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Selective Toxicity of Three Acaricides to the Two-Spotted Spider Mite *Tetranychus urticae* and Predatory Mite *Phytoseuilus persimilis* in Apple Orchards

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ABSTRACT

In Egypt, phytophagous mites are serious pests on crops, vegetables and fruits and frequently cause considerable losses in plant yields. Some commercial acaricides with a degree of selective toxicity towards two-spotted spider mite are *Tetranychus urticae* Koch (Acari: Tetranychidae), but its selective toxicity towards *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) is under debate. In this study, the field experiments were conducted to evaluate the selectivity of three acaricides on motiles of both two-spotted spider mite and its predator *P. persimilis* after 3, 7, 14, 21 and 30 days of treatment. Acaricides were sprayed at 1 and 1/2 field recommended rate on apple orchards; flufenoxuron (60.00 and 30.00 mg a.i., L^{-1}), fenpyroximate (25.00 and 12.50 mg a.i. L^{-1}) and abamectin (7.50 and 3.75 mg a.i., L^{-1}). All tested acaricides affected the two mite's survival; the *T. urticae* was more susceptible to flufenoxuron application than the *P. persimilis*. Results showed that half of the recommended rate of flufenoxuron showed slightly toxic effect on *P. persimilis* after 30 d. Flufenoxuron exhibited moderate toxic to the predatory mite at the two field rates after 14 days and was favorably selective (more toxic to *T. urticae* than to *P. persimilis*) at all tested periods. In contrast, fenpyroximate and abamectin were found to be very toxic to the predatory mite at recommended field rate after 30 days and unfavorably selective (more toxic to *P. persimilis*). In conclusion, fenpyroximate and abamectin should be used carefully in Integrated Pest Management programs.

Key words: Selective toxicity, acaricides, flufenoxuron, fenpyroximate, abamectin, side effect, *Phytoseuilus persimilis*, *Tetranychus urticae*, apple trees

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* is one of the most serious pests in some of agricultural systems (Deligeorgidis *et al*., 2006, 2007). Fruit clusters may also be attacked, resulting in dark spots on the skin and damage has been reported (Prischmann *et al*., 2002; Sivritepe *et al*., 2009). It ingest leaf cell contents, thus reducing plant photosynthesis (Park and Lee, 2002) and potentially decreasing fruit quality and yield (Flaherty and Wilson, 1999).

Phytoseiulus persimilis is well known as a predatory mite that specializes on the *Tetranychid* 0species and it may considered as one of tools in the integrated pest management program for controlling spider mite *T. urticae* in many countries throughout the world (Cote *et al.*, 2002; Kim and Yoo, 2002). In other words, obligatory predators (specialists) such as *Phytoseiulus persimilis* Athias-Henriot and *Galendromus helveolus* (Chant) living only on spider mites of the family Tetranychidae (Al-Shammery, 2010; Fouly *et al.*, 2011). Fathi and Nouri-Ganbalani (2009) mentioned that the use of indigenous species of the predators is preferred than the imported species. Predator-prey interactions in apple orchards may be affected by chemical control to other pests and thus knowledge of acaricide side-effects is essential when managing spider mite populations. However, some predatory mite species tend to disappear from the field after reducing pest mites by providing only short-term control (Walzer *et al.*, 1999). After threshold levels of *T. urticae* are surpassed, release of predators combined with compatible acaricide is more effective than using chemical or biological control tactics alone (Trumble and Morse, 1993). It is important to know if acaricides have adverse undesirable effects on the predatory mites (Nadimi *et al.*, 2008). Combining tactics involving reduced-risk pesticides and selective releases of predatory mites may yield more acceptable control of the two-spotted spider mite while maintaining predatory mite populations in the field (Rhodes *et al.*, 2006). Although pesticide usage was often reduced in orchards managed with this simplified programme, a management programme specifically incorporating biological and selective pesticide control of apple pests was desired (Agnello *et al.*, 2003). Several acaricides including flufenoxuron, fenpyroximate and abamectin are currently used in Egypt, however, the side effects of the acaricides to key spider mite predator including *P. persimilis* are unidentified. Chemicals in either class could impact spider mite densities directly through spider mite mortality, and indirectly by negatively affecting natural enemies (Prischmann *et al.*, 2005). In many cases, the combined use of chemical and biological control might provide the best approach for both managing pest populations and minimizing selection for resistance (Gentz *et al.*, 2010). The Integrated Pest Management (IPM) which is based on selective toxicity of the phytophagous mites and harmless to predatory mite, became the most relevant strategy of plant protection (Leake, 2000; Linquist, 2000; Klassen, 2000).

The aim of present study was to clarify the selective toxicity of some acaricides on two-spotted spider mite *T. urticae* and its predatory mite *P. persimilis* on apple trees.

MATERIALS AND METHODS

Chemicals: Acaricides were selected and concentrations were used based on recommendation of the Egyptian Ministry of Agriculture. The acaricides tested, their trade names, formulations and one and 1/2 field recommended concentrations applied are as follows:

1) Mite growth regulators: flufenoxuron (Cascade®, EC 10%) at the rates of 60.00 and 30.00 mg a.i. L^{-1}; 2) Pyrazole acaricides: fenpyroximate (Ortus®, SC 5%) at the rates of 25.00 and 12.50 mg a.i. L^{-1}; 3) Macrocyclic lactone: abamectin (Vertimec®, EC 1.8%) at the rates of 7.50 and 3.75 mg a.i. L^{-1}. To minimize drift, pesticides were applied on apple trees with a backpack sprayer in the morning.

Field experiments and mite sampling: The field trials were carried out in the apple tree orchard in Egypt (Menoufiya, latitude 30° 33'28" N, longitude 31° 00' 58" E) in 2009. The apple trees (variety 'Anaa 106/111') were planted in 1999. Replications are four plots (six trees were sprayed and 4 trees assessed for each plot) per treatment were made in a randomized block design. Starting three days after spraying, thirty leaves per plot were randomly collected from the interior trees of sprayed plots, and taken to the laboratory, where the number of *T. urticae* and *P. persimilis* predator motiles were counted under a stereomicroscope (magnification 10x) for evaluation the efficiency of tested acaricides.

The numbers of living mites were counted and the first assessment was made 24 h before application. Predator and prey were recorded 1 d before treatment and 3, 7, 14, 21 and 30 days after treatment. Reduction in mites population was calculated: $X = 100 (1 - Ab/Ba)$ (X = reduction %, A = number of mites before spraying in untreated plot, B = before spraying in treated plot, a = after spraying in untreated plot, b = after spraying in treated plot) as explained by Raudonis *et al*. (2009).

Categories for suppression to those employed by the International Organization for Biological Control (IOBC) for assessment of pesticide toxicity to predatory and phytophagous mites in field trials, as follow: non-toxic (<25% mortality), slightly toxic (25-50%), moderately toxic (51-75%), very toxic (>75%) (Hassan *et al*., 1987). Selectivity of miticides was mostly based on suppression of *T. urticae*, compared with suppression of *P. persimilis*.

Statistical analysis: Conventional statistical methods were used to calculate means the number of *T. urticae* or *P. persimilis* among treatments was compared with a single factor Analysis of Variance (ANOVA). Specific differences were identified with Duncan's multiple range test to determine differences ($p<0.05$) by CoStat (2006), Berkeley, CA, USA.

RESULTS

The three tested acaricides reduced the mean number of both mite species. Significant differences between the mean numbers of two-spotted spider mite, *T. urticae* after application of three acaricides by two field rats and in untreated trees were recorded after 3 to 30 days (Table 1). Only fenpyroximate showed slightly toxic effect (mean number of *T. urticae* was 20) after 7 days of treatment by field rate. In contrast, abamectin gave long time to control *T. urticae* mite till 30 days after application by two field rats. The three acaricides by the recommended field rate still active till 30 days. However, the recommended field rate is more effective than half field rate after 30 days. Also, significant differences between the mean numbers of *P. persimilis* after application of three acaricides by two field rats and in untreated trees were recorded (Table 2). Abamectin gave long time residual side effect against predatory mite *P. persimilis* after 30 days by field rate. In contrast, two field rates of flufenoxuron were slight toxic to *P. persimilis* after 3 to 30 days in comparison with other two acaricides.

Table 1: Average numbers of two-spotted spider mite *T. urticae* motiles per 30 leaves after application three acaricides at 1 and 1/2 field recommended concentrations on apple orchards

		Mean number of *T. urticae* after application per 30 leafs (days)					
Treatment	Recommended conc.	1	3	7	14	21	30
Abamectin	1	183^{a}	3^{a}	5^{a}	12^{a}	28^{a}	39^{a}
	1/2	195^{ab}	2^{a}	5^{a}	30^{b}	69^{ab}	102^{b}
Fenpyroximate	1	213^{b}	5^{a}	20^{b}	28^{b}	51^{a}	57^{a}
	1/2	162^{a}	4^{a}	9^{a}	39^{bc}	90^{b}	90^{b}
Flufenoxuron	1	186^{a}	6^{a}	7^{a}	26^{b}	41^{a}	72^{a}
	1/2	171^{a}	7^{a}	8^{a}	41^{c}	82^{b}	90^{b}
Untreated	0	189^{ab}	222^{b}	258^{c}	306^{d}	327^{c}	228^{c}

Values followed by the same letter within each vertical column are not significantly different (p = 0.05) according to Duncan's multiple range test

Table 2: Average numbers of predatory mite *P. persimilis* motiles per 30 leaves after application some acaricides at 1 and 1/2 field recommended concentrations on apple orchards

		Mean number of *P. persimilis* after application per 30 leafs (days)					
Treatment	Recommended conc.	1[#]	3	7	14	21	30
Abamectin	1	14[a]	1[a]	1[a]	2[a]	5[a]	7[a]
	1/2	13[a]	1[a]	1[a]	2[a]	8[b]	11[b]
Fenpyroximate	1	14[a]	1[a]	1[a]	3[a]	7[ab]	10[b]
	1/2	15[a]	1[a]	2[a]	5[ab]	9[b]	16[bc]
Flufenoxuron	1	12[a]	3[b]	4[b]	9[b]	13[bc]	19[c]
	1/2	13[a]	3[b]	6[b]	11[b]	17[c]	26[c]
Untre[a]ted	0	15[a]	21[c]	29[c]	39[c]	44[d]	53[d]

Values followed by the same letter within each vertical column are not significantly different (p = 0.05) according to Duncan's multiple range test

Table 3: Mortality and toxicity ratings of some acaricides applied at 1 and 1/2 field recommended concentrations to two-spotted spider mite *T. urticae* and the predatory mite *P. persimilis* in apple orchards

			% Mortality of mites after application [a] (days)				
Treatment	Recommended conc.	Mite sp.	3	7	14	21	30
Abamectin	1	*T. urticae*	98.60[e]	98.44[e]	95.95[e]	89.58[e]	82.33[e]
		P. p[e]rsimilis	95.44[e]	96.71[e]	94.27[e]	87.70[e]	86.18[e]
	1/2	*T. urticae*	99.08[e]	98.53[e]	90.50[e]	79.55[e]	56.65[d]
		P. p[e]rsimilis	95.02[e]	96.40[e]	93.74[e]	78.64[e]	75.69[e]
F[e]npyroximate	1	*T. urticae*	97.96[e]	93.09[e]	91.91[e]	86.16[e]	77.82[e]
		P. p[e]rsimilis	95.44[e]	96.71[e]	91.82[e]	83.36[e]	80.17[e]
	1/2	*T. urticae*	97.95[e]	95.93[e]	85.32[e]	67.89d	53.94[d]
		P. p[e]rsimilis	95.71[e]	92.78[e]	86.92[e]	79.59[e]	70.06[d]
Fluf[e]noxuron	1	*T. urticae*	97.25[e]	97.28[e]	91.33[e]	87.23[e]	67.91[d]
		P. p[e]rsimilis	82.14[e]	83.25[e]	71.15[d]	63.44d	55.51[d]
	1/2	*T. urticae*	96.56[e]	96.53[e]	85.15[e]	72.32d	56.37[d]
		P. p[e]rsimilis	83.39[e]	76.02[e]	66.91[d]	54.91d	42.85[ca]

[a]Values followed by the same letter within are not significantly different according to toxicity ratings: [b] Non-toxic (< 25% mortality), [c]Slightly toxic (25-50%), [d] moderately toxic (51-75%), [e]very toxic (> 75%)

Acaricides were then categorized into classes similar to those employed by the IOBC to rate pesticide toxicity to natural enemies of insect and mite pests (Table 3). Abamectin provides long residual control of two-spotted spider mite *T. urticae* on apple trees after 21 days by 1/2 field recommended conc. According to IOBC classification, two field rates of abamectin were very toxic (>75% mortality) to *P. persimilis* after 30 days. At half field rate, fenpyroximate showed moderate toxic (70.06% mortality) and flufenoxuron was slightly toxic acaricide (42.85% mortality) to predator mite *P. persimilis* after 30 days of application.

The two-spotted spider mite, *T. urticae* was more susceptible than the predator mite *P. persimilis* to flufenoxuron application on apple trees. Flufenoxuron was exhibit moderate toxic to the predatory mite at the two field rates after 14 days (66.91-71.15% mortality) and favourably selective (more toxic to *T. urticae* than to *P. persimilis*) from 14 to 21 days after treatment by field recommended conc. All three acaricides at two field rats on *P. persimilis* were very toxic (76.02 to 96.71% mortality) after 7 days. However, mortality was highest after exposure to abamectin and fenpyroximate at two field rats (78.64-87.70% mortality) after 21 days to the predatory mite *P. persimilis* and unfavourably selective (more toxic to *P. persimilis* than to *T. urticae*). Among the three acaricides evaluated, only flufenoxuron was slightly toxic to *P. persimilis* with half field rate after 30 days.

DISCUSSION

Numerous field studies demonstrated that adequate control can be achieved with correct combination of acaricides and this predatory mite *P. persimilis* (Osborne and Petitt, 1985; Cashion *et al.*, 1994). The level of compatibility will usually depend on the post application interval (Cote *et al.*, 2002). In study higher toxicity of flufenoxuron was achieved 7 days after treatment than 3 days after treatment with field rate. It can be explained that flufenoxuron does not kill directly and two mites remain alive. Only few days later mites become inactive and cannot molt successfully and in consequence it dies. Fenpyroximate and abamectin at the field and half field rates were very toxic to *P. persimilis* after 14 and 21 days. The use of these two compounds in the field would probably result in severe reduction of *P. persimilis*. Thus they are incompatible in IPM programs to control two-spotted spider mite. The results are consistent with results reported for fenpyroximate and abamectin by Blumel and Hausdorf (2002). Even at half of the field rate, abamectin was very toxic to *P. persimilis* after 30 days. Based on present observations these effects could be caused by residual toxicity of these two acaricides on survival of the predator mite. Although various phytoseiidae species have responded differently to abamectin, a reduction in reproduction is common to all (Zhang and Sanderson, 1990). Application of abamectin was highly toxic to predatory mite, *Amblyseius cucumeris* adult females causing 92% mortality at 7 days after treatment (Kim *et al.*, 2005). It would be an appropriate substitute to fenpyroximate and abamectin in IPM programs. For example, investigation of different concentrations of pesticides (especially lower rates) should be evaluated. The relative toxicity of pesticides to pests, predators and immature stages of the predators should provide an adequate indication for selectivity of pesticides, which is essential for development of pest management programs (Jeppson *et al.*, 1975). Abamectin gave season-long control of the European red mite *Panonychus ulmi* in apple orchards in South Africa (Botha *et al.*, 1993).

CONCLUSION

Flufenoxuron may be incorporated in IPM programs based on *P. persimilis* without any additional studies. The other two acaricides, fenpyroximate and abamectin were very toxic: mortality of *P. persimilis* ranged from 78.64 to 87.70% after three weeks of treatment. Flufenoxuron was moderately toxic by two rates (mortality of *P. persimilis* ranged from 71.15 to 66.91%) after two weeks of treatment and slightly toxic (mortality 42.85%) after thirty days of treatment by lower rate. Based on the results, flufenoxuron may be considered favorable selectivity acaricide. Therefore, the use of fenpyroximate and abamectin should be used carefully in IPM programs.

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