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Side effects of five new acaricides on the predator *Galendromus occidentalis* (Acari, Phytoseiidae)

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Abstract. Contact and residual effects of etoxazole, spiromesifen, fenpyroximate, bifenazate, and acequinocyl on life parameters of *Galendromus occidentalis* (Nesbitt) were studied under laboratory conditions. Fenpyroximate reduced adult female longevity to <24 h, and no eggs were laid. Longevity of spiromesifen- and acequinocyl-treated adult females was reduced to 4 days, with observed reductions in fecundity and fertility. Etoxazole and bifenazate did not reduce adult female longevity, but progeny were not produced.

Introduction

Predatory mites in the Acari family Phytoseiidae are often effective management components of agricultural systems (Hoy et al. 1983). *Galendromus occidentalis* (Nesbitt) (Acari, Phytoseiidae) is widely used in biological control programs in California and throughout the world (European and Mediterranean Plant Protection Organization 2002; Gerson et al. 2003). It is a major type II (McMurtry and Croft 1997) biocontrol agent of web spinning spider mites (especially *Tetranychus* spp.) infesting deciduous tree crops, hops and protected crops (McMurtry 1982).

Despite their effectiveness for biological control of spider mites, phytoseiids alone are not always able to maintain spider mite populations below damaging levels. Thus, identification of selective pesticides for use in IPM programs is urgently needed (Sterk et al. 1999). Etoxazole, spiromesifen, fenpyroximate, bifenazate and acequinocyl are new miticides registered for use in the United States. However, their selectivity against phytoseiids should be considered.

Knowledge of acaricide selectivity to beneficial arthropods is important to their utility in IPM programs. Selectivity has traditionally been evaluated by considering adult female mortality as the end point, estimating values that measure median lethal concentration (LC_{50}) or median lethal dose (LD_{50}) (Robertson and Worner 1990; Stark et al. 1997). Because these evaluations focus on a single life stage and generally for a short duration of time (1–4 days

in most cases), the result of these bioassays do not accurately assess the total effects of a pesticide on an exposed population (Stark and Banken 1999). Sublethal effects should be combined with lethal effects to estimate the total effect of a pesticide (Stark et al. 1995).

Some research has been reported for effects of etoxazole, bifenazate and acequinocyl on two species of predatory mites: *Phytoseiulus persimilis* (Athias-Henriot) (Kim and Yoo 2002) and *Amblyseius womersleyi* Schicha (Kim and Seo 2001). No studies have been published for any of these miticides on *G. occidentalis*. In this paper we report observed side effects of five new acaricides on the longevity, fecundity, fertility and progeny development of newly emerged adult females of *G. occidentalis*, exposed to a 'worse case' situation where exposure occurs by both contact and residue.

Materials and methods

A phytophagous mite *Tetranychus urticae* Koch colony maintained on cotton (*Gossypium hirsutum* L.) seedlings started in a greenhouse at UC Davis provided food for the *G. occidentalis* in this study. A *G. occidentalis* colony was maintained on detached cotton leaves infested with mixed stages of *T. urticae*. The original source of the predator colony was Biotactics Inc. (Riverside, California). Both colonies were maintained in environmental chambers at 24 ± 1 °C, 75–85% RH and 16:8 photoperiod. The active ingredients tested, their trade names, formulations and concentrations applied are listed in Table 1. The concentrations selected were labelled rates for each product.

Bioassays

Arenas

Each experimental arena consisted of five green bean leaf discs of 20 mm diameter, cut with a cork borer from leaves collected from untreated green bean leaves collected from plants grown in a greenhouse at UC Davis. The leaf discs were placed on wet filter paper inside a 90 mm diameter Petri dish. The dish cover had three 6 mm diameter holes in the lid to prevent excessive humidity.

Effects on longevity, fecundity, fertility, and development of progeny

Treatments were chosen to simulate complete predator exposure to the chemicals. The adult female *G. occidentalis*, its prey and the leaf surface upon which it was placed were all treated with an acaricide. The formulated acaricide products mixed with distilled water to the desired concentrations were applied using a 200-ml hand sprayer held 30 cm away from the leaf discs resulting in a

Table 1. Acaricides and rates evaluated for side effects on *G. occidentalis*.

Active ingredient	Trade name	% a.i. and formulation	Concentration used (ppm)
Fenpyroximate	Fujimite[a]	5 SC	62.50
Etoxazole	Zeal[b]	72 WP	24.12
Acequinocyl	Kanemite[c]	15 SC	158.00
Bifenazate	Acramite[d]	50 WS	112.75
Spiromesifen	Oberon[e]	23 SC	76.20

[a]Nichino America Inc., Wilmington, Delaware. [b]Valent U.S.A. Corp., Walnut Creek, California. [c]Arysta Corp., San Francisco, California. [d]Chemtura Corp., Middlebury, Connecticut. [e]Bayer Inc., Greensboro, North Carolina.

10.6 ± 0.53 μl/cm^2 deposit. The untreated controls were sprayed with distilled water alone. The treated leaf discs were air-dried for 5 min after spraying and then covered. One newly eclosed *G. occidentalis* adult female was transferred to each leaf disc. Five *T. urticae* females and eggs were placed on the leaf disc to provide food for the predator. Cotton leaves infested with *T. urticae* were treated at the same time as the rearing arenas. These leaves yielded treated prey used as a food source for the *G. occidentalis* as needed during the bioassay. The bioassay was conducted at 27 ± 1 °C, 50–60% RH and 16:8 photoperiod in a single environmental chamber. Egg laying and survival were recorded daily. There were 20 replicates of all acaricide treatments and the control.

To determine effects of acaricides on progeny, 50 eggs laid by the treated females were placed individually on green bean leaf discs treated the same day and in the same manner as previously described. Mortality and developmental time of each life stage were recorded daily.

Statistical analysis

Longevity, fecundity, and fertility were analysed by ANOVA with means separated by LSD ($p < 0.05$) (SPSS 2003).

Results

There was a significant difference in female longevity between acaricide treatments ($F = 23.29$; df = 5, 99; $p < 0.001$). Of the acaricides evaluated fenpyroximate had the greatest direct impact on adult female longevity, with none surviving more than 24 h (Table 2). Because no females survived this treatment, fecundity, fertility, and progeny development could not be determined. Etoxazole and bifenazate had no significant effect ($p > 0.05$) on adult longevity compared to the control. Acequinocyl and spiromesifen treatments significantly reduced adult female longevity relative to the untreated control,

Table 2. Longevity, fecundity, fertility and progeny development for *G. occidentalis* females treated within 12 h of adult eclosion with labelled rates of five different acaricides.

Acaricide	Adult longevity (days)	Total eggs/female	Fertility (% hatch)	Immature development (days)	Immature mortality (%)
Control	6.53 ± 0.49a	18.4 ± 1.84a	88	5	0
Etoxazole	6.27 ± 0.71a	10.5 ± 1.89b	0	–	–
Spiromesifen	4.15 ± 0.32b	1.8 ± 0.56d	0	–	–
Fenpyroximate	< 1c	0	0	–	–
Bifenazate	5.65 ± 0.53a	5.5 ± 1.05c	28	**	100
Acequinocyl	3.90 ± 0.35b	3.1 ± 0.61cd	31	**	100

Means followed by the same letter are significantly different at $p < 0.05$ by LSD.
**All larvae died after eclosion from the egg.

averaging about 4 days relative to 6.5 days for untreated ($p < 0.01$). There was also a significant difference in fecundity between treatments ($F = 33.99$; df = 5, 99; $p < 0.001$). All of the acaricides reduced *G. occidentalis* fecundity (Table 2). Spiromesifen and acequinocyl had the greatest deleterious impacts, followed by bifenazate. Eggs placed on leaf surfaces following application of etoxazole or spiromesifen (Table 2) did not hatch. Bifenazate and acequinocyl reduced fertility by 67% and 65% relative to the untreated control. Progeny development from treated females could not be measured because none survived to become adults (Table 2).

Untreated *G. occidentalis* females had a preoviposition period of 24 h and reached the oviposition peak 72 h following treatment, maintaining an average fecundity of around 2.5 eggs/day until day seven following treatment (Figure 1). Treated females never produced as many eggs at the oviposition peak as did untreated females. For all acaricides with the exception of etoxazole, the oviposition peak occurred 72 h following treatment, but peak egg production was only about 1 egg/day. Daily egg production by females treated with etoxazole peaked on day 5 following treatment, but eggs per day was ≥1 for days 2–8 following treatment.

Discussion

Fenpyroximate was the most acutely toxic to *G. occidentalis* among the acaricides in our study. Longevity of treated adult females was reduced to less than 24 h, with no eggs being produced. Our results differ from those recorded by Sato et al. (2002) treating *Neoseiulus californicus* (McGregor) adult females using a Potter tower at 1.5 mg/cm^2 deposit which indicated a higher tolerance (LC_{50} 69.6 ppm) of this predator to fenpyroximate than was found for *T. urticae* (LC_{50} 24.0 ppm). Bifenazate reduced longevity, fecundity and fertility in our study. Although adult female survival did not differ from the control (Table 2), larvae that hatched from eggs laid on treated surfaces, did

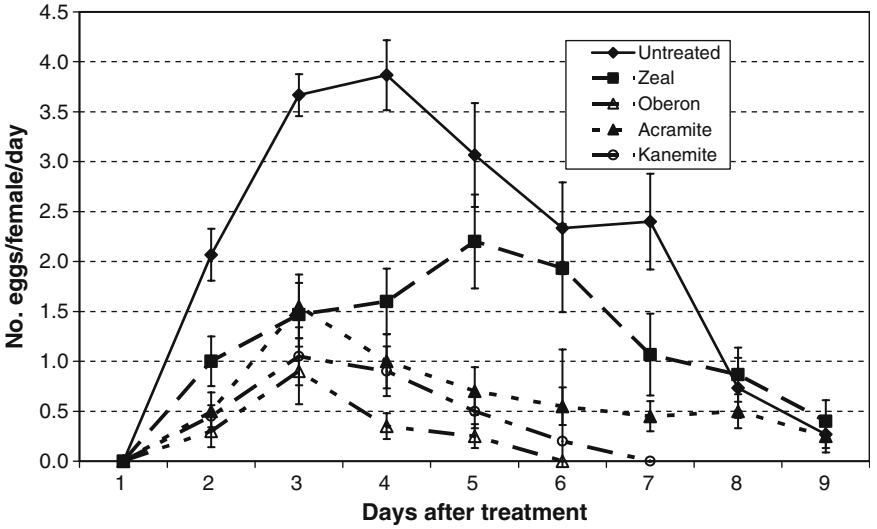

Figure 1. Number of eggs laid per female per day, by female *G. occidentalis* sprayed within 12 h of adult eclosure with labelled rates of five different acaricides. The first day following treatment is also the preovipositional period.

not reach the adult stage. Dekeyser et al. (1996) reported bifenazate to be harmless to adult female *G. occidentalis*. Studies on *P. persimilis* (Kim and Yoo 2002) and *A. womersleyi* (Kim and Seo 2001) with bifenazate using the same concentration as in our study, indicated low mortality of treated females 168 h after treatment, and no effect on fecundity and fertility. Acequinocyl reduced longevity, fecundity and fertility in our study, and larvae emerging from the eggs did not reach the adult stage. Kim and Yoo (2002) and Kim and Seo (2001) reported that acequinocyl had relatively low impact on *P. persimilis* and *A. womersleyi* adult female survival, fecundity and fertility. In our study etoxazole had no effect on adult female longevity and less effect on fecundity than did the other acaricides, but the eggs did not hatch. These results agree with those of Kim and Yoo (2002) for *P. persimilis* and Kim and Seo (2001) for *A. womersleyi* who described low mortality of adult females, no effect on fecundity, but complete mortality before reaching the adult stage when applying a concentration of 25 ppm. Spiromesifen reduced longevity and fecundity of *G. occidentalis*, and eggs laid did not hatch. Although our results for etoxazole side effects on *G. occidentalis* agree with the cited studies of other phytoseiid species, our results for bifenazate, fenpyroximate and acequinocyl are somewhat different. Susceptibility between species and populations, and differences in experimental methods could be the responsible for conflicting results.

Our laboratory results clearly show that all the acaricides tested had detrimental side effects on *G. occidentalis*. Although the side effects were manifested differently, the cumulative effects on adult female longevity,

fecundity, fertility and development of progeny resulted in none of the treatments producing a complete *G. occidentalis* generation. IOBC/WPRS (Sterk et al. 1999) guidelines suggest that the 'worse case situation' is preferred to test side effects of pesticides on beneficial organisms. Our experimental methods exposed the predatory mite to the 'worse case situation' possible in the field. The newly molted adult females, their food and the leaf substrate upon which they were placed and later deposited eggs were treated with the labelled rate of an acaricide that would normally be applied. Further studies defining the specific effects of direct spray contact and residual exposure are necessary to determine compatibility of acaricide applications with augmentative *G. occidentalis* releases and conservation programs.

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