Non-target Impacts of Agricultural Biostimulants Compared with Sulfur-Based Fungicides on Phytophagous Mites 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 phytophagous mites on the apple cultivar 'Zestar! in an organic orchard.

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, pest and beneficial arthropods, 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 Horticulture Research Center in South Burlington, Vermont, USA. Sprays for each organic management system (OMS-1, 2, and 3) were applied to five three-tree plots of the cultivar 'Zestar' 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 when no sulfur-based fungicides were applied. 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. OMS-3 is the standard organic management system applied by commercial organic apple growers in Vermont and serves as the control in this study. All materials used were organically approved. The three systems were applied to the same trees over two consecutive growing seasons (2013, 2014) to assess multi-year effects on phytophagous mites.

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. All OMS sprays were applied with an attached hydraulic handgun. 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.

'Zestar!' leaf samples were evaluated for the number of motile phytophagous mites (combined numbers per leaf of European red mite and two-spotted spider mite) on five dates on a bi-weekly schedule throughout each growing season from 1 July through 26 August. Ten intermediate-age leaves were selected randomly from each of the trees in the five three-tree replicates at mid-canopy height encircling the tree. The ten leaves collected from each tree in the five three-tree replicates were mite-brushed using a Leedom mite brusher (Hazelrigg, 2015). The total number of motile (all stages except egg) phytophagous mites was counted for each tree.

Statistical analyses of data were performed with JMP 11 (SAS Institute; Cary, NC). Analysis of variance (ANOVA) was used to compare system effects. Significant differences between means were determined by using Tukey-Kramer HSD test ($p < 0.05$).

RESULTS AND DISCUSSION

On all except the first sampling date in 2013, OMS-2 had numerically the lowest mean number of mites per leaf and OMS-3 had the highest (Table 1). Although there was no significant difference among the systems on the first sampling date, on all subsequent dates OMS-2 had significantly less mites per leaf than one or both of the sulfur-based systems. Regarding the sulfur-based systems, only on the 29 July and 12 August sampling dates, were mite incidence significantly different between OMS-1 and OMS-3 with more mites observed on OMS-3. In general, mite numbers remained low in all systems until 29 July 2013, when the established economic threshold of five mites per leaf was exceeded in OMS-1 and OMS-3 (Cooley et al., 2014).

In 2014, OMS-2 again had numerically the lowest mean number of mites per leaf across all sampling dates. However, depending on the sampling date, the incidence of mites was not significantly different from that observed in either OMS-1 or OMS-3. No statistical differences in mite numbers were detected between OMS-1 and OMS-3 on any date. The established mite threshold was reached by the 29 July sampling date in OMS-1 and OMS-3 and then incidence decreased below the threshold on the subsequent sampling dates. The number of mites in OMS-2 never exceeded the established mite thresholds in 2014.

Research has shown that when there are high populations of phytophagous mites coupled with the absence of predatory mites, the cause is typically linked to use of pesticides that are toxic to the predator (Krieter et al., 1998; Nyrop et al., 1998). Since predatory mites were not assessed in this study conducted on 'Zestar' trees, it cannot be determined whether the lower population of phytophagous mites in OMS-2 is linked to the survival of higher numbers of predacious mites in that system when compared with the sulfur-based systems. However, in the larger orchard study when predacious mite incidence was assessed on vegetative terminals of 'Ginger Gold', 'Honeycrisp' and Liberty', relatively low incidence of predacious *T. pyri* was observed on the foliage of all three systems in both years which would indicate that predacious mite populations were not a significant factor in explaining the different levels of phytophagous mites among the systems (Hazelrigg, 2015). Because of limited orchard size, the experimental design did not include a system of 'non-treated' trees. Therefore, it cannot be determined if predacious mite populations would be higher on non-treated trees compared to the trees in the three management systems under investigation, and whether the subsequent phytophagous mite populations would be lower.

Table 1. Mean number of motile phytophagous mites (European red mite and two-spotted spider mite data combined) per leaf on 'Zestar' intermediate-age leaves on five dates

	Mean number of mites per leaf									
	2013 Sampling dates					2014 Sampling dates				
Systems	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug	1 Jul	15 Jul	29 Jul	12 Aug	26 Aug
OMS-1	0.1	1.0 ab	6.1 b	20.8 b	18.4 a[z]	2.1 a	3.4	5.6 ab	4.6	7.2 a
OMS-2	0.1	0.6 b	4.4 b	9.2 b	5.2 b	0.4 b	1.5	2.2 b	2.0	2.1 b
OMS-3	0.1	1.7 a	11.2 a	27.9 a	20.9 a	1.5 ab	3.6	6.9 a	5.4	5.4 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

CONCLUSIONS

The research documents OMS-2, comprised of agricultural biostimulants and representing a novel management system for Vermont organic apple orchards, did not result in increased phytophagous mite populations compared to more traditional sulfur-based management systems in either year. When differences among the systems were observed, the mean number of phytophagous mites per leaf were lower in OMS-2 compared to the sulfur-based systems. It is also important to note that the difference in the number of sulfur sprays between the two sulfur-based systems did not appear to have a major effect on the phytophagous mite populations. Before further adoption 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 pest and beneficial arthropods, tree growth, yield and fruit quality must be considered.

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