Residual Toxicities of Pesticides to the Predaceous Mite *Galendromus helveolus* (Acari: Phytoseiidae) on Texas Citrus

Tian-Ye Chen[1], J. Victor French[1], Tong-Xian Liu[2] and John V. da Graça[1]

[1]*Citrus Center, Texas A&M University-Kingsville, 312 N. International Blvd., Weslaco, TX 78596*
[2]*Vegetable IPM Laboratory, Texas Agricultural Experiment Station, Texas A&M University, 2415 E. Highway 83, Weslaco, TX 78596*

ABSTRACT

Galendromus helveolus **(Chant) is one of the most prevalent predaceous mite species found on Texas citrus. Bioassay experiments were undertaken to assess the residual toxicity of six commonly used citrus pesticides to *G. helveolus*. Oxamyl (Vydate® L) and pyridaben (Nexter® 75WP) were highly toxic to *G. helveolus*, with adult mortality recorded until 6 days post-spray. Dicofol (Kelthane® MF) and fenbutatin-oxide (Vendex® 50WP) were moderately toxic to adults, with residual mortality recorded 2 days and 1 day post-spray, respectively. Abamectin (Agri-Mek® 0.15EC) was slightly toxic, with the residual killing effect existing less than 1 day post-spray. Diflubenzuron (Micromite® 25WS) was innocuous to *G. helveolus*, with no significant adverse effects on adult survival, fecundity and egg viability when exposed to the pesticide residues.**

RESUMEN

Galendromus helveolus **(Chant) es una de las especies mas comunes de ácaros predatores que se encuentran en cítricos en Texas. Se realizaron bioensayos para evaluar la toxicidad residual de 6 pesticidas usados comúnmente en cítricos sobre *G. helveolus*. Oxamyl (Vydate® L) y pyridaben (Nexter® 75 WP) fueron altamente tóxicos a *G. helveolus*, registrándose mortalidad en adultos hasta 6 días después de la aspersión. Dicophol (Kelthane®MF) y óxido de fenbutatina (Vendex® 50 WP) fueron moderadamente tóxicos a los adultos , registrándose una mortalidad residual de 2 días y 1 día después de la aspersión respectivamente. Abamectin (Agri-Mek® 0.15EC) fue ligeramente tóxico, con un efecto exterminador residual de menos de 1 día después de la aspersión. El diflubenzuron (Micromite® 25 WS) fue inocuo a *G. helveolus*, sin que se registraran efectos adversos en la sobrevivencia de los adultos, la fecundidad y la viabilidad de los huevecillos tras la exposición a los residuos del pesticida.**

Index Key Words: Galendromus helveolus, predatory mite, pesticide toxicity, citrus.

Predaceous mites have been recognized as highly important in regulating phytophagous mites and other pests on citrus (McMurtry 1982, 1985, 1986; McMurtry et al. 1992; Muma 1970, 1971; Grafton-Cardwell and Ouyang 1995; Grafton-Cardwell et al. 1997; Tanigoshi and Congdon 1983). Several species of phytophagous mites occur on Texas citrus, including citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), citrus red mite, *Panonychus citri* (McGregor), Texas citrus mite, *Eutetranychus banksi* (McGregor), and three species of false spider mites, *Brevipalpus californicus* (Banks), *B. phoenicis* (Geijskes), and *B. obovatus* Donnadieu.

Several different pesticides have been tested and used for citrus mite control (French 1974, 1982, French and Bruno 1996, French and Hernandez 1992 a, b, French and Rakha 1994, French and Villarreal 1988, 1990, French et al. 1985). In order to utilize predaceous mites in the integrated pest management (IPM) program on citrus, it is essential to acquire information on the toxicity of commonly used pesticides to these predators. However, very little information is available on comparative toxicities of pesticides to predaceous mites on Texas citrus. *Galendromus helveolus* (Chant) is one of the most prevalent predaceous mite species found on Texas citrus, and was recovered in at least 11 months of the year from citrus foliage (Browning 1983). *G. helveolus* has been recorded as a predator of avocado brown mite, *Oligonychs punicae* (Hirst) (Tanigoshi and McMurtry 1977), citrus red mite, *P. citri* (McGregor), Texas citrus mite, *E. banksi* (McGregor), six spotted spider mite, *Eotetranychus sexmaculatus* (Riley), two spotted spider mite, *Tetranychus urticae* Koch and citrus rust mite, *P. oleivora* (Ashmead) (Muma 1970; Sandness & McMurtry 1970; Caceres & Childers 1991). Our research showed that *G. helveolus* is also an effective predator of the false spider mite, *B. californicus* (Chen et al. Submitted for Publication).

Therefore, bioassay experiments were undertaken to assess the residual toxicity to *G. helveolus* of commonly used pesticides on Texas citrus.

MATERIALS AND METHODS

Pesticides tested. The pesticides tested are listed in Table1 by trade name, common chemical name, the manufacturer and the recommended citrus treatment rate.

Predaceous mite cultures. *Galendromus helveolus* was initially obtained from Biotactics, Inc. (Riverside, CA). The adult predaceous mites were transferred onto a number of grapefruit leaves infested with citrus red mite, *P. citri*. A sticky resinous material, Tanglefoot (Tanglefoot Co. Grand Rapids, MI), was applied along the leaf edges to confine both the citrus red mites and the predaceous mites. The predaceous mites were allowed to feed on the citrus red mites in these leaf arenas. The leaves with mites were placed in petri dishes (9 cm in diameter, and 1.5 cm in depth), with the leaf petioles bound in water-saturated cotton tissue to keep the leaf fresh. After one day of feeding, the *G. helveolus* were used for the bioassay tests.

Bioassays. *Test 1*: 'Marrs' variety sweet orange trees on the Texas A&M Citrus Center Research Farm were sprayed with the different pesticides using recommended application rates. Control trees were sprayed with water only. The pesticides were applied using a CO_2 Koke Kap back pack sprayer (R&D Sprayers, Opelousas, LA) until foliar run-off. The initial bioassays were conducted after spraying as soon as the leaves dried (about 2-3 h) and were designated as the 0 day post-spray sample. The treated leaves were collected from the field. Tanglefoot was applied along the leaf edge to act as a barrier, and 10-20 female adult *G. helveolus* were introduced into each leaf arena. Citrus red mites were provided as food for *G. helveolus*. Each leaf was placed inside a separate petri dish, and moist cotton tissue bound to the petiole to keep it fresh. The petri dishes were left uncovered to prevent mite mortality due to any fumigant action of the tested pesticides. To measure residual effects of the pesticides, new sets of leaves were excised from the trees at different days after spraying, i.e. 1, 2, 4, 6, 8 etc. days post-spray, with new groups of *G. helveolus* exposed to the upper surfaces of the sprayed leaves. The mite-infested leaves in the petri dishes were maintained at 26±1º C, 50-60% RH, and a photoperiod of 14:10 h (L:D). Each treatment was replicated four times. Mortality of *G. helveolus* was recorded at 24 h, 48 h and 72 h after exposure to the residues, and the test terminated at the post-spray date (days) when no further predaceous mite mortality was recorded.

Test 2: Since insect/mite growth regulators are generally slow acting, an added experiment was conducted to determine the effect of diflubenzuron on adult *G. helveolus*. Leaves of 'Marrs' sweet orange were sampled from orchard trees at different days after spraying. Ten male and 10 female adults were transferred onto each leaf arena, and exposed to the pesticide residues at different days post- spray. There were four replicates for each bioassay. The adult survival rate was recorded daily until 120 h (five days) after exposure to the residues. The number of eggs laid daily were counted for five days and removed after counting. For testing egg viability, 10 eggs were randomly selected daily from each leaf arena, and transferred onto new untreated leaf arenas for incubation. A total of 50 eggs were selected and incubated at 26±1º C, 50-60% RH, with a photoperiod of 14:10 h (L:D).

Data Analysis. Percentage mortality data in test 1 were transformed to the arcsine square root, and analyzed using the general linear model (PROC GLM) (SAS Institute 1996). The means were separated using the Duncan's multiple range test (DMRT) after a significant *F* test at *P*=0.05. Untransformed data are presented in all tables. The percentage survival, eggs laid per female per day, and the percentage egg viability in test 2 were analyzed with *t*-test (two- tailed), and the significance level was *P*=0.05.

RESULTS

The residual effects of the different pesticides on the adult *G. helveolus* are shown in Tables 2-8. Oxamyl and pyridaben were highly toxic to *G. helveolus* adults. One hundred percent mortality (after 72h exposure) was recorded when the predaceous mites were exposed to the residues of each of these chemicals at 0, 1, 2, and 4 days post-spray (Tables 2-5). When exposed to the residues at 6 days post-spray, significant mortalities (12.8% for oxamyl and 10.9% for pyridaben after 72h exposure) of *G. helveolus* were still recorded (Table 6). However, no mortality was recorded when exposed to the residues at 8 days post- spray (Table 7).

Dicofol and fenbutatin-oxide were moderately toxic to *G. helveolus* adults. When exposed to the residues of dicofol at 0 day and 1 day post-spray, 100% mortalities were recorded after 72 h exposure (Tables 2 & 3). A low mortality (8.7% at 72 h after exposure) was recorded on the 2 day post-spray dicofol residue (Table 4). There was no mortality recorded when exposed to the 4 day post-spray residue (Table 5). Similarly, 100% adult mortality was recorded when exposed to the residues of fenbutatin-oxide at 0 day, with 23.2% mortality at 1 day post-spray (Table 2, 3). There was no significant mortality recorded when exposed to the 2 day post-spray residue (Table 4).

Abamectin was slightly toxic to *G. helveolus* adults, with 36.6% mortality (after 72 hr) recorded when exposed to the 0 day residue (Table 2), and 10.0% to the 1 day post-spray residue (Table 3). There was no mortality when exposed to the 2 day post-spray residue (Table 4).

Diflubenzuron caused no mortality of adult *G. helveolus*, and it did not affect the fecundity and egg viability. When exposed to the 0 day post-spray residue, the egg production was 1.99 per female per day, and the egg viability was 96.25%, compared to 2.03 and 98.75% when exposed to the water (Table 8). Similar results were found in the tests, in which *G. helveolus* were exposed to the 1 and 2 day post-spray residues.

DISCUSSION

Pyridaben is a novel pesticide, classified in the pyridazinone chemical group. It has been found highly toxic to the predaceous mite, *Euseius mesembrinus* (Dean) (Childers et al. 2001). It was also found to be toxic to the parasitoid, *Cotesia*

Table 1. List of six pesticides commonly used on Texas citrus.

Trade name	Common name	Manufacturer	Rate used
Agri-Mek® 0.15EC	abamectin	Novartis, Greensboro, NC	8 fl oz/acre or 0.32 ml/l
Kelthane® MF	dicofol	Rohm and Haas, Philadelphia, PA	6 pts/acre or 3.76 ml/l
Micromite® 25WS	diflubenzuron	Uniroyal, Middlebury, CT	1.25 lb/acre or 0.75 g/l
Nexter® 75WP	pyridaben	BASF, Research Triangle Park, NC	8 oz/acre or 0.3 g/l
Vendex® 50WP	fenbutatin-oxide	Griffin, Valdosta, GA	3 lb/acre or 1.8 g/l
Vydate® L	oxamyl	Du Pont, Wilmington, DE	3 pts/acre or 1.87 ml/l

Table 2. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 0 day after spray).

	% Mortality ± SE[z] at different times after exposure		
Treatments	24 h	48 h	72 h
oxamyl	100.0±0.0a	100.0±0.0a	100.0±0.0a
pyridaben	29.5±0.1b	99.2±0.8a	100.0±0.0a
dicofol	100.0±0.0a	100.0±0.0a	100.0±0.0a
fenbutatin-oxide	13.0±0.2c	39.9±0.4b	100.0±0.0a
abamectin	6.7±1.9c	6.7±1.9c	36.6±0.1b
diflubenzuron	0.0±0.0d	0.0±0.0d	0.0±0.0c
water	0.0±0.0d	0.0±0.0d	0.8±0.8c

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

Table 3. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 1 day after spray).

	% Mortality ± SE[z] at different times after exposure		
Treatments	24 h	48 h	72 h
oxamyl	100.0±0.0a	100.0±0.0a	100.0±0.0a
pyridaben	94.3±1.8a	99.2±0.8a	100.0±0.0a
dicofol	94.3±1.8a	99.2±0.8a	100.0±0.0a
fenbutatin-oxide	0.0±0.0b	21.3±1.1b	23.2±0.1b
abamectin	4.5±1.1b	4.5±1.1b	10.0±0.0c
diflubenzuron	0.0±0.0b	0.0±0.0b	0.0±0.0d
water	0.0±0.0b	0.0±0.0b	0.8±0.8d

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

Table 4. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 2 days after spray).

	% Mortality ± SE[z] at different times after exposure		
Treatments	24 h	48 h	72 h
oxamyl	100.0±0.0a	100.0±0.0a	100.0±0.0a
pyridaben	10.1±0.1b	100.0±0.0a	100.0±0.0a
dicofol	0.0±0.0c	3.0±0.8b	8.7±0.1b
fenbutatin-oxide	0.0±0.0c	0.0±0.0c	1.1±1.1c
abamectin	0.0±0.0c	0.0±0.0c	0.0±0.0c
diflubenzuron	0.0±0.0c	0.0±0.0c	0.0±0.0c
water	0.0±0.0c	0.0±0.0c	0.0±0.0c

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

flavipes (Cameron), but nontoxic to the twice-stabbed ladybeetle, *Chilocorus cacti* L., and parasitoids *Catolaccus grandis* (Burks), and *Allorhogas pyralophagus* Marsh (Legaspi et al. 2000). Our test results showed that pyridaben (Nexter® 75 WP, at 0.3g/liter) was highly toxic to adult *G. helveolus*, with the residual killing effects lasting 6 days.

Abamectin was significantly toxic to the various life stages of western predatory mite, *Metaseiulus occidentalis* (Nesbitt) (=*Galendromus occidentalis*) (Grafton-Cardwell and Hoy 1983). At the tested field spray rates (4, 8, and 16 ppm), few *M. occidentalis* survived and fecundity was reduced. Also, the larvae were more susceptible to the chemical at 0.1, 4, 8, and 16 ppm, than to adult females. Eggs hatched when exposed to the residues, but none of the larvae survived to the nymphal stage. In contrast, abamectin was less toxic to the predatory mite, *Phytoseiulus persimilis* Anthias-Henriot (Zhang and

Table 5. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 4 days after spray).

Treatments	% Mortality ± SE[z] at different times after exposure		
	24 h	48 h	72 h
oxamyl	83.3±0.2a	100.0±0.0a	100.0±0.0a
pyridaben	8.7±0.1b	100.0±0.0a	100.0±0.0a
dicofol	0.0±0.0c	0.0±0.0b	0.0±0.0b
fenbutatin-oxide	–[y]	–	–
abamectin	–	–	–
diflubenzuron	–	–	–
water	0.0±0.0c	0.0±0.0b	0.0±0.0b

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

[y]– test not conducted because of no significant mortality on bioassay at previous day.

Table 6. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 6 days after spray).

Treatments	% Mortality ± SE[z] at different times after exposure		
	24 h	48 h	72 h
oxamyl	0.8±0.8a	2.4±2.4a	12.8±0.3a
pyridaben	0.8±0.8a	8.7±0.1a	10.9±0.1a
dicofol	–[y]	–	–
fenbutatin-oxide	–	–	–
abamectin	–	–	–
diflubenzuron	–	–	–
water	0.0±0.0a	0.0±0.0a	0.0±0.0b

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

[y]– test not conducted because of no significant mortality on bioassay at previous day.

Table 7. Percentage mortality of *Galendromus helveolus* exposed to treated leaves (collected at 8 days after spray).

Treatments	% Mortality ± SE[z] at different times after exposure		
	24 h	48 h	72 h
oxamyl	0.0±0.0a	0.0±0.0a	0.0±0.0a
pyridaben	0.0±0.0a	0.0±0.0a	0.0±0.0a
dicofol	–[y]	–	–
fenbutatin-oxide	–	–	–
abamectin	–	–	–
diflubenzuron	–	–	–
water	0.0±0.0a	0.0±0.0a	0.0±0.0a

[z]Means in the same column followed by the same letters do not differ significantly at p=0.05 (Duncan's multiple range test, SAS Institute, 1996).

[y]– test not conducted because of no significant mortality on bioassay at previous day.

Table 8. Percentage survival (at 120 h after exposure), egg production, and egg viability of *Galendromus helveolus* when exposed to the residues of diflubenzuron.

Treatment	Residual time (days after spray)	% survival ± SE[z]	Eggs/female/day ± SE[z]	% egg viability ± SE[z]
Diflubenzuron	0	100.00±0.00a	1.99±0.01a	96.25±1.25a
Water	0	100.00±0.00a	2.03±0.02a	98.75±1.25a
Diflubenzuron	1	100.00±0.00a	1.99±0.02a	95.63±0.63a
Water	1	100.00±0.00a	2.02±0.02a	98.75±1.25a
Diflubenzuron	2	100.00±0.00a	2.05±0.02a	98.75±1.25a
Water	2	100.00±0.00a	2.09±0.01a	99.38±0.63a

[z]Means in the same column of different residual time followed by the same letters do not differ significantly at p=0.05 (two-tailed t test, SAS Institute, 1996).

Sanderson 1990). At concentrations of 0.08-16 ppm, abamectin did not significantly affect the survival and mobility of *P. persimilis*, but reproduction was significantly reduced at the higher concentrations (8 and 16 ppm). They concluded that abamectin at selective sublethal concentrations (i.e., 14 ppm) could be of value in adjusting predator/prey ratios in integrated management of spider mite pest species. In our experiments, abamectin (Agri-Mek® EC, at 0.32 ml/liter) had a slight residual toxicity to *G. helveolus*.

Dicofol, a conventional miticide, has been found to be toxic to several species of predaceous mites. For example, Dicofol 1.6 E (at 22.5 liters/ha) reduced *Euseius stipulatus* (Athias-Henroit) population densities beyond 66 days post-spray in the Oceanside area of California (Jones and Parrella 1983). Dicofol 18.5 EC (at 1,200 mg AI/liter) caused high mortality to the lab strain and the Rocky Hill strain of *Euseius hibisci* (Chant) in California (Tanigoshi and Congdon 1983). Dicofol 4EC (at 7.01 liters/ha) was highly toxic to *Euseius mesembrinus*, a very important predatory mite in Florida citrus (Childers et al. 2001). Our test results showed that Dicofol (Kelthane® MF, at 3.76 ml/liter) had a high residual toxicity to *G. helveolus* for 1 day post-spray.

Fenbutatin-oxide had a low residual toxicity to the predatory mite, *Euseius hibisci* (Chant) (Machlitt strain, California) (Tanigoshi and Fargerlund 1984). Our test results indicated that fenbutatin-oxide (Vendex® 50WP, at 1.8g/liter) had a high residual toxicity to *G. helveolus* at 0 day post-spray (immediately after sprayed foliage dried), but low toxicity thereafter i.e., 1 day post-spray.

Oxamyl 2L (at 7.5 liters/ha) reduced *Euseius stipulatus* (Athias-Henroit) population densities beyond 66 days post-spray in Oceanside area of California (Jones and Parrella 1983). We found that oxamyl was highly toxic to *G. helveolus* with the residual killing effects of oxamyl (Vydate® L, at 1.87 ml/liter) lasting through 6 days post-spray.

Anderson and Elliott (1982) reported that diflubenzuron was non-toxic to the phytoseiid mite species, *Tylodromus occidentalis* (= *G. occidentalis*) and the stigmaeid mite, *Zetzellia mali*. Our test results indicated that diflubenzuron (Micromite® 25 WS, at 0.75 g/liter) had no adverse effects on the adult stage of *G. helveolus*. However, the effects of this insect growth regulator on immature *G. helveolus* are unknown.

In summary, oxamyl and pyridaben were highly toxic to the adult *G. helveolus*, with the adult mortality recorded until 6 days post-spray. Dicofol and fenbutatin-oxide were moderately toxic with the residual killing effects lasting 2 days and 1 day post-spray, respectively. Abamectin was slightly toxic to *G. helveolus*, with residual killing effects lasting less than 1 day post-spray. Diflubenzuron was not toxic to *G. helveolus*, with no significant adult mortality recorded when exposed to the residues.

Predaceous mites are often released in field to control phytophagous pests. For example, releases of *G. occidentalis* have been made on such crops as cotton, grape, and almond in California (McMurtry and Croft 1997) and hops in the pacific Northwest United States (Strong and Croft 1995). *G. helveolus* was released to control *Oligonychus perseae* on avocado in California (Kerguelen and Hoddle 1999); and *Euseius tularensis* Congdon was released to control citrus thrips, *Scirtothrips citri* (Moulton) in California (Grafton-Cardwel and Ouyang 1995). When releasing predaceous mites in the field as biological control agents, the residual toxicity of commonly used chemicals must be taken into careful consideration. These data present information on the residual toxicities of six pesticides on adult *G. helveolus*. Additional chemical bioassays need to be conducted on the immature stages of *G. helveolus*. Moreover, the effect of pesticides on other species of predaceous mites found on Texas citrus should be evaluated. Several species of predaceous mites viz., *G. occidentalis*, *A. fallacis*, *P. persimilis*, *Typhlodromus pyri*, have been studied to improve resistance to pesticides (Hoy 1985). Such studies also need to be conducted on *G. helveolus* in the future.

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