Assessment of Bioassay Techniques and Residual Effect of Certain Acaricides against the Two Spotted Spider Mite, *Tetranychus urticae* Koch and The Predatory Mite, *Phytoseiulus persimilis* Athias-Henriot

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ABSTRACT

Experiments were conducted in the laboratory and the greenhouse to assess the effects of five acaricides against *Tetranychus urticae* Koch and its natural enemy *Phytoseiulus persimilis* Athias-Henriot. The acaricidal activity of the tested compounds against *T. urticae* was assessed by the slide dip and leaf disk dip techniques. Data showed that slide dip technique was efficient method to screen abamectin, chlorfenapyr and fenpyroximate; while the leaf disk dip technique was efficient method to determine the toxicity of ethion and etoxazole. The difference between the compounds may be due to their mode of actions. Results indicate that ethion, chlorfenapyr and etoxazole are very less toxic to *P. persimilis* adult females than those of *T. urticae*. Direct count for each of the prey and predator in order to assess the impact of compounds tested under greenhouse conditions, confirmed the results obtained to a large extent in the laboratory experiments.

Key Words: Bioassay techniques, Acaricides, *Tetranychus urticae*, *Phytoseiulus persimilis*.

INTRODUCTION

Integration of a biological control agent into agricultural IPM systems can not be achieved unless the natural enemy can survive after pesticides application (Hoy 1985). In addition, knowledge of pesticide selectivity to beneficial arthropods is important to its utility in IPM programs, creating better conditions for natural enemies and helping to reduce pesticide applications. Predatory mites of the family Phytoseiidae are effective as biological control agents in agricultural systems (Hoy *et al.*, 1983). *Phytoseiulus persimilis* Athias-Henriot, is worldwide used in biological control programs in the world (Gerson *et al.*, 2003). It is a major biocontrol agent of webbing spider mites (especially *Tetranychus spp*.) that infest many crops in greenhouses and open fields (Mcmurtry, 1982). The two-spotted spider mite, *Tetranychus urticae* Koch, is a major pest of agricultural systems, mainly annual crops and vegetables (Helle & Sabelis ,1985). Numerous acaricides are used to control this pest, and consequently it has developed resistance to several acaricides. *T. urticae* outbreaks are induced by a number of factors, frequently by the use of pesticides non-selective towards its natural enemies (Mcmurtry *et al.*, 1970). Consequently, plant pest populations may increase to more damaging levels than occurred before treatment (Croft, 1990). Since resistance to acaricides in *T. urticae* spread rapidly, biological control tactics are crucial to manage spider mite populations (Gerson & Weintraub, 2007). However, that it is important to study predator as natural enemy when considering control of *T. urticae*. In this prespective, studies on the side-effects of pesticides should address both *P. persimilis* and its prey, *T. urticae*. A large number of publications have dealt with the effects of pesticides on *T. urticae* as it easily develops resistant strains to acaricides (Ako *et al.*, 2004).Thus, some trials in laboratory and greenhouse to assess the effects of five acaricides against *T. urticae* and its natural enemy *P. persimilis* were conducted.

MATERIALS AND METHODS

Rearing prey mite

The two spotted spider mite, *T. urticae* was reared on kidney bean *(Phaseolus vulgaris* L.) planted in a greenhouse (3-4 weeks after germination), and maintained at 25 - 28°C, 40 - 60% R.H. with a photoperiod of 16 L: 8 D (h).

Rearing predatory mite

The phytoseiid predator *P. persimilis* was reared in plastic tray (25 x 25 cm) placed in a plastic box (40 x 60 x 7 cm) containing water to prevent mite escape. Fresh kidney bean leaves heavily infested with prey were supplied every 1 or 2 days and old leaves were removed once a week. *P. persimilis* rearing was conducted under laboratory conditions of 23 ± 2°C, 50–70% R.H. and L16:D8 photoperiod.

Tested acaricides

1- Ethion (Endo® 50% EC) IRAC 1B; organophosphate
Chemical name: *O,O,O′,O′*-tetraethyl S,S′-methylene bis(phosphorodithioate), was obtained from Elhelb Pesticides and Chemicals Co.
2- Fenpyroximate (Ortus super® 5% EC) IRAC 21; METI

Chemical name: tert-butyl(E)-α-(1,3-dimethyl-5-phenoxypyrazol-4-ylmethyleneaminooxy)-p-toluate, was obtained from Nichino America Ancorpurishn.

3- Etoxazole (Baroque®10%SC) IRAC 10B; mite growth inhibitor
Chemical name: *(RS)*-5-tert-butyl-2-[2-(2,6-difluorophenyl)-4,5-dihydro-1,3-oxazol-4-yl]phenetole, was obtained from Sumitomo Chemical Co., Ltd.

4- Chlorfenapyr (Challenger® 36% SC) IRAC 13; arylpyrrole
Chemical name: 4-bromo-2-(4-chlorophenyl)-1-ethoxymethyl -.5 trifluoromethyl.-1H-pyrrole-3-carbonitrile, was obtained from BASF Corpor.

5- Abamectin (Vertimec® 1.8% EC) IRAC 6; avermectin
Chemical name: 5-*O*-demethylavermectin A_{1a} (i) mixture with 5-*O*-demethyl-25-de(1-methylpropyl)-25-(1-methylethyl)avermectin A_{1a} (ii) , was obtained from Syngenta Agro.

Bioassay techniques

Slide dip assay

Tested acaricides concentrations were prepared from stock solutions in water. All concentrations were given as parts per million (ppm). A piece of double-sided adhesive tape was fixed to a microscope slide. A second piece of adhesive was placed, sticky side up, onto the double-sided tape. Ten female adults (one day old) of *T. urticae* and *P. persimilis* were then placed on their backs to each slide with a fine hair brush. At least six concentrations of each acaricide were used. Each concentration was replicated four times. Slides were dipped into 200 ml beaker containing acaricides solutions so that the mites were immersed for five seconds to ensure complete wetting. Control mites were similarly dipped in water only. Thereafter, slides were touched down, on edge, on absorbent paper towelling and then allowed to dry under the laboratory conditions. After 24 h, mites were examined, and incapable of moving an appendage when gently prodded with a fine brush were considered dead (Thistlewood *et al.,* 1992 and Sang-Guei *et al.,* 2002).

Leaf disk dip assay

The leaf disk assay was conducted using method described earlier by Pree *et al.,* (1989). The kidney bean leaf disks (2.5 cm diameter) cut from seedlings were dipped in concentrations of the various acaricides for 30 seconds. The discs were put on wet cotton wool in petri-dish and kept under constant conditions ((25 ± 2°C, 65 ± 5% R.H. and 16:8 photoperiod). Ten female adults (one day old) of *T. urticae* were transferred on each disk with a fine brush. Concentration mortality regressions were based on tests with six concentrations of each acaricide, and were expressed as parts per million of active ingredient (a.i.). Control disks were dipped in tap water. Tests were repeated 4 times for each concentration of each acaricide. Mortality of mites treated with acaricides in all tests was assessed after 24 hrs.

In the two previous techniques, mortality data were corrected according to Abbott formula (1925), the corrected mortality percentage of each acaricide was statistically computed according to Finney (1971). The corresponding concentration probit lines (LC-p lines) were estimated in addition to determine 50 and 90% mortalities. Slope values of tested acaricides were estimated. In addition, the efficiency of different compounds was measured by comparing the tested compound with the most effective compound by using the equation of Sun (1950), toxicity index = LC_{50} of the most effective compound/LC_{50} of the tested compound x 100.

Assessment of persistence and residual efficacy:

The residual toxicity assays were conducted using methods described by Sáenz-de-Cabezòn *et al.,* (2007). Each acaricide was tested at the concentration recommended for field applications according to Agricultural Pesticides Committee (APC 2010), Egypt as follow: ethion (Endo® 50% EC) at the rate of 600ml/feddan (1 feddan = 4200m^2) =1500 ppm; fenpyroximate (Ortus super® 5% EC) at the rate of 50ml/100 Liter =25 ppm; etoxazole (Baroque®10%SC) at the rate of 25ml/100 Liter =25 ppm; chlorfenapyr (Challenger® 36% SC) at the rate of 45ml/100 Liter =162 ppm; abamectin (Vertimec® 1.8% EC) at the rate of 40ml/100 Liter =7.2 ppm.

A 100 ml volume of each recommended concentration was sprayed on kidney bean *(P. vulgaris*) plants to run-off using a 200 ml hand trigger sprayer with adjustable one nozzle set to mist position. Untreated plants were sprayed with distilled water alone. Five replicates were used for each treatment and the control. The plants were grown in a greenhouse at 25–28°C, 40–60% R.H. and a photophase of at least 16 h conditions. Drip irrigation and nutrients were applied uniformly to all plants and no pesticides were used prior to the experimental applications. Each bioassay unit consisted of five 20 mm diameter kidney bean leaf disks, cut with a cork borer from five treated and six untreated leafs removed from the plants. The disks were cleaned and placed on wet cotton wool inside a 90 mm diameter Petri dish. Additional water was added to prevent mite escape from the disks.

Bioassays were conducted under constant conditions (25±2°C, 65±5%R.H. and 16:8 photoperiod).

Bioassays for *T. urticae* and *P. persimilis* were conducted in separate sets of bioassay units. Ten females of *T. urticae* were transferred on each disk with a fine brush. Mortality was recorded 24 hours after mites were placed on the disk. Six replicates of each acaricide treatment and control were conducted. Mites were considered dead if they were unable to react when gently probed with a fine brush. These procedures were repeated with treated and untreated leafs removed from the plants after 1, 3, 5, 7 and 9 days of application.

An adequate number of treated or untreated *T. urticae* females (25 active stages of *T. urticae* per 5 predator females) were transferred to each replicate as prey for *P. persimilis*. Mortality of *P. persimilis* was recorded after 24 hours after being placed a surplus of *T. urticae* on a disk in second trial. Six replicates (one bioassay unit) of each acaricide treatment and control were conducted. These procedures were followed at 1, 3, 5, 7 and 9 days after application. In both tests the half-life time values were computed by Ldp Line program.

Effect of tested acaricides on population density:

This experiment was conducted in a greenhouse planted with kidney bean *(P. vulgaris*) at 25 - 28°C, 40 - 60% RH with a photoperiod of 16 : 8 h (L : D). Each acaricide was applied at the concentration suggested for field applications according to APC 2010, Egypt. Alive *T. urticae* and *P. persimilis* were counted and recorded at pre-spraying and after 1, 3, 5, 7 and 9 days of application. Lower surface of the leaves was examined carefully using stereomicroscope. Five replicates were used for each treatment and the control. Spray was applied using a hand sprayer with one nozzle sprayer of 200 ml capacity. Percentage of reduction was estimated according to the equation of Henderson & Tilton (1955).

Statistical analysis

Data of population density were subjected for one way analysis of variance (ANOVA), and the means were separated using Duncan's multiple range Test CoHort Software, (2004).

RESULTS AND DISCUSSION

Comparison of bioassay techniques

The toxicity of five tested acaricides to *T. urticae* using two techniques was represented in Table (1). Generally, abamectin proved to be the most potent compound giving LC_{50} value of 0.031 and 0.122 ppm followed by fenpyroximate (3.21 and 4.29 ppm), ethion (23.38 and17.65 ppm), chlorfenapyr (12.55 and 87.69 ppm) and etoxazole (49.22 and 42.47 ppm) in slide dip and leaf disk dip techniques, respectively.

Toxicity index values showed the acaricidal effect of abamectin (100) on *T. urticae* compared with the other tested acaricides. These values reached (0.966 & 2.844%), (0.247 & 0.139%), (0.133 & 0.691%) and (0.063 & 0.287%) for fenpyroximate, chlorfenapyr, ethion and etoxazole in slide dip and leaf disk dip techniques; respectively.

Table (2) indicated the toxicity of five tested acaricides to *P. persimilis* using slide dip technique. The results revealed the same trend of acaricides action on prey, also abamectin was the superior compound (LC_{50} = 0.014ppm) followed by fenpyroximate (2.56 ppm), chlorfenapyr (16.19 ppm), ethion (36.90 ppm) and etoxazole (94.92 ppm); respectively.

The abamectin was effective compound based on 100 % mortality and the toxicity index of the other compounds were 0.547, 0.086, 0.038 and 0.015% in case of fenpyroximate, chlorfenapyr, ethion and etoxazole; respectively.

Evaluation of persistence and residual efficacy:

Persistence of tested acaricides on kidney bean *(P. vulgaris*) planted in a greenhouse to *T. urticae* was shown in Table (3). Chlorfenapyr gave the greatest persistence (LT_{50} = 4.99days), whereas ethion caused the smallest persistence (LT_{50} = 2.61days). The tested acaricides were arranged in an ascending order of persistence (from the lowest to the highest persistence) as follows: ethion, fenpyroximate, etoxazole, abamectin and chlorfenapyr with persistence ratio 0.52, 0.63, 0.74, 0.88 and 1.00 fold; respectively.

Concerning the bioresidual efficacy on *P. persimilis* by feeding method with treated *T. urticae* at time intervals in days after application (Table 4), revealed the same trend of acaricides action on prey but was less effective on predatory. The persistence ratio of *P. persimilis* reached to 0.52, 0.59, 0.59, 0.99 and 1.00 folds for ethion, fenpyroximate, etoxazole, abamectin and chlorfenapyr; respectively. It is clear from previous data; the high persistence ratio was recorded with chlorfenapyr.

Table (1): Toxicity of five tested acaricides to *Tetranychus urticae* Koch using two techniques.

	Tested compounds	Ethion	Fenpyroximate	Etoxazole	Chlorfenapyr	Abamectin
Slide dip technique	LC50(ppm) (limits at 95%)	23.38 (16.01-32.45)	3.21 (2.16-4.47)	49.22 (35.73-79.96)	12.55 (6.16-25.57)	0.031 (0.019-0.049)
	LC90(ppm) (limits at 95%)	165.94 (99.83-406.85)	23.86 (15.92-42.10)	360.93 (176.60-1453.99)	1355.45 (665.17-2762.06)	0.607 (0.289-2.127)
	Slope	1.506±0.244	1.471±0.175	1.481±0.255	0.630±0.120	0.995±0.147
	Toxicity index(%)	0.133	0.966	0.063	0.247	100
Leaf disk dip technique	LC50 (ppm) (limits at 95%)	17.65 (3.53-32.68)	4.29 (2.76-6.38)	42.47 (30.93-68.09)	87.69 (56.58-135.90)	0.122 (0.08-0.181)
	LC90(ppm) (limits at 95%)	316.48 (168.59-1667.18)	71.72 (39.06-181.25)	312.25 (146.19-2079.75)	1154.99 (745.28-1789.95)	1.86 (1.04-4.33)
	Slope	1.022±0.266	1.048±0.131	1.479±0.335	1.145±0.175	1.084±0.126
	Toxicity index(%)	0.691	2.844	0.287	0.139	100

Table (2): Toxicity of five tested acaricides to *Phytoseiulus persimilis* Athias-Henriot using slide dip technique

Tested compounds	LC_{50}(ppm) (limits at 95%)	LC_{90}(ppm) (limits at 95%)	Slope	Toxicity index(%)
Ethion	36.90 (26.49-46.47)	124.86 (87.56-275.37)	2.421 ± 0.525	0.038
Fenpyroximate	2.56 (1.41-3.84)	26.74 (16.86-55.49)	1.258 ± 0.191	0.547
Etoxazole	94.92 (53.55- 366.33)	1906.86 (450.14-103510)	0.984 ± 0.24	0.015
Chlorfenapyr	16.19 (9.44-28.81)	468.11(191.73-1957.12)	0.877 ± 0.118	0.086
Abamectin	0.014 (0.009- 0.022)	0.20 (0.127-0.314)	1.112 ± 0.162	100.00

Table (3): Persistence of tested acaricides on kidney bean *(Phaseolus vulgaris* L.) planted in a greenhouse to *Tetranychus urticae* at time intervals in days after application.

Tested compounds	Mortality percentage after application (Days)					Lt_{50} (days) limits at 95%	PR*
	1	3	5	7	9		
Ethion	91.52	50.85	23.73	6.67	1.67	2.61(1.56-3.42)	0.52
Fenpyroximate	91.52	54.24	28.81	13.33	0.00	3.12 (2.76-3.49)	0.63
Etoxazole	89.83	76.27	33.90	16.67	0.00	3.68 (3.06-4.43)	0.74
Chlorfenapyr	91.52	86.44	69.49	30.00	5.00	4.99 (4.36-5.70)	1.00
Abamectin	96.61	76.27	54.24	18.33	5.00	4.37 (3.86-4.95)	0.88

* Persistence ratio (PR) compared with the highest persistence (Chlorfenapyr)

Table (4): The bioresidual efficacy on *Phytoseiulus persimilis* at time intervals in days after application.

Tested compounds	Mortality percentage after application (Days)					Lt_{50} (days) (limits at 95%)	PR*
	1	3	5	7	9		
Ethion	75.86	30.00	6.67	3.33	0.00	1.79 (1.54-2.03)	0.52
Fenpyroximate	82.76	33.33	6.67	0.00	0.00	2.01 (1.77-2.27)	0.59
Etoxazole	79.31	36.67	10.00	0.00	0.00	2.03 (1.75-2.31)	0.59
Chlorfenapyr	86.21	86.67	30.00	6.67	3.33	3.42 (2.79-4.19)	1.00
Abamectin	89.66	86.67	16.67	6.67	6.67	3.39 (2.69-4.26)	0.99

* Persistence ratio (PR) compared with the highest bioresidual efficacy (Chlorfenapyr)

Table (5): Efficiency of tested acaricides on population density of *Tetranychus urticae* at time intervals in days.

Tested compounds			Ethion	Fenpyroximate	Etoxazole	Chlorfenapyr	Abamectin	Control	LSD 5%
Pre-application		M±SD	12.72±3.59	12.72±3.59	12.72±3.59	12.96±3.96	13.12±3.71	9.20±2.44	
Mean number per leaf and percent of reduction after application (days)	1	M±SD	1.16±1.55b	0.92±1.29b	0.96±1.40b	2.40±1.78b	1.24±1.61b	12.40±3.80a	1.572
		% R	93.23	94.63	94.4	86.26	92.99	-	
	3	M±SD	2.96±2.65bc	3.36±2.51bc	2.44±1.98c	0.96±1.37c	5.16±1.62b	14.80±4.56a	2.242
		% R	85.53	83.58	88.07	95.4	75.55	-	
	5	M±SD	7.92±3.50c	10.60±2.93b	3.92±2.11d	2.60±2.50d	11.12±3.29b	19.20±5.32a	2.115
		% R	70.17	60.07	85.23	90.39	59.39	-	
	7	M±SD	15.28±4.06bc	17.08± 5.14b	13.20±3.83cd	11.04±2.75d	15.80±3.59bc	21.04±6.11 a	2.704
		% R	47.47	41.29	54.62	62.75	47.34	-	
	9	M±SD	22.20±7.75a	21.52±6.71ab	20.88±6.20ab	15.92±4.71c	17.76±4.72bc	23.24±10.20a	4.051
		% R	30.91	33.03	35.02	51.37	46.41	-	
General mean of % reduction			65.46	62.52	71.47	77.23	64.34	-	

Table (6): Efficiency of tested acaricides on population density of *Phytoseiulus persimilis* at time intervals in days.

Tested compounds			Ethion	Fenpyroximate	Etoxazole	Chlorfenapyr	Abamectin	Control	LSD 5%
Pre-application M±SD			6.36±2.67	6.36±2.67	6.36±2.67	6.36±2.67	6.36±2.67	4.76±1.98	
Mean number per leaf and percent of reduction after applicatio n (days)	1	M ±SD	0.32± 0.55 bc	0.84±1.18 bc	0.96±1.34 b	0.64±0.86 bc	0.24±0.52 c	3.92±1.68 a	0.621
		% R	93.89	83.96	81.67	87.78	95.42	-	
	3	M ±SD	0.84±0.90 c	2.16±1.40 b	1.08±1.29 c	0.64±0.95 c	0.56±0.92 c	6.00±2.06 a	0.716
		% R	89.52	73.06	88.91	92.02	93.01	-	
	5	M ±SD	2.56±1.16 c	3.72±1.54 b	2.16±1.75 c	1.88±1.67 c	2.40±1.94 c	7.40±2.78 a	1.049
		% R	74.11	62.38	78.15	80.99	75.73	-	
	7	M ±SD	3.12±0.97 d	5.68±2.11 b	5.44±1.78 b	4.32±1.93 c	3.92±1.73cd	8.20±2.10 a	0.887
		% R	71.52	48.16	50.35	60.57	64.22	-	
	9	M ±SD	4.48±2.04 c	11.16±3.51 a	11.16±2.53 a	9.88±2.86 a	7.60±3.41 b	11.20±3.49 a	
		% R	70.06	25.69	25.42	33.98	49.21	-	
General mean of % reduction			79.82	58.65	64.9	71.07	75.52	-	

Table (7): Comparison between the two used techniques on *Tetranychus urticae*

Tested compounds	Technique	LC_{50} (ppm)	Toxicity index(%)
Ethion	Slide dip	23.38	75.58
	Leaf disk dip	17.65	100.00
Fenpyroximate	Slide dip	3.21	100.00
	Leaf disk dip	4.29	74.80
Etoxazole	Slide dip	49.22	79.96
	Leaf disk dip	42.47	100.00
Chlorfenapyr	Slide dip	12.55	100.00
	Leaf disk dip	87.69	14.31
Abamectin	Slide dip	0.03	100.00
	Leaf disk dip	0.12	25.41

Table (8): Comparison between the toxicity of acaricides to *Tetranychus urticae* and *Phytoseiulus persimilis*

Tested compounds	Prey and predatory mites	LC_{50} (ppm)	Toxicity index(%)
Ethion	*T. urticae*	23.38	100.00
	P. persimilis	36.90	63.35
Fenpyroximate	*T. urticae*	3.21	79.71
	P. persimilis	2.56	100.00
Etoxazole	*T. urticae*	49.22	100.00
	P. persimilis	94.92	51.85
Chlorfenapyr	*T. urticae*	12.55	100.00
	P. persimilis	16.19	77.48
Abamectin	*T. urticae*	0.031	45.16
	P. persimilis	0.014	100.00

Efficiency of tested acaricides on population density:

Table (5) showed that the initial and residual effect of tested acaricides against *T. urticae* infestation. Concerning the initial effect (after one day of spraying), no significant differences were obtained among all tested acaricides. After three days, there were significant differences in the effects of tested acaricides. The effects of chlorfenapyr and etoxazole were most striking, which caused 95.40 and 88.07% reduction; respectively. The most effective compound till the end of the experiment was chlorfenapyr, which caused 51.37 % reduction at the ninth day. The efficiency of the tested acaricides could be arranged according to the general mean of reduction percentage in a descending order as follows: chlorfenapyr, etoxazole, ethion, abamectin and fenpyroximate they were 77.23, 71.47, 65.46, 64.34 and 62.52% ;respectively.

All treatments reduced the population density of the predatory mite *P. persimilis*, with significant differences between treatments and the control (Table 6). Abamectin had the highest initial effect (95.42% reduction); while the lowest was obtained with etoxazole, 81.67% reduction in population density than control, after one day from application. After 9 days from application, significant differences did not emerge between etoxazole, fenpyroximate, chlorfenapyr and control. On the other hand fenpyroximate showed the lowest general mean of reduction percentage in population density of *P. persimilis* than control, recording 58.65% reduction. An ascending order of the rest toxicants was etoxazole (64.90%), chlorfenapyr (71.07%), abamectin (75.52%) and ethion (79.82%).

The slide dip technique provides efficient method against *T. urticae* for testing abamectin, chlorfenapyr and fenpyroximate, but the leaf disk dip technique was more efficient method for determining the toxicity of ethion and etoxazole. The difference between the compounds and some of them may be due to the difference in mode of action of each compound (Table 7).

For this reason, it is important to be fully aware with the mode of action of acaricide before choosing the best bioassay technique to assess acaricides. Our studies largely concentrated on acaricides representing distinctly different primary target sites of action. The mode of action of chosen acaricides to study initially were ethion IRAC 1B, organophosphate, an inhibitor of acetylcholinesterase, non-systemic with predominantly contact action; fenpyroximate IRAC 21, mitochondrial electron transport inhibitors (METI) at Complex I (Hirata *et al.,* 1995), quick knockdown activity against larvae, nymphs and adults, mainly by contact and ingestion, also some moulting inhibitory activity on nymphs; etoxazole IRAC 10B, mite growth inhibitor was determined to be chitin biosynthesis inhibition (Nauen & Smagghe, 2006), contact with effect on eggs, larvae and nymphs, with no effect on adults; chlorfenapyr IRAC 13, arylpyrrole, inhibitor and uncoupler of the oxidative phosphorylation, mainly stomach and some contact action, exhibits good translaminar, but limited systemic; abamectin IRAC 6, avermectin, primary mode of action is to block synaptic transmission, a chloride channel activator (GABA agonist), contact and stomach action (Decombe *et al.,* 2004). However, the survival rate of *T. urticae* adult females in treatment with etoxazole was much higher than those of the other acaricidal treatments (Kim & Yoo 2002). Reports have shown that etoxazole interfere with the molting process of mite juvenile stages and have little effect against adults (Anderson *et al.*, 1986; Sumitomo Chemical 1995).

The present results indicate that for the strains tested, ethion, chlorfenapyr and etoxazole are much less toxic to *P. persimilis* adult females than to *T. urticae* adult females (Table 8). Kim & Yoo, (2002) showed that survival at 168 h after treatment with etoxazole was 86% for *P. persimilis* adult females and 66 % for those of *T. urticae* . Thus, etoxazole was also less toxic to adult female predators than to their prey, also chlorfenapyr could be used as selective acaricide in integrated mite management program because it is more toxic to *T. urticae* than to *P. persimilis* (Zhang & Sanderson, 1990). Moreover, they reported that feeding on *T. urticae* intoxicated with abamectin reduced 50% of the reproductive rate of *P. persimilis* female.

In addition, the predators alone may not be able to maintain spider mite populations below an economic injury level for an extended period of time (Kim *et al.,* 1997 and Ibrahim & Yee 2000). In the presence of chemical applications, biological control of spider mites may be achieved by the selective use of the pesticides that are more toxic to pest species than to natural enemies (Spollen & Isman 1996). Thus, selective acaricides are needed to adjust the prey/predator ratio and to maintain adequate long-term control efficacy.

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