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Side-effects of a number of insecticides on predatory mites in apple orchards

Valeria Malagnini [a], Mario Baldessari [b], Carlo Duso [c], Alberto Pozzebon [c], Gino Angeli [a]

[a] Dipartimento Innovazione nelle Produzioni Vegetali, Centro Trasferimento Tecnologico, Fondazione Edmund Mach, San Michele all'Adige, Trento, Italy.

[b] Dipartimento Alimenti e Trasformazione, Centro Trasferimento Tecnologico, Fondazione Edmund Mach, San Michele all'Adige, Trento, Italy.

[c] Department of Agronomy, Food, Natural Resources, Animals and Environment, University of Padova, Legnaro, Padova, Italy.

ABSTRACT

Background: *Amblyseius andersoni* is a common predatory mite occurring in fruit orchards located in Europe and North America. Its role in preventing spider mite outbreaks is widely recognized, in particular when selective pesticides are used. The compatibility between plant protection products and predatory mites is crucial to preserve their activity. There is a need to investigate the effects of pesticides on beneficials using multiple approaches. **Objectives**: Field and laboratory experiments were conducted to evaluate the effects of a number of insecticides on *A. andersoni*. **Methods**: The effects of neonicotinoids (i.e., acetamiprid, imidacloprid, thiacloprid, thia-methoxam) were compared with those of pyrethroids (i.e., tau-fluvalinate), well known for their negative impact on predatory mites. Insecticides were applied 1-3 times in an experimental fruit orchard located in Northern Italy. Laboratory trials focused on their effects on the survival and the fecundity of predatory mite females. **Results**: Field experiments showed a decline in predatory mite numbers in plots treated with neonicotinoids or tau-fluvalinate compared to the untreated control. However, predatory mites in neonicotinoid plots reached higher densities compared to those recorded in tau-fluvalinate plots. Spider mite (*Panonychus ulmi*) populations reached moderate to high densities in plots treated with tau-fluvalinate while their densities were negligible in the remaining plots. *Amblyseius andersoni* survival was moderately affected by some neonicotinoids in the laboratory while they significantly reduced predatory mite fecundity. In contrast tau-fluvalinate exerted severe effects on survival and fecundity of predatory mites. Finally, escaping rate increased after pesticide exposure suggesting possible alterations in predatory mite behavior. **Conclusions**: Neonicotinoid applications significantly affected predatory mite densities in field conditions and this phenomenon appeared to be influenced by their impact on female fecundity. Their effects on survival were less severe. Implications of these results for IPM tactics in fruit orchards are discussed.

Introduction

Despite progress in reducing pesticide use in fruit growing areas of Europe and North America, insecticides are still requested to control aphids, scales and stink bugs (Ioriatti *et al.* 2019; Beers *et al.* 2019). Insecticide side-effects on beneficials can promote outbreaks of secondary pests since of their impact on natural antagonists. Infestations of phytophagous mites in fruit orchards

are a clear example of this syndrome: mite pests are commonly controlled by predators, mainly by phytoseiid mites (Acari, Phytoseiidae) where pesticide use is minimal or selective pesticides are used (Blommers 1994; Croft 1994; Beers *et al.* 2016a, b; Schmidt-Jeffris *et al.* 2019). A number of predatory mite species have been considered non-target organisms in trials aimed at evaluating the effects of pesticides on beneficials and various approaches have been adopted in this field of research (Bergeron and Schmidt-Jeffris 2020; Schmidt-Jeffris *et al.* 2021). The need to conduct field and laboratory trials has been stressed since longtime (e.g., Sterk *et al.* 1999; Bostanian *et al.* 2009). The variety of pesticide side-effects, from lethal to sublethal as well from direct to indirect, on beneficials has suggested new experimental models (e.g., Desneux *et al.* 2007; Stavrinides and Mills 2009; Duso *et al.* 2020). In addition, it has been recognized that the compatibility of pesticides with conservation biological control tactics based on predatory mites should be developed at a local level (Bostanian *et al.* 2010; Lefebvre *et al.* 2011, 2012; Pozzebon *et al.* 2014).

In the last two decades, reduced risk-insecticides (e.g., neonicotinoids) have been presented as an alternative to broad-spectrum insecticides but their side-effects on beneficials have been matter of discussion (e.g., Calvo-Agudo *et al.* 2019; Furlan *et al.* 2021). In this framework the side-effects of neonicotinoids on predatory mites represent an interesting case-study (e.g., Bostanian *et al.* 2009, 2010; Zanuzo Zanardi *et al.* 2017). The side-effects of four neonicotinoids on the predatory mite *Amblyseius andersoni* (Chant) have been investigated in field and laboratory conditions. *Amblyseius andersoni* is a common predatory mite occurring in fruit orchards in Europe and North America (Ivancich Gambaro 1975; Genini *et al.* 1991; Messing and Croft 1991; Blommers 1994; Szabó *et al.* 2014). Strains resistant to conventional pesticides (organophosphates, carbamates, pyrethroids) in European fruit orchards have been reported for this species since the 1970s (Ivancich Gambaro 1975; Anber and Overmeer 1988; Anber and Oppenoorth 1989; Duso *et al.* 1992; Bonafos *et al.* 2007). The replacement of broad-spectrum insecticides by reduced risk-insecticides represents an interesting scenario for studies on the compatibility between pesticides and beneficial organisms.

Material and methods

Field studies

The effects of insecticides on *A. andersoni* populations were evaluated in an apple orchard located at the experimental station of E. Mach Foundation (FEM, S. Michele all′Adige, Trento, Italy) in the 2009 growing season. Five insecticides commonly applied in apple orchards were considered (Table 1). An untreated control was included for comparison.

Insecticides were applied once (12 May), twice (9 June) or three times (8 July) in separate blocks according to codling moth control timing. A completely randomized design was followed with four replicates per treatment; each replicate consisted of 15 plants. Sampling was carried out before and every 5-10 days after insecticide applications (for about one month from the last application). A total of 60 leaves per treatment (15 leaves per replicate) were removed and transferred to the laboratory where predatory and phytophagous mites were

Table 1 Insecticides considered in field and laboratory trials.

IRAC Group	Chemical sub-group	Active ingredient	Trademark	Dose
4A	Neonicotinoids	Acetamiprid	Epik®	100 g hl^{-1}
4A	Neonicotinoids	Imidacloprid	Confidor® 200SL	50 ml hl^{-1}
4A	Neonicotinoids	Thiacloprid	Calypso®	25 ml hl^{-1}
4A	Neonicotinoids	Thiamethoxam	Actara® 25WG	30 g hl^{-1}
3A	Pyrethroids	Tau-fluvalinate	Klartan® 20EW	40 ml hl^{-1}

counted under a dissecting microscope. Phytoseiid specimens were mounted on slides, in Hoyer's medium, and identified under a phase contrast microscope.

Data were analyzed with a linear mixed repeated measures model with the MIXED procedure of SAS® (ver. 9.4; SAS Institute, 2016). Mite densities were considered as response variables with repeated measures made at different times, i.e., sampling dates. Using an F test ($\alpha = 0.05$) we evaluated the effect of insecticide application, time and their interaction. Degrees of freedom were estimated using the Kenward–Roger method (Littell *et al.* 1996). Differences among treatments were evaluated with a *t*-test ($\alpha = 0.05$) to the least-square means with the Tukey's adjustment. Slice option of the LSMEANS statement was used for the F-test partition of interactions between insecticide application and time. Data were checked for the analysis' assumptions and square-root transformation was applied.

Laboratory studies

Insecticides applied in field trials were tested at the same concentrations in the laboratory. Apple leaves were treated with insecticides using a Potter Burkard tower (1.7 ± 0.1 mg/cm^2 of insecticide solution) and then mated *A. andersoni* females of same age were transferred onto the leaves to expose them to fresh insecticide residues. To prevent mite escape and leaf desiccation, leaves were placed onto wet cotton prior to mite transfer. *Tetranychus urticae* Koch eggs and females were provided every day as food for predatory mites. The experimental units were kept in a climatic chamber at 25 ± 2 °C, $70 \pm 10\%$ relative humidity and 16L:8D photoperiod. Effect of insecticides on female survival was evaluated after 2 and 72 h. Surviving females were observed daily for additional 4 days to assess pesticide effects on fecundity. Escaped or drowned females were removed from the initial number. In total we assessed 45–50 females per insecticide.

We analyzed the data with a linear model using the GLM procedure of SAS® (ver. 9.4; SAS Institute, 2016). An F test ($\alpha = 0.05$) was used to evaluate the effect of insecticides on mite survival, fecundity and escaping rate (number of escaped or drowned females/initial number of females). Treatments were compared using Tukey–Kramer test ($\alpha = 0.05$). The Blümel and Hausdorf (2002) formula was used for fecundity calculation. In order to meet the models' assumptions, data on survival were arcsin-transformed while log x+1 transformation was applied to data on fecundity.
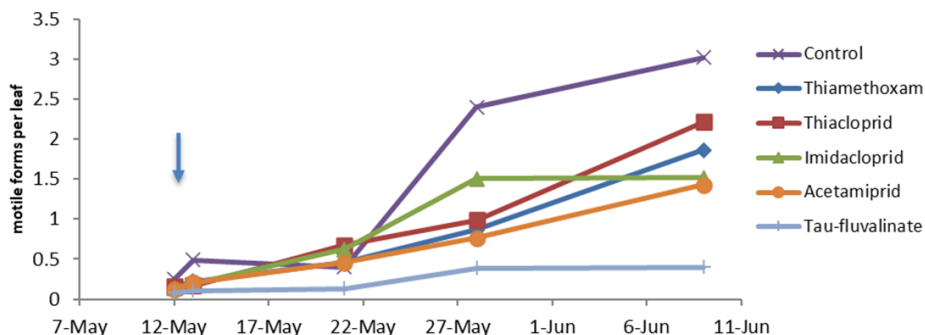
Results

Field studies

In the first experiment (single insecticide application) there were no differences among treatments prior to insecticide applications ($F_{5, 202} = 0.67$; $P = 0.648$). Later, insecticides affected predatory mite populations compared with the control ($F_{5, 70.2} = 22.1$; $P < 0.0001$; Figure 1; Table 2). The effects of time and interaction treatment * time were also significant (respectively: $F_{4, 160} = 110.64$; $P < 0.0001$; $F_{20, 172} = 4.01$; $P < 0.0001$). Predatory mite populations were lower in tau-fluvalinate than in neonicotinoid plots and among the latter in acetamiprid than in thiacloprid plots (Table 2). In this trial *P. ulmi* populations were not detected.

Also in the second experiment (two insecticide applications) there were no differences among treatments prior to the first insecticide application ($F_{5, 228} = 0.76$; $P = 0.578$) while insecticides significantly reduced predatory mite populations compared with the control ($F_{5, 72} = 46.99$; $P < 0.0001$; Figure 2; Table 3). The effects of time and interaction treatment * time were also significant (respectively: $F_{8, 204} = 63$; $P < 0.0001$; $F_{40, 209} = 3.17$; $P < 0.0001$). Predatory mite populations reached the lowest densities in tau-fluvalinate plots. Additional differences emerged among neonicotinoids: predatory mites were less abundant in acetamiprid than in thiamethoxam plots (Table 3). *Panonychus ulmi* populations were detected from
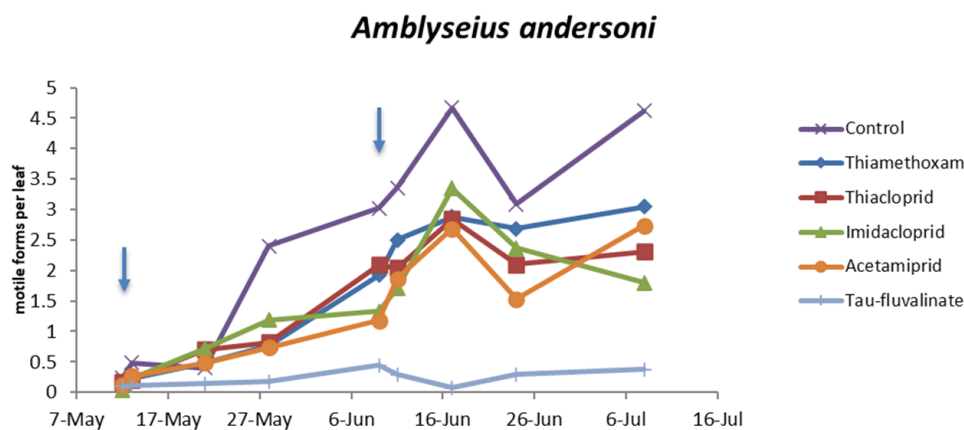
Figure 1 Seasonal abundance of *Amblyseius andersoni* in the first field experiment. Arrow indicates the spraying date.

mid-June onwards. There were more spider mites in tau-fluvalinate than in the remaining plots ($F_{5, 36.2} = 2.96$; $P = 0.025$; Figure 3; Table 4). The effects of time and interaction treatment * time were also significant (respectively: $F_{8, 182} = 15.32$; $P < 0.0001$; $F_{40, 193} = 2.67$; $P < 0.0001$).

In the third experiment (three insecticide applications) there were no differences among treatments prior to the first insecticide application ($F_{5, 154} = 0.87$; $P = 0.50$) while insecticides significantly reduced predatory mite populations compared with the control ($F_{5, 49.1} = 48.25$; $P < 0.0001$; Figure 4; Table 5). The effects of time and interaction treatment * time were also significant (respectively: $F_{12, 132} = 29.34$; $P < 0.0001$; $F_{60, 120} = 2.49$; $P < 0.0001$). The lowest *A. andersoni* densities were reached in tau-fluvalinate plots. Moreover, there were less predatory mites in acetamiprid and imidacloprid than in thiacloprid plots (Table 5). *Panonychus ulmi* numbers increased from mid-June onwards in tau-fluvalinate than in the remaining plots ($F_{5, 23.7} = 4.65$; $P = 0.004$; Figure 5; Table 6). The effects of time and interaction treatment * time were also significant (respectively: $F_{12, 133} = 5.98$; $P < 0.0001$; $F_{60, 119} = 3.1$; $P < 0.0001$).

Table 2 Results of pairwise t-test ($\alpha = 0.05$) to the least-square means with the Tukey's adjustment performed on *Amblyseius andersoni* densities observed in treatments receiving a single insecticide application. Asterisks (*) indicate significant differences between treatments ($\alpha = 0.05$).

Treatment	Treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
Thiamethoxam	Thiacloprid	-0.03625	0.05256	70.2	-0.69	0.4927
Thiamethoxam	Imidacloprid	-0.01544	0.05256	70.2	-0.29	0.7698
Thiamethoxam	Acetamiprid	0.08148	0.05256	70.2	1.55	0.1256
Thiamethoxam	Tau-fluvalinate	0.378	0.05256	70.2	7.19	<.0001*
Thiamethoxam	Control	-0.2523	0.07434	70.2	-3.39	0.0011*
Thiacloprid	Imidacloprid	0.0208	0.05256	70.2	0.4	0.6935
Thiacloprid	Acetamiprid	0.1177	0.05256	70.2	2.24	0.0283*
Thiacloprid	Tau-fluvalinate	0.4142	0.05256	70.2	7.88	<.0001*
Thiacloprid	Control	-0.216	0.07434	70.2	-2.91	0.0049*
Imidacloprid	Acetamiprid	0.09692	0.05256	70.2	1.84	0.0694
Imidacloprid	Tau-fluvalinate	0.3934	0.05256	70.2	7.48	<.0001*
Imidacloprid	Control	-0.2368	0.07434	70.2	-3.19	0.0022*
Acetamiprid	Tau-fluvalinate	0.2965	0.05256	70.2	5.64	<.0001*
Acetamiprid	Control	-0.3338	0.07434	70.2	-4.49	<.0001*
Tau-fluvalinate	Control	-0.6303	0.07434	70.2	-8.48	<.0001*

Figure 2 Seasonal abundance of *Amblyseius andersoni* in the second field experiment. Arrows indicate the spraying dates.
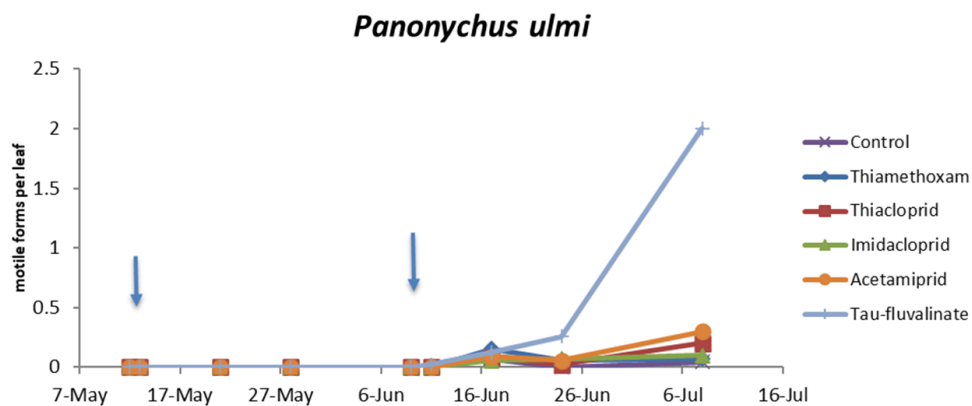
Laboratory experiments

Insecticides affected *A. andersoni* survival ($F_{5, 38} = 4.04$; P = 0.005; Figure 6), in particular tau-fluvalinate reduced female survival by 75%. Among neonicotinoids, there were no differences between thiamethoxam and the control while the remaining active ingredients were associated to intermediate effects (Figure 6). All insecticides reduced *A. andersoni* fecundity ($F_{5, 30} = 2.96$; P = 0.027) compared to the control (Figure 7). Escaping rate was also influenced by insecticides ($F_{5, 38} = 3.92$; P = 0.006) and the most relevant effects were caused by tau-fluvalinate (Figure 8). Only imidacloprid was not associated to adverse effects in terms of escaping rate.

Discussion

Field applications of tau-fluvalinate significantly reduced *A. andersoni* densities especially when repeated two-three times during the growing season. These observations confirm the results obtained on *Kampimodromus aberrans* (Oudemans) in fruit orchards located in the same

Table 3 Results of pairwise t-test ($\alpha = 0.05$) to the least-square means with the Tukey's adjustment performed on *Amblyseius andersoni* densities observed in treatments receiving two insecticide applications. Asterisks (*) indicate significant differences between treatments ($\alpha = 0.05$).

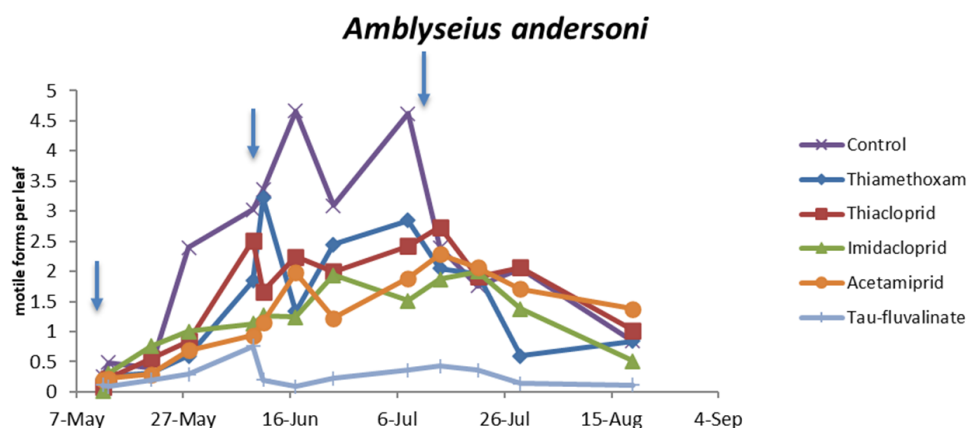| Treatment	Treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
Thiamethoxam	Thiacloprid	0.03358	0.06368	72	0.53	0.5996
Thiamethoxam	Imidacloprid	0.09315	0.06368	72	1.46	0.1479
Thiamethoxam	Acetamiprid	0.1296	0.06368	72	2.04	0.0455*
Thiamethoxam	Tau-fluvalinate	0.733	0.06368	72	11.51	<.0001*
Thiamethoxam	Control	-0.2903	0.07799	72	-3.72	0.0004*
Thiacloprid	Imidacloprid	0.05957	0.06368	72	0.94	0.3527
Thiacloprid	Acetamiprid	0.09606	0.06368	72	1.51	0.1358
Thiacloprid	Tau-fluvalinate	0.6994	0.06368	72	10.98	<.0001*
Thiacloprid	Control	-0.3239	0.07799	72	-4.15	<.0001*
Imidacloprid	Acetamiprid	0.03649	0.06368	72	0.57	0.5684
Imidacloprid	Tau-fluvalinate	0.6398	0.06368	72	10.05	<.0001*
Imidacloprid	Control	-0.3834	0.07799	72	-4.92	<.0001*
Acetamiprid	Tau-fluvalinate	0.6033	0.06368	72	9.47	<.0001*
Acetamiprid	Control	-0.4199	0.07799	72	-5.38	<.0001*
Tau-fluvalinate	Control	-10 232	0.07799	72	-13.12	<.0001*

Figure 3 Seasonal abundance of *Panonychus ulmi* in the second field experiment. Arrows indicate the spraying dates.

region (Duso *et al.* 2014). In the latter investigation, tau-fluvalinate caused 100% mortality on *K. aberrans* females in the laboratory. In the present study *A. andersoni* mortality was of about 75% but surviving females did not lay eggs. The detrimental effects of tau-fluvalinate on predatory mites have been recorded even on other species using different experimental procedures (Petit and Karan 1991; Bellows *et al.* 1992; Grout *et al.* 1997; Amin *et al.* 2009). Regarding sublethal effects, tau-fluvalinate significantly increased *A. andersoni* escaping rate, a phenomenon likely associated to repellency. It should be mentioned that pyrethroid residues can induce adverse effects (increased locomotory activity or escape) also on spider mites (Holland *et al.* 1994) with implications for mite outbreaks. Field concentrations of pyrethroids can disrupt predator–prey dynamics in apple orchards (Bostanian *et al.* 1985; Bowie et *al.*, 2001) and this phenomenon was noticed in two of our field trials. Therefore, the use of tau-fluvalinate in fruit orchards requires a careful evaluation.

Most of insecticides tested in the present study belonged to neonicotinoids. Their application reduced *A. andersoni* densities in field conditions compared to the control plots, but these effects were less severe than those reported for tau-fluvalinate. The reduction in population

Table 4 Results of pairwise t-test ($\alpha = 0.05$) to the least-square means with the Tukey's adjustment performed on *Panonychus ulmi* densities observed in treatments receiving two insecticide applications. Asterisks (*) indicate significant differences between treatments ($\alpha = 0.05$).

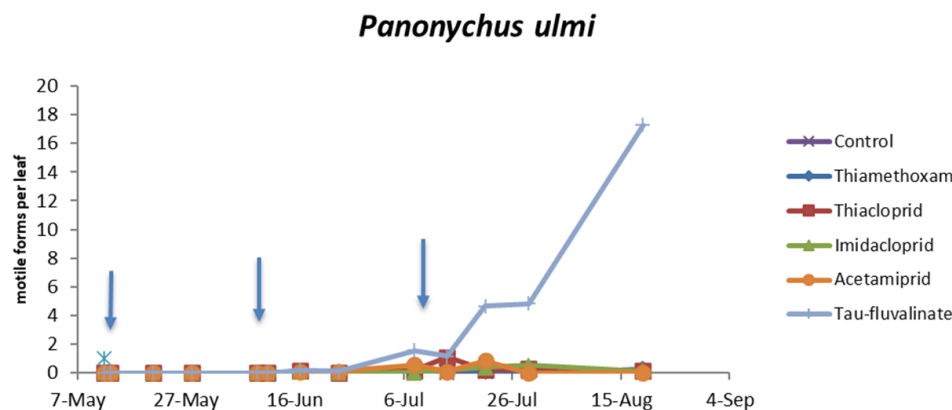| Treatment	Treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
Thiamethoxam	Thiacloprid	-0.01361	0.05075	36.2	-0.27	0.7902
Thiamethoxam	Imidacloprid	0.000185	0.05075	36.2	0	0.9971
Thiamethoxam	Acetamiprid	-0.02515	0.05075	36.2	-0.5	0.6232
Thiamethoxam	Tau-fluvalinate	-0.1572	0.05075	36.2	-3.1	0.0038*
Thiamethoxam	Control	0.01174	0.06216	36.2	0.19	0.8512
Thiacloprid	Imidacloprid	0.01379	0.05075	36.2	0.27	0.7874
Thiacloprid	Acetamiprid	-0.01154	0.05075	36.2	-0.23	0.8214
Thiacloprid	Tau-fluvalinate	-0.1435	0.05075	36.2	-2.83	0.0076*
Thiacloprid	Control	0.02535	0.06216	36.2	0.41	0.6858
Imidacloprid	Acetamiprid	-0.02533	0.05075	36.2	-0.5	0.6207
Imidacloprid	Tau-fluvalinate	-0.1573	0.05075	36.2	-3.1	0.0037*
Imidacloprid	Control	0.01156	0.06216	36.2	0.19	0.8535
Acetamiprid	Tau-fluvalinate	-0.132	0.05075	36.2	-2.6	0.0134*
Acetamiprid	Control	0.03689	0.06216	36.2	0.59	0.5565
Tau-fluvalinate	Control	0.1689	0.06216	36.2	2.72	0.01*

Figure 4 Seasonal abundance of *Amblyseius andersoni* in the third field experiment. Arrows indicate the spraying dates.

size observed in our trials could be caused by the effect of neonicotinoids on predatory mite fecundity. Similar effects have been reported for other predatory mite species (Castagnoli *et al.* 2005; Villanueva and Walgenbach 2005; Bostanian *et al.* 2009). There were some differences between neonicotinoids, in particular acetamiprid proved to be less selective than other neonicotinoids and these effects could be related to a more pronounced reduction in fecundity observed in laboratory trials. Bostanian *et al.* (2009) reported a high toxicity of acetamiprid and imidacloprid to *Galendromus occidentalis* (Nesbitt) whereas thiamethoxam and thiacloprid showed slight or negligible effects. An increase in escaping rate was noticed for three out of four neonicotinoids suggesting some alterations in predatory mite behavior. Various sublethal and behavioral effects (included irritancy) have been reported for some neonicotinoids even if their implications for spider mite control are not always clear (e.g., Poletti *et al.* 2007; Beers and Schmidt-Jeffris 2015; Schmidt-Jeffris *et al.* 2021). Previous research found that irritability and repellency may favor the escape of phytoseiids from contaminated surfaces and seemed associated with the least selective products (Monteiro *et al.*, 2019). In our case the highest escaping rates were associated with thiamethoxam and thiacloprid; implications of this

Table 5 Results of pairwise t-test ($\alpha = 0.05$) to the least-square means with the Tukey's adjustment performed on *Amblyseius andersoni* densities observed in treatments receiving three insecticide applications. Asterisks (*) indicate significant differences between treatments ($\alpha = 0.05$).

Treatment	Treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
Thiamethoxam	Thiacloprid	-0.06287	0.06371	49.1	-0.99	0.3286
Thiamethoxam	Imidacloprid	0.1025	0.06371	49.1	1.61	0.1141
Thiamethoxam	Acetamiprid	0.06855	0.06371	49.1	1.08	0.2872
Thiamethoxam	Tau-fluvalinate	0.6501	0.06371	49.1	10.2	<.0001*
Thiamethoxam	Control	-0.2903	0.06371	49.1	-4.56	<.0001*
Thiacloprid	Imidacloprid	0.1654	0.06371	49.1	2.6	0.0124*
Thiacloprid	Acetamiprid	0.1314	0.06371	49.1	2.06	0.0445*
Thiacloprid	Tau-fluvalinate	0.713	0.06371	49.1	11.19	<.0001*
Thiacloprid	Control	-0.2274	0.06371	49.1	-3.57	0.0008*
Imidacloprid	Acetamiprid	-0.03395	0.06371	49.1	-0.53	0.5965
Imidacloprid	Tau-fluvalinate	0.5476	0.06371	49.1	8.6	<.0001*
Imidacloprid	Control	-0.3928	0.06371	49.1	-6.17	<.0001*
Acetamiprid	Tau-fluvalinate	0.5816	0.06371	49.1	9.13	<.0001*
Acetamiprid	Control	-0.3588	0.06371	49.1	-5.63	<.0001*
Tau-fluvalinate	Control	-0.9404	0.06371	49.1	-14.76	<.0001*

Panonychus ulmi

Figure 5 Seasonal abundance of *Panonychus ulmi* in the third field experiment. Arrows indicate the spraying dates.
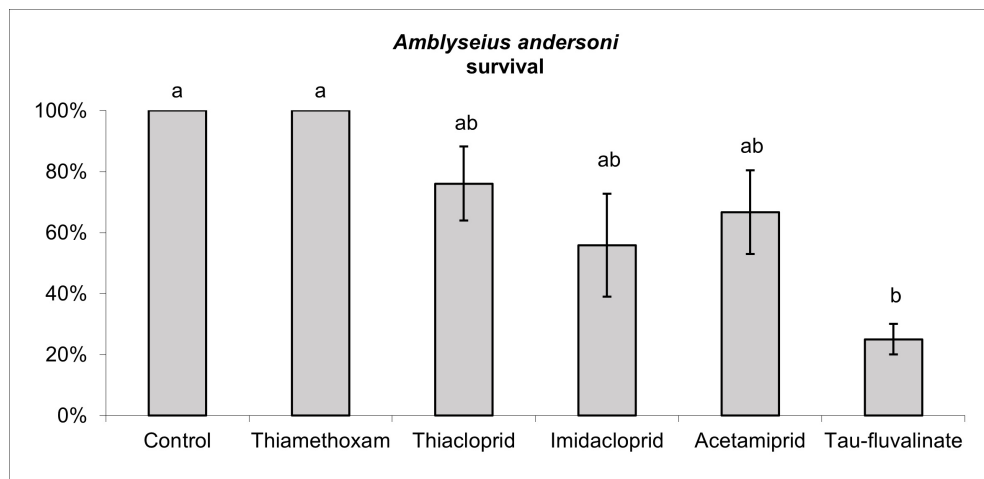
phenomenon should be investigated more in depth.

In this study single or multiple applications of neonicotinoids were not associated with spider mite increases in the experimental season. The limited effect of neonicotinoids on *A. andersoni* survival in the laboratory confirms the results of experiments conducted on various predatory mites (James 1997; James and Vogele 2001; Poletti *et al.* 2007; Lefebvre *et al.* 2011; Duso *et al.* 2014). The negative effects of neonicotinoids on *A. andersoni* fecundity represent a serious risk for one of the most important objectives of IPM tactics: to preserve stable populations of predatory mites in fruit orchards. While most of these insecticides have been banned in Europe, their use is still significant in other continents.
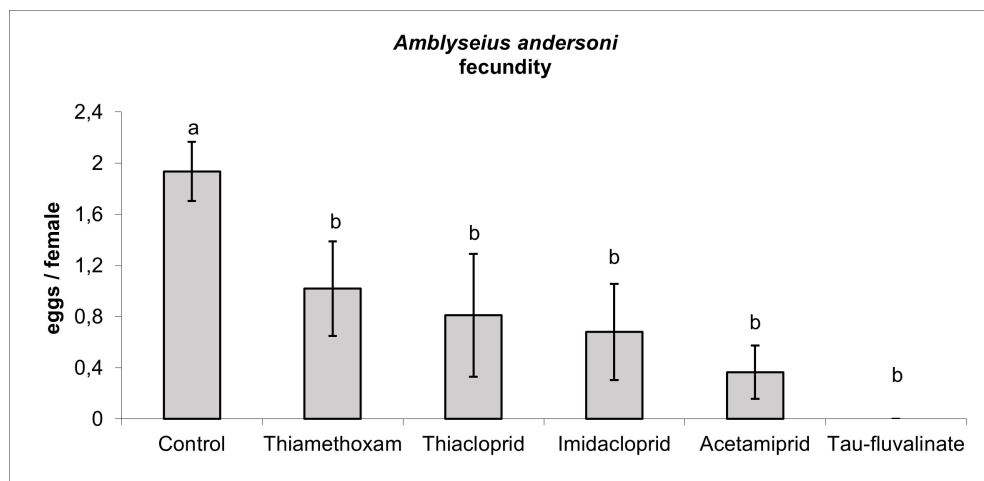
It should be stressed that predatory mite species and strains exhibit a variation in their susceptibility to pesticides. In North America, *A. andersoni* proved to be less susceptible to imidacloprid than *Galendromus occidentalis* (Nesbitt) and *Neoseiulus fallacis* (Garman) (James 2003). The use of neonicotinoids could favor the less susceptible species (and strains) in predatory mite communities irrespectively of their adaptation to environmental factors. Climate change is also influencing the composition and structure of predatory mite communities in

Table 6 Results of pairwise t-test (α = 0.05) to the least-square means with the Tukey's adjustment performed on *Panonychus ulmi* densities observed in treatments receiving three insecticide applications. Asterisks (*) indicate significant differences between treatments (α = 0.05).

Treatment	Treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
Thiamethoxam	Thiacloprid	-0.07798	0.1627	23.7	-0.48	0.6361
Thiamethoxam	Imidacloprid	-0.02817	0.1627	23.7	-0.17	0.864
Thiamethoxam	Acetamiprid	-0.03463	0.1627	23.7	-0.21	0.8332
Thiamethoxam	Tau-fluvalinate	-0.6199	0.1627	23.7	-3.81	0.0009*
Thiamethoxam	Control	0.03985	0.1627	23.7	0.24	0.8086
Thiacloprid	Imidacloprid	0.04981	0.1627	23.7	0.31	0.7622
Thiacloprid	Acetamiprid	0.04335	0.1627	23.7	0.27	0.7922
Thiacloprid	Tau-fluvalinate	-0.5419	0.1627	23.7	-3.33	0.0028*
Thiacloprid	Control	0.1178	0.1627	23.7	0.72	0.476
Imidacloprid	Acetamiprid	-0.00646	0.1627	23.7	-0.04	0.9687
Imidacloprid	Tau-fluvalinate	-0.5917	0.1627	23.7	-3.64	0.0013*
Imidacloprid	Control	0.06802	0.1627	23.7	0.42	0.6796
Acetamiprid	Tau-fluvalinate	-0.5853	0.1627	23.7	-3.6	0.0015*
Acetamiprid	Control	0.07448	0.1627	23.7	0.46	0.6512
Tau-fluvalinate	Control	0.6597	0.1627	23.7	4.06	0.0005*

Figure 6 Survival of *Amblyseius andersoni* females exposed to fresh residues of a number of insecticides. Different letters indicate significant differences at Tukey–Kramer test (α = 0.05).

Figure 7 Fecundity of *Amblyseius andersoni* females exposed to fresh residues of a number of insecticides. Different letters indicate significant differences at Tukey–Kramer test (α = 0.05).

perennial crops. Experimental studies should be addressed to evaluate the impact of pesticides in different environmental scenarios.
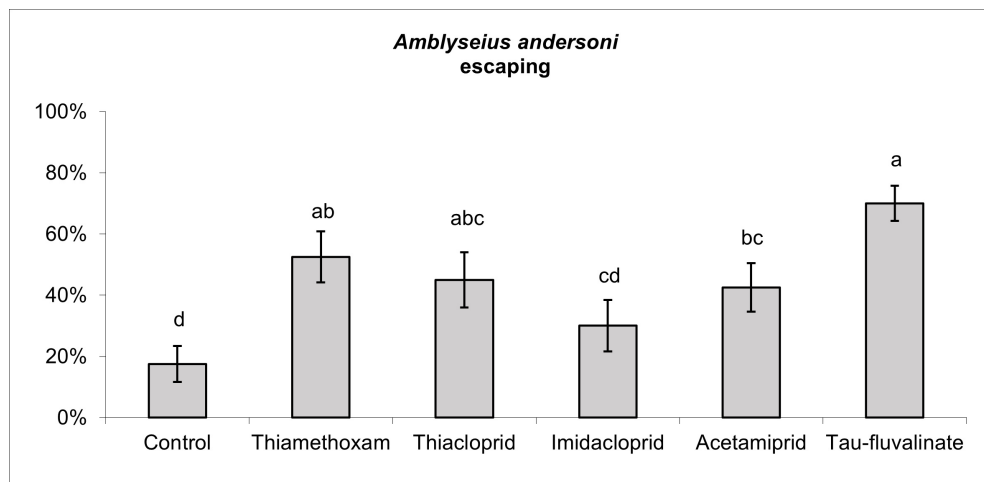
Acknowledgements

ORCID

Valeria Malagnini https://orcid.org/0000-0001-9686-0299
Mario Baldessari https://orcid.org/0000-0003-4687-9404

Figure 8 Escaping rate of *Amblyseius a*ndersoni females exposed to fresh residues of a number of insecticides. Different letters indicate significant differences at Tukey–Kramer test (α = 0.05).

Carlo Duso https://orcid.org/0000-0002-2600-2536
Alberto Pozzebon https://orcid.org/0000-0002-2445-7211
Gino Angeli https://orcid.org/0000-0002-4924-0481

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