Using Acaricides in Combination with *Phytoseiulus persimilis* Athias-Henroit to Suppress *Tetranychus urticae* Koch Populations[1]

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Abstract Acaricides are often used to suppress populations of the twospotted spider mite, *Tetranychus urticae* Koch. Problems associated with acaricide use have led some ornamental producers to incorporate releases of the predaceous mite *Phytoseiulus persimilis* Athias-Henriot into pest management programs. Our objective was to determine if acaricides could be used with *P. persimilis* to suppress *T. urticae.* Ten acaricides were tested against *T. urticae* on infested *Buddleia* × *davidii* 'White Profusion' cuttings. Abamectin, chlorfenapyr, Gowan 1725, horticultural oil and neem oil suppressed *T. urticae* populations 3, 7 and 14 d after application. Bifenthrin suppressed *T. urticae* populations 7 and 14 d after application, and hexythiazox suppressed *T. urticae* populations 14 d after application. Azadirachtin, pyridaben and spinosad did not suppress populations. Acaricide applications followed by release of *P. persimilis* reduced *T. urticae* populations, but suppression with acaricides followed by predatory mite release was not significantly greater at all times than with acaricide applications alone, or with predator releases without previous acaricide application. Results demonstrate that efficacy is variable among the acaricides tested and that acceptable levels of *T. urticae* suppression can be achieved with acaricides and *P. persimilis.*

Key Words Acaricides, *Phytoseiulus persimilis, Tetranychus urticae,* population suppression

Twospotted spider mite, *Tetranychus urticae* Koch, infestations can quickly reduce the economic and aesthetic value of ornamental plants (Johnson and Lyon 1991). *Tetranychus urticae* damage may include webbing, fine stippling, leaf yellowing, leaf drop, and even plant death (Helle and Sabelis 1985). Female *T. urticae* can develop from egg to adult in approximately 6.5 d at 30°C (Sabelis 1981), and females can lay as many as 60 eggs in 5 d (Helle and Sabelis 1985). The short life cycle makes this pest an important threat to plant health and suppression of populations difficult.

Frequent acaricide applications to manage *T. urticae* populations compel growers to use numerous pesticides to circumvent the onset of pesticide resistance. *Tetranychus urticae* populations have developed resistance to hexythiazox in Australia (Hernon et al. 1993), and resistance to other chemicals can occur with numerous pesticide applications (Helle and Sabelis 1985). There also are concerns about worker and public exposure to greenhouse and nursery grown crops that are treated with pesti-

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cides. These concerns, plus the cost and logistics of multiple pesticide applications, have led some growers to use the predatory mite *Phytoseiulus persimilis* Athias-Henriot to suppress *T. urticae* populations. In Florida, *P. persimilis* reduced acaricide applications by providing 87 to 92% control of *T. urticae* spider mite on croton and 100% control on areca palms (Cashion et al. 1994). Successful biological control programs using *P. persimilis* against *T. urticae* have been established in greenhouse ranges in The Netherlands (Sabelis 1981). Releases of *P. persimilis* in interiorscapes to suppress mite populations have been performed with varying degrees of success (Lindquist 1981).

Limitations of the effectiveness of *P. persimilis* arise when environmental conditions contribute to reduced fecundity or when *T. urticae* populations reach very high densities. Optimum conditions for rapid population development of *P. persimilis* are 27°C and 60% to 85% RH (Stenseth 1979). A temperature of 27°C with <40% RH reduces the reproductive rate of *P. persimilis* by increasing egg mortality (Stenseth 1979). *Phytoseiulus persimilis* sensitivity to sub-optimal environmental conditions is a significant disadvantage because most greenhouses have temperatures and humidity levels that are outside these optima for part of the day, but within a near ideal range for *T. urticae* population growth.

Selective use of acaricides may create a favorable situation for release of *P. persimilis* by reducing *T. urticae* to levels that can be maintained by the predator, provided other environmental conditions are suitable. Additionally, biological control may be enhanced through careful selection of acaricides and releasing predators into the crop once acaricide residues are no longer toxic to them. The objective of this study was to determine the efficacy of selected acaricides and examine the performance of two acaricides for use prior to release of *P. persimilis*.

Materials and Methods

Acaricide efficacy and density manipulation. Butterfly bush plants (*Buddleia* × *davidii* cv. 'White profusion') were started from cuttings and grown in plastic containers with a peat-based, soil-less medium and fertilized with 18-18-18 Osmocote™ (Scotts Co., Marysville, OH) slow release fertilizer. No pesticides had been applied to stock plants from which the cuttings were taken. *Tetranychus urticae* colonies were maintained on lima beans, *Phaseolus vulgaris* L., in rearing cages at 30°C and 14:10 (L:D) h. Each rearing cage was a clear plastic container (20 × 40 × 30 cm) with an open top fitted with thrips-proof screening. The mites used to initiate the colony originated from an infested rose purchased at a local nursery.

Acaricide trials were conducted in 0.9-L. glass jars. Fifteen-cm long cuttings were taken from *Buddleia* plants, and lower leaves were removed leaving two or three nodes (four to six leaves). Cuttings were rinsed with tap water to remove any arthropods from foliage. Water was added to the jars for a 3 to 6 cm depth. The entire jar unit, complete with a single *Buddleia* cutting, was placed inside a glass battery jar, with 5 cm depth of water. Petroleum jelly was applied to the inner perimeter of the battery jar to prevent mite escape. The battery jar was placed in a large plastic tray, which had double-sided sticky tape on the outside. The entire unit was placed under high intensity discharge mercury vapor lighting with 14:10 (L:D) h. Cuttings were allowed to form roots in the jars before mites were released. Temperatures during the experiment averaged 28°C (12 to 43°C); relative humidity averaged 46% (28 to 65%).

Each *Buddleia* cutting was infested with 10 *T. urticae* adults 1 wk before acaricide

application. On the day of the acaricide applications, mite eggs, immatures and adults were counted. Acaricides in the study were abamectin, azadirachtin, bifenthrin, chlorfenapyr, Gowan 1725, hexythiazox, horticultural oil, neem oil, pyridaben and spinosad. Tested materials were mixed with tap water and applied to cuttings while under a fume hood using a compressed air sprayer. Control plants were sprayed with tap water. Cuttings were sprayed until runoff, returned to their jar with water, and allowed to dry in a fume hood for approximately 30 min. The number of eggs, immatures and adults were counted 3, 7 and 14 d after application. The total number of all mite stages was analyzed. Ten replications were conducted for each acaricide treatment. Temperatures during the experiment averaged 28°C with a range from 21.8 to 33.0°C. Relative humidity averaged 45% with a range of 32 to 55%. Data were analyzed by analysis of variance, and means were separated with Duncan's multiple range test (SAS Institute 1998).

Hexythiazox or oil followed by *P. persimilis* greenhouse trials. Rooted *Buddleia* cuttings were grown in a greenhouse in 10-cm containers with peat-based, soil-less medium. Plants were fertilized with 18-18-18 Osmocote slow-release fertilizer that was applied 2 wks after transplanting. Plants were grown under natural light conditions until they reached a height of 30 to 45 cm. Granular imidacloprid was applied to the soil surface at labeled rate to suppress whitefly and aphid populations.

Plants in completely randomized design with different treatments were separated by 60 cm to prevent mites from moving between them. Overhead watering was avoided to prevent mites from being washed from plants. Each plant was infested with 10 *T. urticae* adults. Plants were inspected daily for mite injury. Hexythiazox or horticultural oil was applied to the appropriate plants when foliar damage was observed. *Phytoseiulus persimilis* were introduced to horticultural oil and hexythiazox groups at a rate of 100 per block 3 d after application of the acaricide. Maximum and minimum daily temperatures and RH were recorded after plants were infested Each acaricide/predator combination treatment had an accompanying control. Samples were taken immediately before acaricide application, 3 d after application (immediately preceding predator release), and 3, 6, 9, 12 and 15 d after predator release. Ten leaves were collected from each treatment (2 from each plant) and dipped in floor wax. Waxed leaf samples were collected immediately after application, dried and stored at 4°C for less than 2 wks, at which time egg, immature and adult counted. Data were later combined and recorded for each leaf. Data were analyzed by analysis of variance; means were separated using Duncan's multiple range test (SAS Institute 1998).

Results

Acaricide efficacy and density manipulation. The mean densities of *T. urticae* on cuttings treated with abamectin, chlofenapyr, Gowan 1725, neem oil and horticultural oil were significantly lower than the control ($F = 3.36$, df = 90, $P > F = 0.0006$, Fig. 1) 3 d after treatment. Populations of *T. urticae* treated with azadirachtin, bifenthrin, hexythiazox, pyridaben and spinosad were not significantly different from the control at this time. One week after treatment, *T. urticae* populations treated with abamectin, bifenthrin, chlorfenapyr, Gowan 1725 and horticultural oil remained significantly less dense than the control ($F = 3.59$, df = 90, $P > F = 0.0003$; Fig. 1). Two weeks after treatment, the mean number of *T. urticae* remained significantly lower than the control in the abamectin, bifenthrin, chlorfenapyr, Gowan 1725, neem oil and horticultural oil

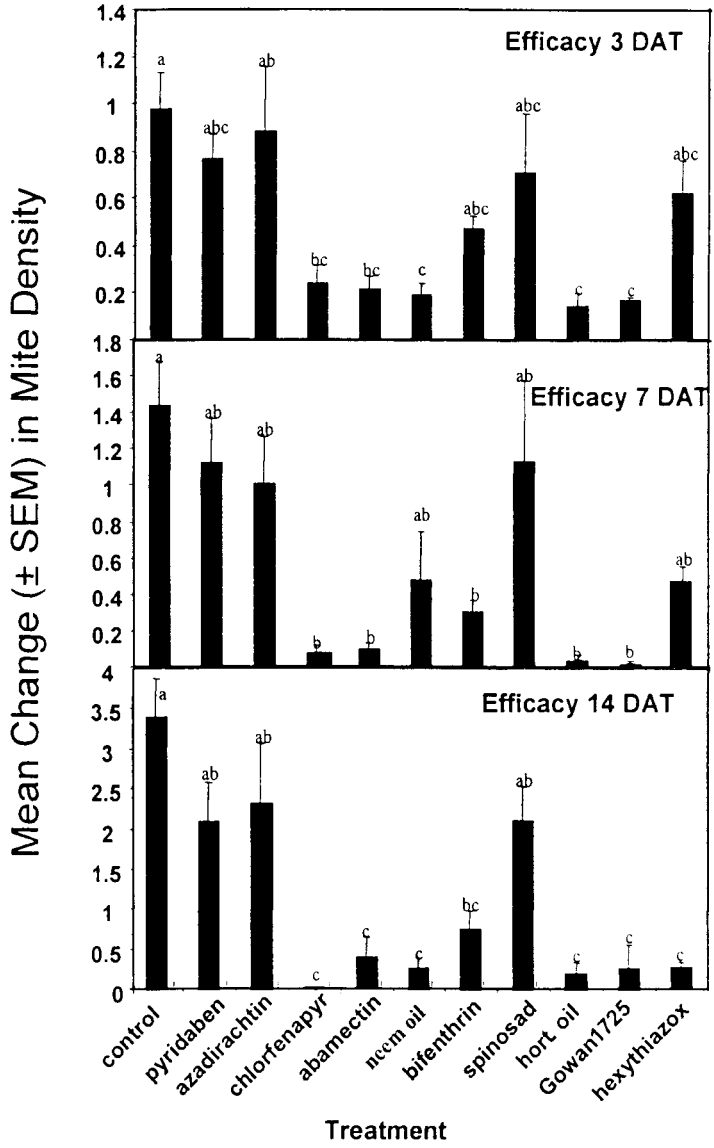

Fig. 1. Effects of acaricides on the population density of *T. urticae* on infested *Buddleia* cuttings. Means indicated with different letters are significantly different (α = 0.05).

treatments, and the hexythiazox treatment showed a difference from the control for the first time. (F = 9.32, df = 90, $P > F$ = <0.001; Fig. 1).

Hexythiazox or oil followed by *P. persimilis* greenhouse trials. The means of *T. urticae* population densities in the *P. persimilis* treatments (alone and with horti-

cultural oil) were significantly less than the control at 9, 12 and 15 d after release (F = 10.76, df = 27, $P > F$ = 0.0001; F = 6.35, df = 27, $P > F$ = 0.0014; F = 9.24, df = 27, $P > F$ = 0.0001; Fig. 2). Although not statistically significant, the means of *T. urticae* in the *P. persimilis* treatment were consistently lower than the means of *T. urticae* in the horticultural oil plus *P. persimilis* treatment. The mean number of *T. urticae* in the horticultural oil treatment was significantly greater than the *P. persimilis* and *P. persimilis* plus horticultural oil treatments 9 and 12 d after release, (F = 10.76, df = 27, $P > F$ = <0.0001; F = 6.35, df = 27, $P > F$ = 0.0014).

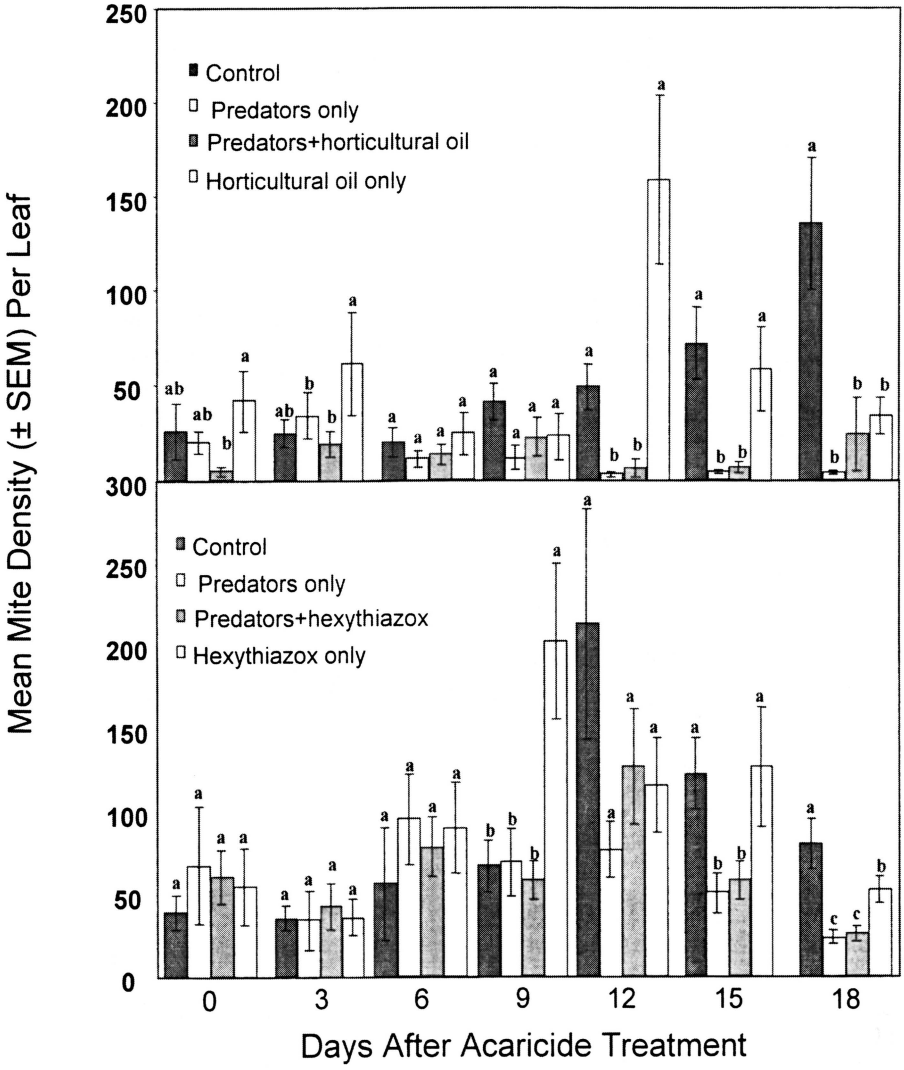

Fig. 2. *Tetranychus urticae* numbers in a greenhouse with horticultural oil or hexythiazox and releases of *P. persimilis* alone and in combination (α = 0.05).

The mean number of *T. urticae* in the *P. persimilis* treatments (alone and with hexythiazox) were significantly less than the control at 12 and 15 d after release (F = 3.70, df = 27, $P > F = 0.0204$; $F = 9.57$, df = 27, $P > F = 0.0001$; Fig. 2). The mean of *T. urticae* populations was significantly greater in hexythiazox treatments compared to *P. persmilis* and *P. persimilis* plus hexythiazox treatments at 6, 12 and 15 d after release ($F = 7.08$, df = 27, $P > F = 0.0007$; $F = 3.70$, df = 27, $P < F = 0.0204$; $F = 9.57$, df = 27, $P > F = <0.0001$). The mean of *T. urticae* populations in the *P. persimilis* treatment was not different from the hexythiazox plus *P. persimilis* treatment on any of the five sample dates.

Discussion

Suppression of *T. urticae* populations provided by acaricides varied among treatments. Abamectin, bifenthrin, chlorfenapyr, Gowan 1725, and horticultural oil suppressed *T. urticae* populations for 7 d in our laboratory trials. We applied abamectin at the labeled rate which provided suppression throughout our evaluation. Residues from abamectin applications as low as 16 ppm have caused 70% mortality to populations of *T. urticae* (Zhang and Sanderson 1990). Wright et al. (1984) found that abamectin residues killed *T. urticae* adults up to 2 wks after application; our results agree with these findings. Chlorfenapyr provided rapid suppression of *T. urticae* populations through the 2-wk period of the trial. Allen and Kharboutli (1999) found no short-term resurgence in mite populations after application of chlorfenapyr in the field. Gowan 1725 and horticultural oil provided rapid suppression through the 2-wk period in our laboratory studies. Haitas et al. (1997) reported that concentrations of 2% refined horticultural oils significantly reduced both egg and mobile stages of *T. urticae.* However, the same level of control may not be achieved with horticultural oil under field conditions due to recolonization or incomplete coverage. Hexythiazox suppressed *T. urticae* beginning 14 d after application. Hexythiazox has ovicidal action and causes female *T. urticae* to lay fewer viable eggs, but is not lethal to the adults (Chapman and Marris 1986). This mode of action delays suppression of *T. urticae* populations. Neem oil provided suppression with a slight resurgence in spider mite populations 7 d after application. The 2% application rate may have a physical mode of action and suffocated the mites, but was not as effective as horticultural oil.

Azadirachtin, pyridaben and spinosad did not suppress *T. urticae* populations in our laboratory assays. The identity of the type of azadirachtin in the formulation that we tested was not available. Although not tested in this study, many neem products are known to have antifeedant effects on arthropod pests (Govindachari et al. 2000). The composition of a particular neem formulation affects its antifeedant activity. Azadirachtin A has greater antifeedant activity than azadirachtin B (Govindachari et al. 2000). Our results and that of others suggest that efficacy among the neem based products is variable and may be dependent on product formulation. Unexpectedly, pyridaben did not suppress *T. urticae* populations in our trials. Sekulic (1995) demonstrated that pyridaben had an LC_{50} of 0.33 ug/ml for larval *T. urticae* and an LC_{50} of 2.96 ug/ml for deutonymphs. This suggests that pyridaben is more efficacious against earlier stages of *T. urticae* at low rates than later stages. In our experiments, we had a mixed mite population, which may have contributed to our results. Spinosyn A and spinosyn D, the primary components of spinosad, applied at 400 ppm cause 100% mortality to test populations of *T. urticae* (De Amicis et al. 1997); however, in

our trials, spinosad did not suppress *T. urticae* populations at the recommended label rate.

Prior to release of predators, selective use of acaricides to reduce mite abundance may conserve natural enemy populations while reducing the need for additional acaricide applications. Previous studies have been conducted on the compatibility of acaricides with *P. persimlis* (Cote et al. 2002, Oomen et. al. 1991, Zhang and Sanderson 1990). Trumble and Morse (1993) demonstrated that a combination of predator releases followed by applications of abamectin after pest mite threshold levels were reached provided a higher value crop in strawberries than abamectin applications alone. Osborne and Petitt (1985) found that applications of insecticidal soap 3 d after release of *P. persimilis* does not adversely affect predator populations and provide enhanced suppression of spider mite populations. Acaricides that have short residual toxicity may be used prior to the release of predators to reduce high-density populations of spider mites, but the timing of application and predator release is critical (Osborne and Petitt 1985). Predators reduced the number of *T. urticae* and improved the appearance of the plants in this study. However, we did not observe any enhancement in biological control from predator-acaricide interaction.

Phytoseiulus persimilis were released at a high density, 20 per plant, to determine if the predators would reduce *T. urticae* populations after acaricide applications. The presence of predator and acaricide synergism when predator numbers are this high was likely to be difficult to detect. Previous field studies using *P. persimilis* and *P. persimilis* with compatible acaricides demonstrate that adequate control can be achieved with optimal combinations of acaricides and *P. persimilis* (Cashion et al. 1994, Osborne and Petitt 1985). Our study found 20 *P. persimilis* per plant in combination with an application of horticultural oil or hexythiazox reduced levels of *T. urticae*. Additional acaricide-predator combinations should be evaluated with varying predator densities to achieve an economically feasible level for the crop.

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