Effects of Selected Pesticides on the Predatory Mite, *Amblyseius cucumeris* (Acari: Phytoseiidae)[1]

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Abstract Effects of field rates of selected pesticides to the predatory mite, *Amblyseius cucumeris* (Oudemans) (Acari: Phytoseiidae), were evaluated in laboratory bioassays. Five of the pesticides tested, acequinocyl, bifenazate, spirodiclofen, spinosad and thiamethoxam, had little effect on the survival and reproduction of *A. cucumeris* adult females and eclosion of eggs deposited by treated predators. Moreover, hatch percentage of *A. cucumeris* eggs was unaffected by exposure to these five pesticides. Etoxazole did not seriously affect the survival and reproduction of adult female predators but caused significant lower eclosion in eggs laid by treated females and 100% egg mortality. Thiacloprid, imidacloprid, fipronil and chlorfenapyr had considerable toxic effect on *A. cucumeris* adult females. Pyraclofos, abamectin and emamectin benzoate were very toxic to adult female predators. Based on the results, acequinocyl, bifenazate, spirodiclofen, spinosad and thiamethoxan appear to be promising candidates for use in integrated pest management programs where *A. cucumeris* is the major natural enemy.

Key Words *Amblyseius cucumeris,* predatory mite, pesticides, field rates, integrated pest management

The predatory mite, *Amblyseius cucumeris* (Oudemans) (Acari: Phytoseiidae), is characterized as a polyphagous predator and can feed on a number of mites and insect species (McMurtry and Croft 1997, Van Rijn and Tanigoshi 1999). *Amblyseius cucumeris* has been successfully used for biological control of the thrips *Thrips tabaci* Lindeman and *Frankliniella occidentalis* (Pergande) on greenhouse crops (Hoy and Glenister 1991, Brodsgaard and Hansen 1992, Spollen and Isman 1996, De Courcy-Williams 2001, Jacobson et al. 2001, Shipp and Wang 2003). In addition, *A. cucumeris* can be an effective predator of several phytophagous mites, e.g., *Polyphagotarsonemus latus* (Banks), *Phytonemus pallidus* (Banks), *Tetranychus urticae* Koch, *Panonychus citri* (McGregor) and *Aponychus corpuzae* (Rimando) (Croft et al. 1998, Easterbrook et al. 2001, Zhang et al. 2001, 2003, Weintraub et al. 2003). This predatory mite has recently been introduced into Korea and is now commercially available.

Current control of thrips and phytophagous mites on their host plants in Korea relies almost exclusively on pesticides (Cho et al. 1999, Kim and Seo 2001). Because of the intensive use of pesticides, pest resurgence can occur when pesticide resistance develops among pest strains and important natural enemies are eliminated

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(Cho et al. 1999, Ibrahim and Yee 2000). In view of a growing interest on environmentally-friendly approaches to control of pests, utilizing biological control agents has become a useful way of solving pesticide resistance. However, biological control agents alone may not be able to maintain pest populations below an economic injury level for an extended period of time (Blumel et al. 1999, Zhang and Sanderson 1990, Ibrahim and Yee 2000, Shipp et al. 2000). Thus, an integrated pest management (IPM) program with a practicable combination of selective pesticides and biological control agents could be of great use. Compared with other biological control agents, relatively little is known about the selectivity of pesticides to *A. cucumeris.* Such information is essential for development of an effective IPM program using *A. cucumeris.* We, therefore, evaluated the effects of selected pesticides on the survival and reproduction of adult females and the hatchability of eggs of *A. cucumeris.*

Materials and Methods

Pesticides. All pesticides used in this study were commercial formulations. Insecticides used were emamectin benzoate 2.15% emulsifiable concentrate (EC), fipronil 5% suspension concentrate (SC), imidacloprid 10% wettable powder (WP), spinosad 10% water dispersible granule (WG), thiacloprid 10% SC, and thiamethoxam 10% WG. Insecticide/acaricides used were abamectin 1.8% EC, chlorfenapyr 5% EC and pyraclofos 35% WP. Acaricides used were acequinocyl 15% SC, bifenazate 23.5% SC, etoxazole 10% SC and spirodiclofen 36% WP. These pesticides were tested at their recommended field rates in Korea. They were selected on the basis of their current and potential use for the control of key greenhouse insect and mite pests affecting cucumber, pepper, tomato and other vegetables.

Colony sources and experimental conditions. The *A. cucumeris* colony was established with mites obtained from Rural Development Administration of Korea in 2003 and has since been reared on waterproofed paper arenas (11 × 11 × 4 cm) with *T. urticae* as a host in a plastic tray (30 × 22 × 7 cm). Moist cotton was wrapped over the edges of the arena, serving both as a barrier and as a water source. The *T. urticae* colony was collected from pear trees and maintained on kidney bean plants (*Phaseolus vulgaris* var. *humilis* Alefeld) in a greenhouse. All tests were conducted at 24 to 26 °C, 50 to 60% RH and an 18 h photophase. Two test arenas, composed of a bean leaf disc (3 cm diam) placed bottom side up on moist cotton in a plastic Petri dish (9 cm diam) with a hole (1 cm diam) in the center, were placed on a plastic water container (14 cm diam, 5 cm height) with a hole (1 cm diam) in the center of the lid. A wick consisting of a strip of cotton was fitted through the center hole of a Petri dish and water container for maintaining moisture in the cotton. Two holes (each 3 mm diam) were drilled in the upper part of the side wall of the water container to refill water using a squeeze bottle. Pesticides were applied until run off with a 1-liter hand sprayer (Komax Co., Seoul, Korea) held 23 cm away from the leaf discs. Predatory mites that ran off the disc or did not respond to touches by a fine brush were considered dead.

Effects of pesticides on *A. cucumeris.* The effects of pesticides on the survival and reproduction of adult females of *A. cucumeris* and eclosion of eggs deposited by treated females were evaluated in trials with 50 adult females (5 replicates with 10 mites per leaf disc). For each pesticide, *A. cucumeris* adult females were transferred from the source colony to leaf discs with the aid of a fine brush. Some twospotted spider mites were added to each disc to keep the adult female predators on the leaf discs. The leaf discs with adult female predators were sprayed with aqueous solution of each pesticide or distilled water, and then allowed to dry for 1 h. A surplus of all stages of *T. urticae* was added to each disc daily to insure an abundance of food. The survival of adult female predators was recorded at 1, 3, 5 and 7 d after treatment. The eggs on each leaf disc were counted daily and transferred to a separate untreated disc to assess the eclosion percentages.

The ovicidal effects of pesticides were evaluated with 50 eggs (10 eggs per leaf disc). Adult females of *A. cucumeris* were placed on leaf discs, allowed to deposit eggs for 24 h, and removed. The number of eggs was then adjusted to 10 per disc on each of 5 leaf discs for each pesticide tested. The leaf discs with predator eggs were sprayed with aqueous solution of each pesticide or distilled water, and then allowed to dry for 1 h. Observation on the egg hatch was made daily.

Data analysis. The significance of the results was analyzed using analysis of variance (ANOVA) and Tukey test in SAS (SAS Institute 1996). Data in the form of percentages were transformed to arcsine values for ANOVA.

Results and Discussion

The effects of the pesticides tested on the survival of *A. cucumeris* adult females at different time intervals after application are shown in Table 1. Generally, the survival rates of *A. cucumeris* adult females in all treatments decreased with time. After 168 h, 70 to 86% of *A. cucumeris* adult females survived in treatments with acequinocyl, bifenazate, spirodiclofen, etoxazole, spinosad and thiamethoxam; these survival rates were not statistically different from the result of control, except in etoxazole treatment. These results indicate that acequinocyl, bifenazate, spirodiclofen, etoxazole, spinosad and thiamethoxam had little or no significant effects on the survival of *A. cucumeris* adult females. Recently, Haruyama (2001) reported that bifenazate is harmless to predaceous mites, such as the phytoseiids *A. cucumeris, A. womersleyi* Schicha and *Phytoseiulus persimilis* Athias-Henriot. Spinosad has also been documented to be nontoxic to *P. persimilis* (Williams et al. 2003). Adult females of *A. cucumeris* exposed to thiacloprid, imidacloprid, fipronil and chlofenapyr had survival rates of 24 to 54% at 168 h after treatment, and these survival rates were significantly different from the control. Pyraclofos and emamectin benzoate were highly toxic with all adult female predators dying within 1 to 3 days of the test. Application of abamectin was also highly toxic to *A. cucumeris* adult females causing 92% mortality at 168 h after treatment.

Table 2 shows the number of eggs deposited by adult female predators treated with pesticides tested and the percentages of eggs eclosion. The treatments of acequinocyl, bifenazate and spinosad did not significantly affect the reproduction of *A. cucumeris* adult females. Reproduction of the predators exposed to spirodiclofen, etoxazole and thiamethoxam was less than that of the control; however, treated females produced 69 to 75% as many eggs as did control females. These results suggest that acequinocyl, bifenazate, spirodiclofen, etoxazole, spinosad and thiamethoxam do not greatly influence the reproduction of surviving adult female predators. In the case of treatments with thiacloprid, imidacloprid and chlorfenapyr, treated females produced 32 to 54% as many eggs as normal females. Egg production by *A. cucumeris* adult females treated with abamectin, fipronil and emamectin benzoate was only 1.4 to 10.5% that of control females. Adult females of *A. cucumeris* exposed to pyraclofos produced no eggs. High percentages of egg hatching (>98%) were recorded in both treated and untreated females, except in etoxazole treatment. The

Table 1. Survival of adult females of *A. cucumeris* on bean leaf discs treated with different pesticides

Pesticides treated	Treatment rate	% Survival (Means ± SEM) after*			
		24 h	72 h	120 h	168 h
Acaricide					
Acequinocyl	1 ml/L	96.0 ± 2.24abc	96.0 ± 2.45ab	88.0 ± 3.74a	86.0 ± 3.99ab
Bifenazate	0.5 ml/L	94.0 ± 2.45abc	88.0 ± 3.74abc	86.0 ± 2.45a	82.0 ± 3.74ab
Spirodiclofen	0.5 g/L	90.0 ± 4.46abc	80.0 ± 5.47cd	76.0 ± 3.99ab	76.0 ± 3.99abc
Etoxazole	0.25 ml/L	98.0 ± 2.00ab	84.0 ± 2.45bc	74.0 ± 3.99ab	70.0 ± 4.46bc
Insecticide/acaricide					
Chlorfenapyr	1 ml/L	42.0 ± 5.82ef	34.0 ± 5.09ef	28.0 ± 4.89de	24.0 ± 2.45ef
Abamectin	0.335 ml/L	16.0 ± 2.45g	14.0 ± 2.45f	8.0 ± 2.00ef	8.0 ± 2.00fg
Pyraclofos	1 g/L	0.0 ± 0h	0.0 ± 0g	0.0 ± 0f	0.0 ± 0g
Insecticide					
Spinosad	0.5 g/L	100.0 ± 0a	96.0 ± 2.45ab	86.0 ± 5.09a	80.0 ± 5.47ab
Thiamethoxam	0.5 g/L	96.0 ± 2.45abc	90.0 ± 0abc	84.0 ± 2.45a	76.0 ± 5.09abc
Thiacloprid	0.5 ml/L	88.0 ± 3.74bc	74.0 ± 6.77cd	58.0 ± 5.82bc	54.0 ± 6.77cd
Imidacloprid	0.5 g/L	84.0 ± 2.45cd	54.0 ± 5.09de	44.0 ± 5.09cd	28.0 ± 3.74de
Fipronil	1 ml/L	64.0 ± 6.77de	40.0 ± 4.46e	26.0 ± 3.99de	24.0 ± 2.45ef
Emamectin benzoate	0.5 ml/L	28.0 ± 4.89fg	0.0 ± 0g	0.0 ± 4.89f	0.0 ± 0g
Control		100.0 ± 0a	96.0 ± 3.99a	90.0 ± 4.46a	88.0 ± 4.89a

* Means in the same column followed by the same letter are not significantly different ($P = 0.05$, Tukey test).

Table 2. Reproduction of adult females of *A. cucumeris* on bean leaf discs treated with different pesticides and percentages of eclosion

Pesticides treated	Number of eggs per leaf disc (Mean ± SEM)	% Eclosion (Mean ± SEM)*
Acaricide		
Acequinocyl	129.8 ± 5.43a	99.4 ± 0.27a
Bifenazate	113.2 ± 4.59ab	99.6 ± 0.42a
Spirodiclofen	99.2 ± 3.43b	98.6 ± 0.67a
Etoxazole	90.2 ± 4.45bc	6.6 ± 1.59b
Insecticide/acaricide		
Chlorfenapyr	45.2 ± 8.01d	99.7 ± 0.26a
Abamectin	5.4 ± 1.03e	100.0 ± 0a
Pyraclofos	0.0 ± 0e	-
Insecticide		
Spinosad	111.8 ± 5.03ab	99.2 ± 0.37a
Thiamethoxam	95.4 ± 5.16bc	99.5 ± 0.29a
Thiacloprid	70.8 ± 9.00c	100.0 ± 0a
Imidacloprid	42.4 ± 6.27d	100.0 ± 0a
Fipronil	13.8 ± 2.01e	98.9 ± 1.12a
Emamectin benzoate	1.8 ± 0.58e	100.0 ± 0a
Control	131.6 ± 6.84a	100.0 ± 0a

* Means in the same column followed by the same letter are not significantly different ($P = 0.05$, Tukey test).

hatch rate of eggs deposited by adult female predators treated with etoxazole was only 6.6%. A report has shown that etoxazole has the transovarial ovicidal activity against *T. urticae* adult females, and thus the hatchability of eggs laid is significantly reduced (Sumitomo Chemical 1995).

The effects of the pesticides tested on *A. cucumeris* eggs are shown in Table 3. Etoxazole and pyraclofos were extremely toxic to eggs of *A. cucumeris* and caused 100% mortality in eggs. In contrast, the treatments of all other pesticides showed no toxic effect on *A. cucumeris* eggs.

In our laboratory studies, acequinocyl, bifenazate, spirodiclofen, spinosad and thiamethoxam had little effect on adult females and eggs of *A. cucumeris* and should fit well into IPM programs designed to utilize this predator. In bioassays conducted with etoxazole, it caused significantly lower eclosion in eggs oviposited by treated females and 100% egg mortality. As such, the use of etoxazole in an IPM system should, therefore, be carefully evaluated. Thiacloprid, imidacloprid, fipronil and chlorfenapyr had considerable toxic effect on *A. cucumeris* adult females. Accordingly, we consider that these pesticides are not reasonably safe for use in IPM programs where *A. cucumeris* is present. Pyraclofos, abamectin and emamectin benzoate, at their

Table 3. Hatchability of eggs of *A. cucumeris* on bean leaf discs treated with different pesticides

Pesticides treated	Treatment rate	% Hatchability (Mean ± SEM)*
Acaricide		
Acequinocyl	1 ml/L	100.0 ± 0a
Bifenazate	0.5 ml/L	100.0 ± 0a
Spirodiclofen	0.5 g/L	100.0 ± 0a
Etoxazole	0.25 ml/L	0.0 ± 0b
Insecticide/acaricide		
Chlorfenapyr	1 ml/L	100.0 ± 0a
Abamectin	0.335 ml/L	98.0 ± 2.00a
Pyraclofos	1 g/L	0.0 ± 0b
Insecticide		
Spinosad	0.5 g/L	98.0 ± 2.00a
Thiamethoxam	0.5 g/L	98.0 ± 2.00a
Thiacloprid	0.5 ml/L	100.0 ± 0a
Imidacloprid	0.5 g/L	100.0 ± 0a
Fipronil	1 ml/L	100.0 ± 0a
Emamectin benzoate	0.5 ml/L	98.0 ± 2.00a
Control		100.0 ± 0a

* Means followed by the same letter are not significantly different ($P = 0.05$, Tukey test).

recommended field rates, caused high mortality of adult female predators. Therefore, it is advisable to limit their use as much as possible, thus reducing the chances of predators being affected by these compounds.

The results of this study provide a comparison of toxic effects of different pesticides to *A. cucumeris* under laboratory conditions. However, care should be taken in translating the results of laboratory tests into predictions of field performance (Hoy and Cave 1985, Zhang and Sanderson 1990). Villanueva-Jimenez and Hoy (1998) also documented that field trial provides more information on pesticide-pest-natural enemy interactions. Thus, additional field trials are needed to evaluate the full impact of different pesticides on *A. cucumeris*.

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