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Toxicity of Some Pesticides Against *Tetranychus urticae* and its Predatory Mites under Laboratory Conditions

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Abstract: The relative toxicity of some pesticides to the two-spotted spider mite *Tetranychus urticae* and its predatory mites, *Phytoseiulus persimilis* and *Amblyseius californicus,* was evaluated under laboratory conditions. Three pesticides namely, dimethoate, bifenthrin and hexythiazox were tested against mite populations. According to LC50 value, the toxicity of pesticides to the adult two-spotted spider mite was respectively bifenthrin (1.82 ppm), dimethoate (117.97 ppm), hexythiazox (537.45 ppm/24 h. 175.75 ppm/72 h). For *P. persimilis* and *A. californicus*, the toxicity of pesticides according to LC values and IOBC toxicity category, bifenthrin and dimethoate were harmful while hexythaizox was harmless after 24 h, moderately harmful after 72 h. The Ovicidal/Ovolarvicidal test indicated that hexythiazox and bifenthrin were extremely toxic to *T. urticae* eggs and larvae. Toxicity of hexythiazox to *A. californicus* and *P. persimilis* larvae was less than the other pesticides. The Nymphicidal test indicated that the activity of bifenthrin was very strong on *T. urticae* nymphs, but the activity of dimethoate was fairly weak and less than hexythaizox. Dimethoate was toxic to *A. californicus* and *P. persimilis* nymphs whilst bifenthrin and hexythiazox were moderately harmful. Hexythiazox appeared to be a promising candidate for a mite management program for *T. urticae*. *A. californicus* was more tolerant than *P. persimilis* to the tested pesticides.

Key words: pesticides · IOBC toxicity criteria · *Tetranychus urticae* · *Phytoseiulus persimilis* · *Amblyseius californicus*

INTRODUCTION

The Two-spotted Spider Mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae) is an important and highly polyphagous pest on cultivated areas. It is particularly dominant in intensive, high-yield cropping systems and affects crops by direct feeding, there by reducing the area of photosynthetic activity and causing leaf abscission in severe infestations [1]. The TSSM causes significant economic losses in tomatoes, peppers, cucumbers and beans growing in greenhouses of Turkey. For the past 25 years, *T. urticae* control in Turkey has been based almost exclusively on pesticides. Many insecticides and acaricides have been registered in Turkey. Unfortunately, spider mites has developed resistance to most available pesticides and the loss of acaricidal efficacy as a result of resistant mite populations is the major problem encountered [2]. Considerable research efforts have been devoted to finding alternative strategies for suppression of *T. urticae*. An alternative in the management of this mite-pest consists in releases of phytoseiid predatory mites (Acari: Phytoseiidae) such as *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius californicus* McGregor (Acari: Phytoseiidae) [3-5], which are considered as important natural enemies of *T. urticae*. The predatory mite, *Phytoseiulus persimilis* is an important natural enemy in the garden and greenhouses [4, 6]. This predatory mite was recorded a natural colonies along the Mediterranean coast of Turkey [7]. Turkish (Hatay) strain of *Phytoseiulus persimilis* is being used from a few years ago in biological control against spider mites in Turkey [8, 9]. *A. californicus* can survive and reproduce on different mite and insect species and pollen [10, 11], although it shows a preference for spider mites [12]. Additionally, *A. californicus* seems to be more tolerant to pesticides than *P. persimilis* [13, 14], *Amblyseius californicus* is recorded naturally from Turkey on strawberry, peach, bean and pepper in 2001 [15]. The researches related to *A. californicus* are very limited especially about its tolerance against pesticides in Turkey. Therefore the using of *A. californicus* for control TSSM must be investigated and compared with the data

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of *P. persimilis* under laboratory and greenhouses conditions. The aim of this study was to determine the toxicity of three pesticides, bifenthrin, dimethoate hexythiazox, on different stages of two-spotted spider mite and its predatories *P. persimilis* and *A. californicus* and to measure the tolerance of these predatories to pesticides under laboratory conditions.

MATERIALS AND METHODS

Chemicals: Two insecticides-acaricides, bifenthrin and dimethoate and a selective acaricide and mite growth regulator hexythiazox, were used in this experiment. These pesticides are commonly used to control spider mites and insects on vegetable crops in Turkey [16]. The recommended field concentration of bifenthrin is 0.06 g a.i. l^{-1} (60 ppm) (Talstar® 10 EC, 100 g a.i. l^{-1}, Bayer): Pyrethroid insecticide-acaricide.

The recommended field concentration of dimethoate is 0.45 g a.i. l^{-1} (450 ppm) (Poligor® EC, 400 g a.i. l^{-1}, Hekta°): Organophosphate insecticide-acaricide.

The recommended field concentration of hexythiazox is 0.05 g a.i. l^{-1} (50 ppm) (Twister® 5 EC, 50 g a.i. l^{-1}, Hektaş). The concentration of pesticides in Ovicidal/Ovolarvicidal, Nymphicidal tests was one-third of the recommended field concentration i.e. bifenthrin 0.02 g a.i. l^{-1} (20 ppm), dimethoate 0.15 g a.i. l^{-1} (150 ppm) and hexythiazox 0.017 g a.i. l^{-1} (17 ppm).

Source of mites: *Tetranychus urticae* was reared on bean plants (*Phaseolus vulgaris* cv. Barbunia) at 25±1°C and 60±10% RH under a 16-h light regime. Clean plants were grown in a climate room (same regime) until they were 2-weeks old and were subsequently added biweekly to the spider mite culture.

The predatory mites *Phytoseiulus persimilis* and *Amblyseius californicus* were reared at 25°C on detached bean leaves infested with two-spotted spider mites. These leaves were put on an inverted flowerpot in a water-containing tray covered with a Plexiglas container. Some 2-3 leaves from the spider mite culture were added to the cultures biweekly. *P. persimilis*, Turkish strain, was collected from fields in Hatay, Turkey.

A. californicus, Spical®, was obtained from Koppert BV in 2006 and was reared on bean leaves with spider mites.

Direct toxicity to adults: The LC50 values were determined using the Leaf-Spray method which is accepted by the IOBC/WRPS Working Group on 'Pesticides and Beneficial Arthropods' as a standard routine test [17]. For TSSM bean leaf was plased on wet cotton wool in a petri dish (9 cm diameter) and 20 female adult mites were transferred to leaf and sprayed (2ml solution) by a Potter spray tower (Auto-Load; Burcard® Scientific) at 1 bar. Six concentrations were used for each pesticide along with three replicates and controls. Mortality was recorded after 24 h for bifenthrin and dimethoate, 24 h and 72 h for hexythiazox beacuse activity of hexythiazox on adult mites is little and take few days. The petri dishes were stored in a cabinet at 25°C, 60±5 % RH, 16 L: 8D light regime. For predatory mites same method (Leaf-Spray method) was applied and the leaf was surrounded with Vaseline to prevent the escape of the predatory mites. for feeding the predatory mites *T. urticae* as prey was used on leaf. 10 adults were used in this treatment. Mortality was recorded after 24 h for bifenthrin and dimethoate, 24 h and 72 h for hexythiazox.

Ovicidal/ovolarvicidal test: Five adult females TSSM were allowed to oviposit for 24 h on bean leaf resting on wet cotton wool in a petri dish (9 cm diameter) and then adults were removed and then 20 eggs per leaf was allowed. The leaf was then sprayed with bifenthrin (20 ppm), dimethoate (150 ppm) and hexythiazox (17 ppm) using a Potter spray tower (2 ml solution). The petri dishes were stored in a cabinet at 25°C, 60±5 % RH, 16L: 8D light regime. For predatory mites five adults were allowed to oviposit for 24-36 h on bean leaf resting on wet cotton wool in a petri dish (9 cm diameter) which were then removed. The mites laid between 10 eggs per leaf.

Hatching ratio and larvael mortality was assessed for seven days after treatment. Three replicates was used in every treatment and control. This method is recommended by the FAO [18].

Nymphicidal test: Again the bean leaf was plased on wet cotton wool in a petri dish (9 cm diameter) and 15 nymphs of TSSM were transferred to leaf and sprayed with bifenthrin (20 ppm), dimethoate (150 ppm) and hexythiazox (17 ppm) by a Potter spray tower (2 ml solution). For each pesticide were used three replicates and control. For predatory mites same method was used and the leaf was surrounded with Vaseline to prevent the escape of the predatory mites. For feeding the predatory mites *T. urticae* as prey was used on leaf. 10 nymphs were transferred to leaf and sprayed by the spray tower. Mortality was recorded after 1, 3, 5 days.

Statistical analysis: LC50 and LC90 values with a 95 % confidence limit and slopes ±SE of the regression were estimated using the computer program POLO [19]. The ANOVA (analysis of variance) was estimated using the computer program Cohort Software and means were compared by Tukey-Kramer test (1WCR).

RESULTS

Direct toxicity to adults: The LC50 and LC90 values of the *T. urticae* and its predators *P. persimilis*, *A. californicus* are given in tables 1, 2 and 3. LC50 value of *P. persimilis* against bifenthrin was very low (0.025 ppm) as compared to the LC50 values of *A. californicus* and *T. urticae* which where 0.67 ppm and 1.82 ppm respectively. Therefore, sensitivity of *P. persimilis* against bifenthrin was higher than *T. urticae* by 72.68 times; while sensitivity of *A. californicus* against bifenthrin comparative with *T. urticae* is only 2.69 times (Table 4). LC 50 value of *P. persimilis* against dimethoate was lower (5.54 ppm) than LC50 values of *A. californicus* (33.76 ppm) and *T. urticae* (117.97 ppm). Therefore, sensitivity of *P. Persimilis* against dimethoate comparative with *T. urticae* was 21.27 times; while sensitivity of *A. californicus* was 3.49 times comparative with *T. urticae* (Table 4). Toxicity of hexythiazox for all mite populations between first and third days after treatment showed tremendous differences. These differences depend on the mite growth regulator activity of this chemical. Generally toxicity of hexythiazox to all adult mites was lower than bifenthrin and dimethoate. LC50 for *P. persimilis*, *A. californicus* and *T. urticae,* in the first day was 184.48, 280.98 and 537.45 ppm but in the third day it was decreased by 28.92, 50.61 and175.75 ppm sespectively. Sensitivity of *P. persimilis* against hexythiazox is higher than *T. urticae* with 6.07 times; while sensitivity of *A. californicus* against hexythiazox comparative with *T. urticae* is only 3.4 times after 72 h (Table 4). Generally sensitivity of *P. persimilis* against tested pesticides is higher than *A. californicus*, which more tolerant than *P. persimilis* to the tested pesticides.

According to LC50 value, toxicity of pesticides to adult of two-spotted spider mite was bifenthrin, dimethoate and hexythiazox.

The classification of pesticides toxicity according to IOBC category (International Organization for Biological Control) under laboratory tests against natural enemies was given in table 5 [20]. Toxicity of pesticides to predatory mites, *P. persimilis* and *A. californicus*; showed that bifenthrin and dimethoate with were harmful effect, hexythiazox was with harmless effect after 24 h while moderately harmful after 72 h (Table 6).

Table 1: LC values (ppm) and probit statistics for *T. urticae* adult against tested pesticides

T. urticae	N	Slope±SE	X^2 (df)	LC50 (95%CL)	LC90 (95%CL)
Bifenthrin	380	0.97±0.11	1.28	1.82	37.16
			-16.00	(1.30-2.57)	(18.97-105.68)
Dimethoate	380	0.64±0.12	3.15	117.97	11318.8
			-16.00	(73.41-216.72)	(2799.14-21248.50)
Hexythiazox	475	1.68±0.18	9.90	537.45	3101.31
(24 h)			-16.00	(453.47-648.69)	(2120.66-5509.29)
Hexythiazox	380	1.10±0.14	4.83	175.75	2514.34
(72 h)			-16.00	(128.24-265.83)	(1211.71-8197.32)

ppm = 0.001 mg a.i l^{-1}

Table 2: LC values (ppm) and statistics for *A. californicus* adult against tested pesticides

A. californicus	N	Slope±SE	X^2 (df)	LC50 (95%CL)	LC90 (95%CL)
Bifenthrin	190	0.97±0.17	1.83	0.67	13.91
			-16.00	(0.41-1.10)	(5.79-78.18)
Dimethoate	190	1.73±0.25	2.72	33.76	184.44
			-16.00	(25.38-44.54)	(119.27-379.56)
Hexythiazox	190	1.25±0.24	2.39	280.98	2951.06
(24 h)			-16.00	(194.59-419.70)	(1414.52-13739.62)
Hexythiazox	190	1.76±0.26	2.69	50.61	269.27
(72 h)			-16.00	(38.76-67.87)	(167.61-609.66)

ppm = 0.001 mg a.i l^{-1}

Table 3: LC values (ppm) and satistics for *P. persimilis* adult against tested pesticides

P. persimilis	N	Slope±SE	X^2 (df)	LC50 (95%CL)	LC90 (95%CL)
Bifenthrin	160	1.66±0.33	1.47	0.025	0.14
			-13.00	(0.017-0.034)	(0.08-0.46)
Dimethoate	190	1.53±0.24	3.06 (16)	5.54	37.88
				(3.99-7.51)	(22.8-93.43)
Hexythiazox	190	1.13±0.21	4.78	184.48	2475.76
(24 h)			-16.00	(123.80-307.50)	(1039.76-15037.55)
Hexythiazox	190	1.90±0.27	1.85	28.92	136.4
(72 h)			-16.00	(22.50-38.03)	(88.46-282.42)

ppm= 0.001 mg a.i l^{-1}

Table 4: LC50 ratio of pesticides for adult of mite populations

	Bifenthrin		Dimethoate		Hexathiazox			
	LC50	Ratio	LC50	Ratio	LC50 (24/h)	LC50 (72/h)	Ratio (24/h)	Ratio (72/h)
T. urticae	1.82	1.00	117.97	1.00	537.45	175.75	1.00	1.00
A. californicus	0.67	2.69	33.76	3.49	280.98	50.61	1.91	3.40
P. persimilis	0.025	72.68	5.54	21.27	184.48	28.92	2.91	6.07

Table 5: Classification of pesticides under laboratory test to natural enemies according to IOBC criteria (Boller *et al*. 2006)

Classifications	Percentage death	Category (Toxicity class)
Harmless or slightly harmful	<%30	1 N
Moderately harmful	%30-79	2 M
Harmful	%80-98	3 T
Harmful	>%99	4 T

Table 6: Category of tested pesticides against *P. persimils* and *A. californicus* according to IOBC criteria and lethal concentration values

Pesticides	Lc value (ppm)	Category
Bifenthrin: recommended	*P. persimils*: LC 99 = 0.62 ppm < 60 ppm	4 T
field concentration is 60 ppm	*A. californicus:* LC 90= 184.44 ppm < 450 ppm, LC 99= 736.22 > 450 ppm	3 T
Dimethoat: recommended	*P. persimils*: LC 99 = 181.43 ppm < 450 ppm	4 T
field concentration is 450 ppm	*A. californicus:* LC 90= 184.44 ppm < 450 ppm, LC 99= 736.22 > 450 ppm	3 T
Hexythiazox: recommended	*P. persimils*: LC 30 = 63.75 ppm > 50 ppm	1 N
field concentration is 50 ppm (24 h)	*A. californicus:* LC 30= 107.34 ppm > 50 ppm	1 N
Hexythiazox: recommended	*P. persimils* için LC 70= 54.56 ppm > 50 ppm	2 M
field concentration is 50 ppm (72 h)	*A. californicus* için LC 50= 50.61 ppm >50 ppm	2 M

Ovicidal/ovolarvicidal test: Hatching ratio for eggs of *T. urticae* in five and seven days after treatment indicated significant differences ($P< 0.05$) between the control and tested pesticides. Hexythiazox was very effective on eggs hatching, hence 11.1 % eggs had hatched, while bifenthrin and dimethoate activity on eggs hatching in seventh day were 77.7 % and 77.7 % respectively. Effectiveness of hexythiazox and bifenthrin on larvae in the seventh day was very toxic and no significant differences were found between hexythiazox and bifenthrin ($P< 0.05$), but there was significant difference with dimethoate (Table 7). Therefore the toxicity of dimethoate was found less than the other tested pesticides to *T. urticae* eggs and larvae. Hatching ratio for *A. californicus*'s eggs showed no difference between the control and tested pesticides after three days of treatment. The hatching ratio in all treatments was 100 %. Thus, there was no effect of pesticides on eggs hatching comparative with control. But larvae mortality against pesticides indicated that there was significant difference between the control and tested

Table 7: Mean (± s.e) values for hatching ratio (percentage hatching) and percent mortality to larvae stage of *T. urticae* against pesticides

	5 days after treatment		7 days after treatment	
	Hatching	Larvae mortality	Hatching	Larvae mortality
Dimethoate	60.0 (±0.58) c	44.4 (±0.80) c	77.7 (±1.45) a	74.0 (±2.10) b
Bifenthrin	68.8 (±1.30) b	83.3 (±2.25) a	77.7 (±1.76) a	97.2 (±1.47) a
Hexythaizox	11.1 (±0.49) d	60.0 (±0.58) b	11.1 (±0.49) b	100.0 (±0.0) a
Control (water)	100.0 (±0.0) a	3.3 (±1.76) d	0.0 (±0.0) c	0.0 (±0.0) c
Statistics (LSD 0.05)	2.45	4.93	3.81	4.15

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

Table 8: Mean (± s.e) values for hatching ratio and percent mortality to larvae stage of *A. californicus* against pesticides and toxicity category

	3 days		5 days	7 days	
	Hhatching	Larvae mortality	Larvae mortality	Larvae mortality	
Dimethoate	100.00	60.0 (±2.08) a	66.6 (±2.02) a	86.6 (±2.40) a	M (2)-T (3)
Bifenthrin	100.00	50.0 (±1.73) b	50.0 (±2.88) b	78.5 (±1.0) b	M (2)
Hexythaizox	100.00	40.0 (±2.88) c	44.0 (±2.42) c	48.0 (±2.64) c	M (2)
Control	100.00	0.0 (±0.0) d	0.0 (±0.0) d	0.0 (±0.0) d	
Statistics (LSD 0.05)		6.45	6.98	6.05	

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

Table 9: Mean (± s.e) values for hatching ratio and percent mortality to larvae stage of *P. persimilis* against pesticides and toxicity category

	3 days		5 days		7 days	
	Hatching	Larvae mortality	Hatching	Larvae mortality	Larvae mortality	
Dimethoate	86.5 (±4.06) b	57.7 (±2.72) b	100	70.8 (±3.31) b	86.6 (±2.40)b	T (3)
Bifenthrin	92.6 (±2.40)ab	75.9 (±2.52) a	100	87.0 (±4.04) a	96.2 (±1.94)a	T (3)
Hexythaizox	95.0 (±3.21) a	37.2 (±1.47) c	100	49.0 (±3.12) c	68.0 (±3.78)c	M (2)
Control	100.0 (±0.0)a	3.3 (±1.76) d	-	0.0 c	0.0 c	
Statistics (LSD 0.05)	9.31	7.12		10.0	7.96	

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

Table 10: Mean (± s.e) values for percent mortality of *T. urticae* nymphs against tested pesticides

	Nymph mortality		
	1 day	3 days	5 days
Dimethoate	20.5 (±0.86) b	36.0 (±2.30) c	43.5 (±3.31) c
Bifenthrin	95.5 (±1.76) a	100.0 (±0.0) a	100.0 (±0.0) a
Hexythaizox	20.0 (±1.15) b	48.9 (±2.88) b	64.4 (±2.02) b
Control (water)	2.3 (±0.33) c	0.0 (±0.0) d	0.0 (±0.0) d
Statistics (LSD 0.05)	3.75	6.03	6.34

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

pesticides and also there was significant difference within pesticides during 7 days after application. Toxicity of hexythiazox was less than the other tested pesticides on larval stage of *A. californicus*. According to IOBC category, toxicity of dimethoate was moderately harmful in third and fifth day but harmful in seventh day of treatment while hexythiazox and bifenthrin were found moderately harmful effect (Table 8). Hatching ratio of *P. persimilis*'s eggs, indicated significant differences ($P < 0.05$) between control, hexythaizox and bifenthrin with dimethoate in third day after treatment. Hatching ratio in fifth day after application was completed (100 %). Effect

Table 11: Mean (± s.e) values for percent mortality of *A. californicus* nymphs against tested pesticides and toxicity category

	Nymph mortality			
	1 day	3 days	5 days	
Dimethoate	100.0 (±0.0) a	100.0 (±0.0) a	100.0 (±0.0) a	T (4)
Bifenthrin	58.3 (±2.96) b	63.8 (±2.17) b	76.6 (±3.51) b	M (2)
Hexythaizox	35.0 (±1.52) c	48.8 (±2.88) c	63.3 (±2.33) c	M (2)
Control (water)	3.3 (±1.76) d	0.0 (±0.0) d	0.0 (±0.0) d	
Statistics (LSD 0.05)	6.14	5.9	6.87	

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

Table 12: Mean (± s.e) values for percent mortality of *P. persimilis* nymphs against used pesticides and toxicity category

	Nymph mortality			
	1 day	3 days	5 days	
Dimethoate	76.0 (±3.78) b	95.3 (±1.45) b	95.3 (±1.45) b	M (2)-T (3)
Bifenthrin	100.0 (±0.0) a	100.0 (±0.0) a	100.0 (±0.0) a	T (4)
Hexythaizox	57.0 (±4.72) c	90.2 (±1.56) c	95.3 (±1.33) b	M (2)-T (3)
Control (water)	3.3 (±1.76) d	0.0 (±0.0) d	0.0 (±0.0) c	
Statistics (LSD 0.05)	10.28	3.47	3.21	

Means with different letters were significant different (P = 0.05. Tukey-Kramer Test)

of pesticides on larval stage within seven days after treatment had indicated important significant difference with the control. Dimethoate and bifenthrin indicated important significant difference with hexythaizox. Therefore, pesticides had no influence on hatching ratio only hatching period fairly was extended. Toxicity of hexythaizox on *P. persimilis* larvae was less than the toxicity of dimethoate and bifenthrin. According to IOBC category, bifenthrin and dimethoate were harmful and hexythiazox was moderately harmful (Table 9).

Nymphicidal test: Mortality of *T. urticae* nymphs indicated that there was a significant difference ($P < 0.05$) between the control and tested pesticides during five days; and also significant differences within tested pesticides (Table 10). Activity of bifenthrin was very strong against nymphs of *T. urticae* as compared to hexythaizox while activity of dimethoate was weak and less than that of hexythaizox. Mortality of *A. californicus* nymphs indicated that there were significant differences between the control and tested pesticides during five days. Activity of dimethoate was very effective against *A. californicus* nymphs after that bifenthrin, hexythaizox in sequence. According to IOBC category, dimethoate toxicity was harmful while bifenthrin and hexythiazox were moderately harmful to *A. californicus* nymphs (Table 11).

Mortality of *P. persimilis* nymphs indicated that there was an important significant difference between the control and tested pesticides during five days. There were important significant differences between tested pesticides in first and third day after treatment while the activity of bifenthrin was very strong against nymphs of *P. persimilis* as compare to dimethoate and hexythiazox. According to IOBC category, toxicity of pesticides was harmful particulary, on the fifth day after treatment, with hexythaizox and dimethoate being moderately harmful on the first day (Table 12).

DISCUSSION

There are many different ways to test the effect of a pesticide or other compounds on predatory mites, beginning with a slide-dip study and progressing in complexity to a field-scale study [21, 22]. A Leaf-Spray method has been used in bioassay tests to evaluate the effect of pesticides on *T. urticae* and predatory mite populations. The IOBC toxicity category was used to evaluate the toxicity of pesticides on predatory mites at different stages [20]. Dimethoate was harmful to adult predatory mites according to LC values. The Toxicity of dimethoate to TSSM adults according to the LC 50 value was less than bifenthrin but more than hexythiazox. Bostanian and Akalach [23] reported that the contact toxicity of dimethoate, abamectin and insecticidal soap to *Amblyseius fallacis* (Garman), *Phytoseiulus persimilis* Athias-Henriot and nymphs of *Orius insidiosus* (Say) was very toxic to all three beneficial adults; indoxacarb should be evaluated as a pest control product in

IPM programmes. The toxicity of dimethoate at 150 ppm in other bioassay tests (Ovicidal/Ovolarvicidal, Nymphicidal) showed moderately harmful/harmful effects on the different predatory mite stages with *A. californicus* being more tolerant than *P. persimilis*; and the toxicity of dimethoate on immature TSSM stages was weak. Wilson *et al.* [24] reported that dimethoate had very low acaricidal activity on TSSM. The effect of bifenthrin against predatory mite adults was harmful and it was very toxic to TSSM adults. At 20 ppm in other bioassay tests, bifenthrin was harmful to *P. Persimilis,* moderately harmful to *A. californicus*; and very toxic to immature TSSM stages. Kenneth *et al.* [25] reported the effects of acaricide residues on *P. persimilis* and *T. urticae* using a leaf disk system. Bifenthrin residue was toxic to *P. persimilis* at all times after application, but was only toxic to *T. urticae* up to one week after application. Hexythiazox was harmless/moderately harmful after 24 h and 72 h respectively to predatory mite adults according to LC values; at 17 ppm in other bioassay tests, hexythiazox was moderately harmful to predatory mite stages and very toxic on TSSM eggs and larvae. Kenneth *et al.* [24] found that abamectin, Gowan 1725, hexythiazox, horticultural oil, neem oil, pyridaben and spionosyn residues caused no mortality to *P. persimilis* 1, 3, 7, or 14 days after application and that *T. urticae* mortality from hexythiazox and spinosad residues was not significantly greater than the control; and bifenthrin and chlorfenapyr residues were toxic to *P. persimilis.* Blümel [26] reported that the side-effects of the acaricide hexythiazox, the fungicide triadimefon and the insecticide heptenophos on the predatory mite *P. persimilis.* The pesticides were either applied separately at a range of concentrations or combined and applied to detached bean leaves using a Potter Tower; no significant differences in the mean mortality rate of the phytoseiid or in the mean reproduction per female was found between the different treatments. Total effect values ranged from 5.4 to 38.7% after separate application of the test products and from 8.9 to 25.5 % after treatment with the various pesticide mixtures. Therefore we conclude that hexythiazox is suitable for use in mite management programs for spider mites and that *A. californicus* is more tolerant to the tested pesticides than *P. persimilis.*

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