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Effects of chlorpyrifos and sulfur on spider mites (Acari: Tetranychidae) and their natural enemies

Deirdre A. Prischmann [a,*], David G. James [b], Lawrence C. Wright [b], Roak D. Teneyck [c], William E. Snyder [a]

[a] *Washington State University, Entomology Department, FSHN 166, P.O. Box 646382, Pullman, WA 99164-6382, USA*
[b] *Washington State University, Irrigated Agriculture Research and Extension Center, 24106 N. Bunn Rd., Prosser, WA 99350, USA*
[c] *I.R.V. Goatheads, P.O. Box 1677, Umatilla, OR 97882, USA*

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Abstract

In many agricultural systems spider mites are believed to be induced pests, only reaching damaging densities after pesticides decimate predator populations. Wine grapes typically receive two types of pesticides, insecticides and fungicides. Chemicals in either class could impact spider mite densities both directly through spider mite mortality, and indirectly by negatively affecting natural enemies. The impact of a broad-spectrum insecticide (chlorpyrifos) and an inorganic fungicide (sulfur) on mites and their natural enemies was monitored in replicate open-field experiments conducted in an abandoned vineyard in Washington State. In both experiments, chemicals were applied within a 2×2 factorial design, allowing assessment of both main and interactive effects of the two chemicals. Following typical management practices on wine grapes in Washington State, we made a single insecticide application early in the season, but repeatedly applied sulfur throughout the season. In the absence of sulfur, chlorpyrifos application led to higher spider mite densities. The main effect of chlorpyrifos appeared to be indirect, perhaps mediated through mortality of generalist phytoseiid mites; generalists appeared to be unable to recover following even a single insecticide application, while there was no evidence for harmful effects of chlorpyrifos on specialist phytoseiid mites. Sulfur had direct suppressive effects on both pest and predatory mites, although in the second experiment the suppressive effect of sulfur on spider mites was weaker when chlorpyrifos was also applied. These field experiments suggest that a complex mix of direct and indirect effects of the two chemicals impacted spider mite population dynamics in our system.

Keywords: *Tetranychus mcdanieli*; Phytoseiidae; Specialist; Generalist; Vineyards; Sulfur; Chlorpyrifos

1. Introduction

Spider mites (Acari: Tetranychidae) are global crop pests that often infest vineyards (*Vitis vinifera* L.) (Flaherty and Wilson, 1999; Huffaker et al., 1970). They ingest leaf cell contents, thus reducing plant photosynthesis (Park and Lee, 2002), and potentially decreasing fruit quality and yield (Flaherty and Wilson, 1999). Spider mites are a classic example of a secondary, or induced, pest that exhibits population outbreaks when pesticides intended to reduce primary pest densities also kill natural enemies (Huffaker et al., 1970; McMurtry et al., 1970). Several arthropods feed on spider mites, notably predaceous mites (Acari: Phytoseiidae), *Stethorus* spp. (Coleoptera: Coccinellidae), and generalist macropredators (Hemiptera, Neuroptera, and Thysanoptera) (Flaherty and Wilson, 1999; McMurtry et al., 1970).

Wine grapes are perennial vines that are commonly sprayed with broad-spectrum insecticides, synthetic fungicides, and sulfur to control arthropod and fungal pests

* Corresponding author. Fax: +1 509 335 1009.
E-mail address: deirdreprischmann@earthlink.net (D.A. Prischmann).

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(Buchanan and Amos, 1992; Emmett et al., 1992). Chlorpyrifos is an organophosphate insecticide used to control cutworms, mealybugs, and grape root borer (Anon., 1998, 2002), and approximately 9800 kg were applied on grapes in 2001 in the United States (NASS, 2002). Sulfur is used to control powdery mildew *Uncinula necator* (Schw.) Burr. and eriophyid mites on grape (Buchanan and Amos, 1992; Emmett et al., 1992). In 2001, approximately 176 million kg of sulfur was used on grapes in the United States, which is almost five times the amount applied on 24 other fruit and vegetable crops surveyed by the National Agricultural Statistics Service in 2001 and 2002 (NASS, 2002, 2003).

Pesticides and their residues often have direct effects on spider mites, including mortality, decreased longevity, and reduced or increased fecundity (van de Vrie et al., 1972). In laboratory assays, chlorpyrifos can have high contact toxicity (Kovach and Gorsuch, 1986), but does not appear to affect spider mite oviposition or life span (Price and James, in press), and has neutral (Cross and Berrie, 1994) or positive effects on pest populations in field experiments (McLaren and Fraser, 1993). Sulfur varies from being non-toxic to highly toxic to spider mites in laboratory assays (Blumel and Hausdorf, 2002; Guichou et al., 2002; Price and James, in press). Price and James (in press) found that sulfur halved longevity and fecundity of *Tetranychus urticae* Koch. Although sulfur can initially suppress pest mite populations (Croft, 1990), mite densities often increase after applications cease, apparently because sulfur increases mortality, and decreases fecundity, of predators (Hanna et al., 1997; James et al., 2002; van de Vrie et al., 1972). Pesticides can also impact spider mite densities indirectly, via negative effects on spider mite natural enemies or by altering plant quality (McMurtry et al., 1970; van de Vrie et al., 1972). Chlorpyrifos is highly toxic to both specialist and generalist phytoseiid mites in laboratory assays (James, 2001; James and Rayner, 1995), but has low to moderate toxicity in field experiments (Childers et al., 2001; Croft, 1990). Sulfur can have harmful effects on phytoseiid (Croft and Brown, 1975; Hanna et al., 1997) and tydeid mites (English-Loeb et al., 1999), which are alternative prey for phytoseiid mites (McMurtry and Croft, 1997), in agricultural fields and laboratory tests (James, 2001; James and Rayner, 1995; Kreiter et al., 1998). Although laboratory experiments are useful for assessing some aspects of pesticide toxicity, field tests are more desirable because pesticide deposition and degradation, residue toxicity and repellency, sublethal effects on population structure, or potential interactions between compounds may differ under field conditions (Croft, 1990).

To investigate how direct and indirect effects of chlorpyrifos and sulfur applications affect the grape mite fauna, we conducted a field experiment, replicated in two separate plots within an abandoned vineyard with naturally high phytoseiid mite populations. We followed the impacts of chlorpyrifos and sulfur, alone and in combination, on the population dynamics of spider mites, specialist and generalist phytoseiid mites, and tydeid mites from May to September. Our objective was to investigate the direct impacts of these chemicals on spider mites, their indirect effects mediated through mite natural enemies, and whether the chemicals interacted in their effects on pest mites and their predators.

2. Materials and methods

2.1. Experimental design

The experimental site was located in Umatilla, OR, in a 'Riesling' vineyard that was previously farmed but had been abandoned (i.e., no pruning, water, or chemicals) since the late 1980s (R.D. Teneyck, personal communication). Vines were not pruned or watered during the experiment, and no sprays were applied other than treatment chemicals. Two replicates (A and B) were assessed simultaneously and located approximately 100 m apart. In both replicates, rows of plants were oriented east to west. In the A replicate, there were 17 rows of grapevines with 2–4 experimental vines per row, while in the B replicate there were 12 rows with 3–5 experimental vines per row. In both replicates, the first and last rows were buffer rows, and did not contain any experimental vines. In the A replicate, 1.45 m separated each row, while there was 1.07 m between rows in the B replicate. In both replicates, each experimental vine was bordered by an unsprayed buffer vine; thus, within a row each experimental vine was separated from other experimental vines by approximately 1.83 m. Vines in the A replicate were not trellised, and had a different physical vine and canopy structure (shorter, less vigorous) than vines in the B replicate, which were trellised. Unmanaged vegetation surrounded each site, including grapevines, Russian olive trees (*Elaeagnus angustifolia* L.), and blackberry bushes (*Rubus armeniacus* Focke), and both replicates had weedy groundcover dominated by Russian thistle (*Salsola* sp.).

The experiment was a completely randomized 2×2 factorial design, with treatments applied randomly to each individual vine; thus an experimental unit consisted of one vine. There were 10 vines in each of the following four treatments, (1) Lorsban-4E (Dow AgroSciences LLC, Indianapolis, IN; chlorpyrifos) applied once in May at a rate of 1.12 kg/ha, (2) Microthiol Disperss (Elf Atochem North America, Agrichemicals Group, Philadelphia, PA; micronized wettable sulfur) applied at 2–3 week intervals at a rate of 11.21 kg/ha, (3) a combination treatment with Lorsban-4E and Microthiol Disperss applied at the same timing and rates as above, and (4) a control treatment without spray applications. Chemicals were applied using a Stihl powered backpack sprayer