on pest and beneficial arthropods on three apple cultivars in Vermont. This research is part of an overall evaluation of the target and non-target effects of an agricultural biostimulant disease management system on foliar and fruit diseases, tree growth, yield and fruit quality (Hazelrigg, 2015).

MATERIALS AND METHODS

The study was conducted in a certified organic orchard at the University of Vermont, South Burlington, VT, USA. Sprays for each organic management system (OMS-1, 2 and 3) were applied to five three-tree plots of the cultivars 'Ginger Gold', 'Honeycrisp' and 'Liberty' arranged in a completely randomized design. OMS-1 was based on the use of sulfur fungicides throughout the season except for the three to four week period of rapid shoot elongation. In OMS-2, the use of sulfur sprays was replaced with a combination of agricultural biostimulants throughout the growing season. OMS-3 was based on the use of sulfur fungicides throughout the season and served as the control in this study since this is the system applied by commercial organic apple growers in Vermont. The fungicide used in OMS-1 and OMS-3 was micronized wettable sulfur. Agricultural biostimulants in OMS-2 were prepared and applied according to a published protocol and schedule (Phillips, 2011) and included pure neem oil, liquid fish, activated microbial inoculant, equisetum (*Equisetum arvense*) tea and stinging nettle (*Urtica doica*) tea. Each application also included kelp meal, unsulfured organic molasses and yucca extract emulsifier. Weather was monitored on-site and data were used in disease models to determine spray timing in OMS-1 and OMS-3. Organic insecticides were applied to the entire orchard following a standard integrated pest management approach based on phenological bud stages plus arthropod scouting and monitoring (Hazelrigg, 2015). In addition, horticultural oil was applied to OMS-1 and OMS-3 following standard organic management procedures for arthropod management.

Standard assessment methods were used during the growing season and/or at harvest to evaluate non-target impacts of the three organic disease management systems on pest and beneficial arthropods (Hazelrigg, 2015). The following foliar pest arthropods or their damage were included in the assessments: spotted tentiform leafminer mines (STLM) (*Phyllonorycter blandcardella*); lyonetia mines (*Lyonetia prunifoliella*); other leafminer mines; white apple leafhoppers (*Typhlocyba pomaria*); green aphids (*Aphis pomi* and/or *Aphis spiraecola*); European red mites (ERM) (*Panonychus ulmi*) and two-spotted spider mites (TSSM) (*Tetranychus urticae*); Japanese beetle (*Popillia japonica*) and potato leafhopper (*Empoasca fabae*). Potato leafhopper damage data were not collected on the cultivar 'Honeycrisp' since the damage symptoms are difficult to distinguish from the cultivar's similar-appearing physiological characteristics.

Fruit were assessed for injury from plum curculio (*Conotrachelus nenuphar*); tarnished plant bug (*Lygus lineolaris*); apple maggot (*Rhagoletis pomonella*); internal Lepidoptera which included damage from codling moth (*Cydia pomonella*), oriental fruit moth (*Grapholita molesta*) and/or lesser appleworm (*Grapholita prunivora*); surface Lepidoptera, including obliquebanded (*Choristoneura rosaceana*) and/or red-banded (*Argyrotaenia velutinana*) leafrollers; European apple sawfly (*Hoplocampa testudinea*); stink bug (Hemiptera: Pentomidae); rosy apple aphid (*Dysaphis plantaginea*) and San Jose scale (*Quadraspidiotus perniciosus*). Fruit 'without arthropod pests or damage' was also noted.

Beneficial arthropod incidence was also recorded and included: predacious mites (*Typhlodromus pyri*); ladybeetle (Coleoptera: Coccinellidae) eggs, larvae and adults; gall midge (Diptera: Cecidomyiidae) larvae; hover fly (Diptera: Syrphidae) eggs and larvae; green lacewing (Neuroptera: Chrysopidae) eggs and larvae; spider mite destroyer (SMD) (*Stethorus punctum*) larvae and adults; black hunter thrips (*Leptothrips mali*); spiders (Arachnida); minute pirate bugs (*Orius insidiousus*) and mullein plant bug (*Campylomma verbasci*) nymphs.

The statistical analyses of data were performed with SAS PROC MIXED (SAS Institute; Cary, NC) using a two-way analysis of variance (ANOVA) with a significance level of $p < 0.05$. If the overall F-test for a main effect (cultivar or OMS) was significant, pairwise comparisons were performed using Tukey's HSD.

RESULTS AND DISCUSSION

Foliar Pest and Beneficial Arthropods

Many insect pests or their damage were not observed or had incidence of less than 1%. Of all the insects or damage evaluated, significant differences among the systems were only detected for Japanese beetle damage in 2013, and for STLM damage incidence in 2014 and then only when means were averaged across all cultivars (Table 1). With both insects, OMS-2 had the least damage but the level was different from only one of the sulfur-based systems and no differences were detected between the two sulfur-based systems. ERM were more prevalent than TSSM during the study (Table 2). In both years, significant differences were only detected when data were averaged across cultivars for ERM; OMS-2 had significantly lower incidence than both sulfur-based systems. Incidence of most of the beneficial arthropods assessed was less than 1.0% or non-existent throughout the orchard in both years. Of all the beneficial arthropods that were assessed in each year, there were only two data sets in 2014 where differences were detected among the systems: in the cultivar 'Ginger Gold', where populations of *T. pyri* were significantly lower in OMS-1 and OMS-2 compared to the full sulfur system (OMS-3); and, when means for adult spider mite destroyer incidence were averaged across cultivars, OMS-2 had significantly less spider mite destroyer adults compared to OMS-3.

Table 1. Insect pests where differences were observed among Organic Management Systems on 'Ginger Gold' (GG), 'Honeycrisp' (HC), and 'Liberty' (L)

	Percent Incidence															
	1-2 Aug, 2013								4-5 Aug, 2014							
	Japanese beetle damage				STLM mines				Japanese beetle damage				STLM mines			
Systems	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All
OMS-1	1.1	14.1	2.3	5.8 ab[z]	1.2	1.0	0.8	1.0	6.3	13.3	8.1	9.2	2.6	0.4	2.3	1.8 a
OMS-2	0.2	5.4	1.7	2.2 b	0.0	0.2	0.4	0.2	4.0	10.8	3.3	6.0	0.7	0.4	0.5	0.6 b
OMS-3	0.8	15.2	3.0	6.4 a	0.3	1.0	0.6	0.6	3.6	12.2	10.1	8.6	0.5	1.7	1.4	1.2 ab

[z] Means within columns followed by the same letter do not differ significantly at $p < 0.05$, Tukey-Kramer HSD; means in columns without letters are not significantly different from each other at $p < 0.05$, Oneway Analysis of Variance

Table 2. Foliage with European red mite (ERM) and two-spotted spider mite (TSSM) on 'Ginger Gold' (GG), 'Honeycrisp' (HC), and Liberty' (L)

	Percent Incidence															
	1-2 Aug, 2013								4-5 Aug, 2014							
	ERM				TSSM				ERM				TSSM			
Treatment	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All
OMS-1	91.4	90.3	97.4	93.0 a[z]	1.9	0.9	2.0	1.6	90.0	88.7	77.9	85.5 a	2.6	10.4	8.3	7.1
OMS-2	55.8	74.4	76.7	68.6 b	1.2	1.0	0.5	0.9	51.9	52.6	44.1	49.5 b	1.1	7.0	7.0	5.0
OMS-3	94.1	76.9	88.8	86.6 a	3.5	0.0	1.2	1.6	94.2	83.7	93.5	90.5 a	5.9	3.0	19.8	9.5

[z] Means within columns followed by the same letter do not differ significantly at $p < 0.05$, Tukey-Kramer HSD; means in columns without letters are not significantly different from each other at $p < 0.05$, Oneway Analysis of Variance

Arthropod Damage on Fruit

Table 3 shows the incidence of arthropod damage to fruit at harvest for both years. Fruit injury caused by some of the major insect pests of apple such as plum curculio, tarnished plant bug, internal- and surface-feeding Lepidoptera was observed on all cultivars in both years. However, no differences among the systems within the cultivars were detected for these insects. When cultivar means were averaged, system differences were only detected for surface-feeding Lepidoptera. In 2013, OMS-2 was not different from either of the sulfur-based systems, but OMS-3 had less damage than OMS-1. In 2014, OMS-2 had less damage than OMS-3, and OMS-3 was not different from OMS-1. Regarding other insect pests, the only difference in injury that was detected within a specific cultivar was associated with San Jose scale in the cultivar 'Honeycrisp'. This cultivar had more damage in the biostimulant system compared to both sulfur-based systems in 2013, and the full-sulfur system in 2014 The percentages of fruit 'without arthropod pests and their damage' for each year showed no significant differences among systems within or across cultivars in either year. Given these fruit data, the type of system did not have a major non-target impact or influence on incidence.

Table 3. Fruit with arthropod damage at harvest on 'Ginger Gold' (GG), 'Honeycrisp' (HC), and 'Liberty' (L)

2013

	Percent Incidence																			
	Plum curculio				Tarnished plant bug				San Jose scale				Surface Lepidoptera				Internal Lepidoptera			
Systems	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All
OMS-1	20.0	15.4	2.7	12.7[z]	3.3	2.7	4.7	3.6	0.0	0.0 b	0.0	0.0	16.7	18.0	5.3	13.3 a	0.7	5.6	1.3	2.5
OMS-2	10.7	20.0	6.7	12.4	4.0	5.0	2.7	3.9	0.0	3.3 a	0.0	1.1	14.3	9.6	4.0	9.3 ab	2.0	1.3	1.3	1.6
OMS-3	5.0	10.6	15.0	10.2	4.2	3.9	0.6	2.9	0.0	0.0 b	0.0	0.0	14.4	3.6	1.1	6.4 b	0.0	3.6	1.1	1.6

2014

	Percent Incidence																			
	Plum curculio				Tarnished plant bug				San Jose scale				Surface Lepidoptera				Internal Lepidoptera			
Systems	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All	GG	HC	L	All
OMS-1	25.3	42.3	8.9	25.5	3.6	9.5	3.3	5.5	0.0	3.0 ab	0.0	1.0 ab	24.4	44.7	10.7	26.6 ab	10.2	2.0	7.6	6.6
OMS-2	15.7	43.6	14.8	23.3	17.1	5.0	5.7	9.6	0.0	18.6 a	0.7	5.6 a	22.4	18.7	3.3	14.5 b	9.0	2.5	0.7	4.2
OMS-3	38.1	19.1	2.7	19.9	17.6	4.7	2.3	8.2	0.0	0.0 b	0.0	0.0 b	21.6	64.8	20.0	35.5 a	20.4	1.7	7.9	10.0

[z] Means within columns followed by the same letter do not differ significantly at $p < 0.05$, Tukey-Kramer HSD; means in columns without letters are not significantly different from each other at $p < 0.05$, Oneway Analysis of Variance

CONCLUSIONS

In summary, the organic disease management system containing biostimulants did not have different non-target impacts for almost all of the pest and beneficial arthropods evaluated in this study compared to the sulfur-based systems, but some impacts were observed. Before adoption of this novel disease management system in commercial orchards, the targeted effects of the agricultural biostimulants on apple scab and other important diseases, in addition to the non-target effects on tree vigor and yield must be considered.

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