Agronomy Research **4**(Special issue), 317–322, 2006

Comparative toxicity of spirodiclofen and lambdacihalotrin to *Tetranychus urticae*, *Tarsonemus pallidus* and predatory mite *Amblyseius andersoni* in a strawberry site under field conditions

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Abstract. The relative toxicity of broad-spectrum acaricide spirodiclofen 240 g AI l^{-1} from a new class of active ingredients and synthetic pyrethroid insecticide–acaricide lambdacihalotrin 50 g AI l^{-1} to the seasonal abundance of *Tetranychus urticae* Koch (Acari: Tetranychidae), *Tarsonemus pallidus* Banks (Acari: Tarsonemidae) and predatory mite *Amblyseius andersoni* Chant (Acari: Phytoseiidae) was evaluated in strawberry sites under field conditions in 2003–2004. The field rate (96 g AI ha^{-1}) of spirodiclofen was very toxic (82.3–96.1% mortality) after 7 and 21 days after treatment to *T. urticae*. The mortality to *T. pallidus* ranged from 76.6-79.3% after 7 days, and from 59.0–74.9% after 21 days following treatment respectively. The rate (48 g AI ha^{-1}) of spirodiclofen was very toxic (78.8–87.8% mortality) after 7 days and moderately toxic (54.1–73.4% mortality) after 21 days following treatment to *T. urticae*. The lower rate of spirodiclofen was moderately toxic after 7 days and from non- to slightly toxic after 21 days following treatment to *T. pallidus*. The toxicity of lambdacihalotrin (25 g AI ha^{-1}) to *T. urticae* was similar to a lower rate of Spirodiclofen. Lambdacihalotrin was non-toxic to *T. pallidus*, but moderately toxic (51.4–62.5% mortality) after 7 and 21 days following treatment to *A. andersoni*. Both rates of spirodiclofen were non-toxic to predatory mites.

Key words: *Amblyseius andersoni*, lambdacihalotrin, spirodiclofen, strawberry, *Tarsonemus pallidus*, *Tetranychus urticae*, toxicity

INTRODUCTION

Tetranychus urticae Koch and *Tarsonemus pallidus* Banks are one of the key pests of horticultural plants, causing serious indirect damage to crops in many countries (Edland, 1994; Price et al., 2002; Raudonis, 2002; Bostanian et al., 2004). Outbreaks of phytophagous mites in horticultural plants have been induced mostly due to applications of broad-spectrum pesticides that kill predators, which would control these mites. The widely used synthetic pyrethroids are very effective against pest insects, but have not had any effect on mites. They also cause an increase in spider mite populations that induce severe damage to plants (Edland, 1994). On the other hand frequent acaricide applications against the increased phytophagous mite populations result in greater resistance (Devine et al, 2001; Elzen, & Hardee, 2003; Van Leeuwen et al., 2005). Experiments showed that the resistance to abamectin exists in spider mites after ten years of use, when compared to spider mites taken from strawberry plants two years earlier (Price et al., 2002).

No data has been reported on toxicity of acaricides and insecticides to phytophagous and predatory mites in strawberries. Only the variety resistant to the two-spotted spider mite was tested in strawberries in Lithuania (Uselis & Rašinskienė, 2001). The numbers of various acaricides were tested against two-spotted spider and predatory mites in different crops (Hassan et al, 1985; Edland, 1994; Sterk et al, 1999; Kim & Yoo, 2002; Choi et al, 2003; Hardman et al, 2003; Kavousi & Talebi, 2003; Marcic, 2003; Bostanian et al, 2004; Raudonis et al., 2004; Martínez-Villar et al, 2005). Meanwhile, spirodiclofen 240 g AI l^{-1} was recently produced by Bayer Crop Science, but there was not enough toxicity data on phytophagous and predatory mites in strawberry. (?)

Thus, experiments performed in 2003–2004 were designed to clarify how the new acaricide–insecticide spirodiclofen affects *T. urticae, T. pallidus* and predatory mite *Amblyseius andersoni* Chant in strawberry.

MATERIALS AND METHODS

The field trials were carried out in the open field of strawberries of the Lithuanian Institute of Horticulture in 2003–2004. Spirodiclofen 240 g AI l^{-1} (trade name Envidor 240 SC) at rates 96 and 48 g AI ha^{-1} and lambdacihalotrin 50 g AI l^{-1} (Karate 50 EC) at rate 25 g AI ha^{-} were treated with sprayer Hardi 4110-12 at a volume 1000 l ha^{-1}. Applications were made before flowering and after harvest on 5 May and 16 July in 2003 and 4 May and 20^{t} July in 2004, respectively. Each replicate consisted of 12 m^2, and the treatments were repeated four times at random plot distribution.

Tests on *A. andersoni* and phytophagous (*T. urticae*, *T. pallidus*) mite species were carried out in the field, according to the following standard characteristics (Hassan et al., 1985; EPPO, 1999): Assessments were made on 10 leaves for estimating the number of two-spotted spider mites per leaf, and on 10 plants for assessing the number of strawberry and predatory mites per plant in each plot, before, 7 and 21 days after application.

Predatory mites were identified according to keys of species (Chant & Hansell, 1971; Chant & Yoshida, 1987; Chant & McMurtry, 1994).

Mortality of mites was calculated: x= 100 (1–Ab/Ba) (x–mortality, %, A–number of mites, before spraying in untreated plot, B–number of mites, before spraying in treated plot, a–number of mites, after spraying in untreated plot, b–number of mites, after spraying in treated plot).

For quantitative toxicity categories we applied those employed by the International Organization for Biological Control for assessment of pesticide toxicity to predatory and phytophagous mites in field trials: non-toxic (< 25% mortality), slightly toxic (25–50%), moderately toxic (51–75%), very toxic (> 75%) (Hassan et al., 1985).

The number of two-spotted spider mites was compared among treatments in this study with a single factor analysis of variance (ANOVA). Specific differences were identified with Duncan's multiple range test.

RESULTS AND DISCUSSION

Tables 1 to 3 describe the effect of spirodiclofen 240 g AI $l^{-1}$and lambdacihalotrin 50 g AI l^{-1} on *T. urticae*, *T. pallidus* and *A. andersoni* in strawberries. Spirodiclofen at field rate 96 g AI ha^{-1}, applied before flowering in strawberries was very toxic to *T. urticae* after 7 and 21 days following treatment during both experimental years. The mortality ranged from 82.3 -96.1% (Table 1). It shows that spirodiclofen 96 g AI ha^{-1} has long term action against *T. urticae*. The lower rate (48 g AI ha^{-1}) of spirodiclofen was very toxic (78.8–87.8% mortality) after 7 days and moderately toxic (54.1–73.4% mortality) after 21 days following treatment of *T. urticae*. The toxicity of lambdacihalotrin (25 g AI ha^{-1}) to *T. urticae* was similar to lower rate of spirodiclofen. There were not found any statistical differences of the number of two-spotted spider mites among both rates of spirodiclofen and lambdacihalotrin after 7 days following-treatment before flowering. The lowest toxicity to *T. urticae* was recorded after 21 days, when lambdacihalotrin and the lower rate of spirodiclofen were applied. The toxic effects of pesticides on mites depends on the chemistry of pesticides, their rates, microclimatic conditions and development stages of the mites (Edland, 1994; Auger et al, 2003; Hardman et al, 2003; Bostanian et al, 2004; Martínez-Villar et al, 2005).

Table 1. Toxicity of spirodiclofen and lambdacihalotrin applied before flowering against two-spotted spider mite (*Tetranychus urticae*) in strawberry.

Treatment	Rate (g AI ha^{-1})	Mean number of mites per 100 leaves			Mortality (%)	
		before treat-ment ^{A}	7 days after treatment	21 days after treatment	7 days after treatment	21 days after treatment
2003 year						
Control	-	182ab	145b	117c	-	-
Spirodiclofen	96	162ab	7a	15a	94.6	85.6
Spirodiclofen	48	205b	20a	35ab	87.8	73.4
Lambdacihalotrin	25	187ab	15a	47b	89.9	60.9
2004 year						
Control	-	100b	77b	355c	-	-
Spirodiclofen	96	67ab	2a	42a	96.1	82.3
Spirodiclofen	48	92ab	15a	150bc	78.8	54.1
Lambdacihalotrin	25	85ab	16a	140bc	75.5	53.6

Table 2. Toxicity of spirodiclofen and lambdacihalotrin applied after harvest against strawberry mite (*Tarsonemus pallidus*) in strawberry.

Treatment	Rate (g AI ha^{-1})	Mean number of mites per 100 plants			Mortality (%)	
		before trea-tment ^{A}	7 days after treatment	21 days after treatment	7 days after treatment	21 days after treatment
2003 year						
Control	-	710c	650c	617c	-	-
Spirodiclofen	96	490a	105a	107a	76.6	74.9
Spirodiclofen	48	615b	250b	305b	55.6	42.9
Lambdacihalotrin	25	900d	865d	815d	0.0	0.0
2004 year						
Control	-	145b	140c	85c	-	-
Spirodiclofen	96	50a	10a	12a	79.3	59.0
Spirodiclofen	48	55a	22b	30b	58.6	6.9
Lambdacihalotrin	25	230c	225d	202d	0.0	0.0

Table 3. Toxicity of spirodiclofen and lambdacihalotrin applied after harvest to predatory mite *A. andersoni*.

Treatment	Rate (g AI ha^{-1})	Mean number of mites per 100 plants			Mortality (%)	
		before treatment [A]	7 days after treatment	21 days after treatment	7 days after treatment	21 days after treatment
2003 year						
Control	-	25a	25b	40b	-	-
Spirodiclofen	96	23a	20b	35b	13.0	4.9
Spirodiclofen	48	20a	25b	40b	0.0	0.0
Lambdacihalotrin	25	25a	10a	15a	60.0	62.5
2004 year						
Control	96	40abc	40a	75bc	-	-
Spirodiclofen	48	50abc	42a	77c	16.0	17.9
Spirodiclofen	25	60c	52a	97bc	13.3	13.8
Lambdacihalotrin	96	35a	17b	30a	51.4	54.3

[A] Means with the same letter in the column are not significantly different (P = 0.05), ANOVA test, n = 100

Spirodiclofen, 96 g AI ha^{-1} was very and moderately toxic to *T. pallidus* after 7 and 21 days following treatment. The mortality to *T. pallidus* ranged from 76.6 - 79.3% after 7 days and from 59.0–74.9% after 21 days following treatment respectively (Table 2). The lower rate of spirodiclofen was moderately toxic (55.6–58.6% mortality) to *T. pallidus* after 7 days and from non- to slightly toxic (6.9–42.9%) after 21 days following treatment. Statistically, the higher rate of spirodiclofen had more affect on strawberry mites in comparison with a lower dose of spirodiclofen. Lambdacihalotrin did not affect *T. pallidus*. Conversely, *T. pallidus* was statistically more abundant, when lambdacihalotrin was applied in comparison with control (Table 2). In 2003 and 2004, 815 and 202 strawberry mites per 100 plants were found, respectively, after 21 days following lambdacihalotrin treatment. The number of strawberry mites was higher after lambdacihalotrin treatment, probably because of less intense predation by *A. andersoni*, which had been at lower densities than in control plots. The control of phytophagous mites using predatory mites has been demonstrated in different crops (Roy et al., 1999; Prischmann et al., 2001; Osakabe, 2002; Waite, 2002). *Amblyseius cucumeris* Oudemans was introduced and provided satisfactory control of *P. pallidus* in strawberry (Petrova et al., 2002; Tuovinen, 2002). Table 3 shows that lambdacihalotrin was moderately toxic to predatory mites and statistically reduced the number of these predators in strawberries. The toxicity of lambdacihalotrin to predatory mites ranged from 51.4-62.5%.

Previous laboratory bioassays and field tests also found lambdacihalotrin to be harmful to predatory mites such as *Typhlodromus pyri* Scheuten, *A. andersoni* and *Phytoseiulus persimilis* Athias-Henriot (Sterk et al., 1999). Both tested rates of spirodiclofen should be rated as selective, because it had no toxic affect on *A. andersoni*. Data was not reported for effects of the spirodiclofen on *T. pallidus* and *A. andersoni* in the strawberry site. The toxic effect of spirodiclofen was observed on *T. urticae* in Canadian apple orchards. In contrast with this study, spirodiclofen was rated as toxic to another predatory mite, *Typhlodromus pyri* Chant (Hardman et al, 2003). However, it is possible that higher toxicity to the predatory mite was obtained because a higher rate of spirodiclofen was used. Other studies have found selective toxicity of the different rates of acaricides to the different species of predatory mites (James, 2003).

CONCLUSIONS

In conclusion, the field rate 96 g AI ha^{-1} of spirodiclofen was rated as very toxic to *T. urticae* and moderately to very toxic to *T. pallidus*. The rate (48 g AI ha^{-1}) of spirodiclofen was from moderately to very toxic to *T. urticae* and from non- to moderately toxic to *T. pallidus.* The highest toxicity is after 7 days; the lower level, after 21 days following acaricide treatment. The toxicity of lambdacihalotrin (25 g AI ha^{-1}) to *T. urticae* was similar to the lower rate of spirodiclofen. Lambdacihalotrin was non-toxic to *T. pallidus*, but moderately toxic to predatory mite *A. andersoni*. Both rates of spirodiclofen were non-toxic to *A. andersoni*. Based on the results, spirodiclofen appears to be the promising candidate for use in integrated mite management programs where predatory mites are the major natural enemy.

REFERENCES

Auger, P., Guichou, S. & Kreiter S. 2003. Variations in acaricidal effect of wettable sulfur on *Tetranychus urticae* (Acari: Tetranychidae): effect of temperature, humidity and life stage. *Pest Manag. Sci.* **59**(5), 559–565.

Bostanian, N. J., Vincent, C., Hareman, J. M. & Larocque, N. 2004. Toxicity of indoxacarb to two species of predacious mites and a predacious Mirid. *Pest Manag. Sci.* **60**(5), 483–486.

Chant, D. A. & Hansell, R. I. 1971. The genus *Amblyseius* (Acarina: Phytoseiidae) in Canada and Alaska. *Can. J. Zool.* **49**, 703–758.

Chant, D. A., & Yoshida, E. 1987. A world review of the *pyri* species group in the genus *Typhlodromus* Sheuten (Acari: Phytoseiidae). *Can. J. Zool.* **65**, 1770–1804.

Chant, D. A. & McMurtry, J. A. 1994. A review of the subfamilies *Phytoseiidae* and *Odrominae* (Acari: Phytoseiidae). *Intern. J. Acarol.* **20**, 223–311.

Choi, W., Lee, S. G., Park, H. M. & Ahn Y. J. 2003. Toxicity of Plant Essential Oils to *Tetranychus urticae* (Acari: Tetranychidae) and *Phytoseiulus persimilis* (Acari: Phytoseiidae). *J. Econ. Entomol.* **97**(2), 553–558.

Devine, G. J., Barber, M. & Denholm, J. 2001. Incidence and inheritance of resistance to METI-acaricides in European strains of the two-spotted spider mite (*Tetranychus urticae*) (Acari: Tetranychidae). *Pest Manag. Sci.* **57**(5), 443–448.

Edland, T. 1994. Side-effects of fungicide and insecticide sprays on phytoseiid mites in apple orchards. *Norweg J. Agric. Sci.* **17**, 195–204.

Elzen, G. W. & Hardee, D. D. 2003. United States Department of Agriculture-Agricultural Research Service research on managing insect resistance to insecticides. *Pest Manag. Sci.* **59**(6-7), 770–776.

EPPO Guidelines for the efficacy evaluation of plant protection products (Introduction, general & miscellaneous guidelines new & revised guidelines). Paris. 1999. 172 p.

James, D. G. 2003. Toxicity of imidacloprid to *Galendromus occidentalis, Neoseiulus fallacis* and *Amblyseius andersoni* (Acari: Phytoseiidae) from hops in Washington State, USA. *Exp. Appl. Acarol.* **31**, 275–281.

Hardman, J. M., Franklin, J. L., Moreau, D. L. & Bostanian N. J. 2003. An index for selective toxicity of miticides to phytophagous mites and their predators based on orchard trials. *Pest Manag. Sci*. **59**, 1324–1332.

Hassan, E., Oomen, P. A., Overmeer, W. P. J., Plevoets, P., Reboulet, J. N., Rieckmann, W., Samsoe-Petersen, L., Shires, S. W., Staubli, A., Stevensen, J., Tuset, J. J., Vanwetswinkel, G. & Zon, A. Q. 1985. Standart methods to the test of side-effects of pesticides on natural enemies of insects and mites developed by the IOBC/WPRS. *Bull OEPP/EPPO*. **15**, 214–255.

Kavousi, A. & Talebi, K. 2003. Side-effects of three pesticides on the predatory mite, *Phytoseiulus persimilis* (Acari: Mar. S. & Yoo, S. S. 2002. Comparative toxicity of some acaricides to the predatory mite, *Phytoseiulus persimilis* and the twospotted spider mite, *Tetranychus urticae*. *BioControl*. **47**(5), 563–573.

Marcic, D. 2003. The Effects of Clofentezine on Life-table Parameters in Two-spotted Spider Mite *Tetranychus urticae*. *Exp Appl Acarol*. **30**(4), 249–263.

Martínez-Villar, E., Sáenz-De-Cabezón, F. J., Moreno-Grijalba, F., Marco, V. & Pérez-Moreno, I. 2005. Effects of azadirachtin on the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). *Exp. App.l Acarol*. **35**(3), 215–222.

Osakabe, Mh. 2002. Which predatory mite can control both a dominant mite pest, *Tetranychus urticae*, and a latent mite pest, *Eotetranychus asiaticus*, on strawberry? *Exp.Appl.Acarol*. **26**(3–4), 219–230.

Petrova, V., Cudare, Zz. & Steinite I. 2002. The efficiency of the predatory mite *amblyseius cucumeris* (acari: phytoseiidae) as a control agent of the strawberry mite *phytonemus pallidus* (Acari: Tarsonemidae) on field strawberry. *Acta Hort*. **567**(2), 675–678.

Price, J. F., Legard, D. E. & Chandler, C. K. 2002. Two spotted spider mite resistance to abamectin miticide on strawberry and strategies for resistance management. *Acta Hort*. **567**(2), 683-686.

Prischmann, D. A., Croft, B. A. & Luh, H. K. 2001. Biological PriControl of Spider Mites on Grape by Phytoseiid Mites (Acari: Tetranychidae, Phytoseiidae): Emphasis on Regional Aspects. *J Econ Entomol*. **95**(2), 340–347.

Raudonis, L. 2002. Monitoring of harmful insects and mites of strawberries. *Hort Veg. Grow*. **21**(4), 102–110.

Raudonis, L., Survilienė, E. & Valiuškaitė, A. 2004. Toxicity of Pesticides to Predatory Mites and Insects in Apple-tree site under field conditions. *Environ. Toxicol.* **19**(4), 291–295.

Roy, M., Broduer, J. & Cloutier, C. 1999. Seasonal Abundance of Spider Mites and Their Predators on Red Raspberry in Quebec, Canada. *Environ Entomol*. **28**(4), 735–747.

Sterk, G, Hassan, SA, Baillod, M, Bakker, F, Bigler, F, Blumel, S, Bogenschutz, H, Boller, E, Bromand, B, Brun, J, Calis, J. N. M, Coremans-Pelseneer, J, Duso, C, Garrido, A, Grove, A, Heimbach, U, Hokkanen, H, Jacas, J, Lewis, G, Moreth, L, Polgar, L, Roversti, L, Samsoe Petersen, L, Sauphanor, B, Schaub, L, Staubli, A, Tuset, J. J., Vainio, A, Van de Veire, M, Viggiani, G, Vinuela, E. & Vogt H. 1999. Results of the seventh joint testing programme carried out by the IOBC/WPRS – Working Group "Pesticides and Beneficial Organisms". *BioControl*. **44**, 99–117.

Tuovinen, T. 2002. Biological control of strawberry mite: a case study. *Acta Hort*. **567**(2), 671–674.

Uselis, N. & Rašinskienė, A. 2001. Assessment of biological and economic properties of strawberry varieties. *Hort. Veg. Grow*. **20**(2), 18–31.

Van Leeuwen, T., Van Pottelberge, S. & Tirry L. 2005. Comparative acaricide susceptibility and detoxifying enzyme activities in field-collected resistant and susceptible strains of *Tetranychus urticae. Pest Manag. Sci*. **61**(5), 499–507.

Waite, G. K. 2002. Advances in the management of spider mites in field-grown strawberries in Australia. *Acta Hort*. **567**(2), 679–682.