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Effect of selective insecticides on the beneficial spider community of a pear orchard in the Czech Republic

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Summary

The effect of four selective insecticides on the spider community of a pear orchard has been studied over a two-year period. Applications were used against resistant populations of the pear psyllid, *Psylla pyri* (Linnaeus), that evolved during "non-selective" insecticide management in the previous years. The effect on spiders was most apparent immediately after application. Application of flucycloxuron was drastic for spiders, but failed in pest control. Tefluhexuron and hexaflumuron were less harmful to spiders and most efficient for the control of the pear psyllid. Both spiders and psyllids were almost unaffected by diflubenzuron application. Partial redundancy analysis (RDA) revealed that the effects of the various selective insecticides on the spider community were significantly different. The ordination diagram helped to determine species susceptibility to these insecticides: for example, ambush spiders (Thomisidae and Philodromidae) were found to be most susceptible to flucycloxuron and hexaflumuron. Diversity indices did not reveal marked differences between treatments. The spider community was not affected after applications of selective insecticides to the extent that it was after non-selective insecticides. The mean abundance, as well as number of species, increased one year after "selective" management. The very high numbers of pear psyllids probably influenced the spider community and allowed hunting spiders, such as *Misumenops tricuspidatus* to become fairly abundant.

Introduction

The effect of insecticide application on natural enemies of insects in agricultural habitats has been studied for about 30 years (e.g. Hassan *et al.*, 1987), especially since it became clear that natural enemies, such as spiders, could enhance the regulation of pests. However, the effect of insecticide applications on spiders in orchards has not often been studied (e.g. Dondale *et al.*, 1979; Mansour *et al.*, 1981). Because new insecticides are constantly being produced, more and more tests are required. The aim is to identify selective pesticides with the least effect on natural enemies, thus supporting their ability for regulation of pests. Selective pesticides are a basis for integrated pest management.

In this paper, I present results of the effect of selective insecticides applied in a pear orchard in the Czech Republic damaged by resistant populations of the pear psyllid *Psylla pyri* (Linnaeus). Until 1992 the orchard was treated only with non-selective insecticides but, as the situation became critical, methidathion (ULTRACID WP40) was applied to the whole area. Over the following two years, the effect of four selective insecticides for control of the pear psyllid and on the community of crown-inhabiting spiders was studied.

Material and methods

The experiment was carried out in 1993 and 1994 on a 5.5 ha pear orchard at Doksany, near Prague, Czech Republic, growing 20-year-old trees (Madame Verté, Conference), spaced 3 × 2 m apart. In 1993, the orchard was subdivided into four 0.5 ha plots. Three of these were treated with a pesticide as follows: plot ANDA with 0.6 l/ha of flucycloxuron (ANDALIN DC25), plot DIMI with 0.25 l/ha of diflubenzuron

	1993				**1994**				
Family / species	ANDA	DIMI	CONS	CTRL	ANDA	DIMI	CONS	NOMO	CTRL
Tetragnathidae									
Tetragnatha pinicola L. Koch		1				15	7		4
Araneidae									
Aculepeira ceropegia (Walckenaer)		4	3						3
Araneus diadematus Clerck									1
Araniella cucurbitina (Clerck)	20	40	16	64	25	49	65	40	121
Gibbaranea gibbosa (Walckenaer)	4	4	4	11	3			7	15
Larinioides patagiatus (Clerck)					3		3	1	4
Mangora acalypha (Walckenaer)	4	20	4	4	3	4	4	2	8
Linyphiidae									
Erigone atra (Blackwall)		1							
Erigone dentipalpis (Wider)							8		
Hylyphantes graminicola (Sundevall)			1						
Linyphia hortensis Sundevall								1	
Meioneta rurestris (C. L. Koch)				1					
Microlinyphia pusilla (Sundevall)	1								
Theridiidae									
Anelosimus vittatus (C. L. Koch)					3	7	2	2	8
Enoplognatha latimana Hippa & Oksala					3		3		5
Robertus sp.						1			
Theridion bimaculatum (Linnaeus)						27	15	43	41
Theridion impressum L. Koch	24	23	19	16	12	35	47	31	60
Theridion pinastri L. Koch		3	4	4			3	1	3
Theridion varians Hahn	21	12	11	33	3	24	20	11	55
Dictynidae									
Dictyna uncinata Thorell			3				3	4	7
Nigma walckenaeri (Roewer)						2			
Clubionidae									
Cheiracanthium virescens (Sundevall)					1				
Clubiona pallidula (Clerck)		12	7	7	3	4	4		8
Philodromidae									
Philodromus cespitum (Walckenaer)	19	31		60	45	55	59	63	135
Philodromus margaritatus (Clerck)					2		3		
Philodromus rufus Walckenaer	1	2	7	11	1				27
Thomisidae									
Misumena vatia (Clerck)		1							
Misumenops tricuspidatus (Fabricius)	7	18	8	4	30	39	37	31	59
Ozyptila praticola (C. L. Koch)		1		2					
Thomisus onustus Walckenaer					5		6	2	2
Xysticus cristatus (Clerck)		1		3			1		6
Xysticus ulmi (Hahn)								1	
Salticidae									
Ballus chalybeius (Walckenaer)						1			3
Pseudicius encarpatus (Walckenaer)		4					2		
Salticus scenicus (Clerck)	2				1	2	1		3
Totals	**103**	**178**	**87**	**220**	**143**	**265**	**293**	**240**	**578**

Table 1: List of spiders collected by tapping branches. The numbers represent total annual capture.

(DIMILIN 48SC), and plot CONS with 0.75 l/ha of hexaflumuron (CONSULT 100EC). The remaining plot was a control (CTRL). The insecticides were applied on 13 April. On 17 May 1994, the applications were repeated; in addition, another plot of identical area (NOMO) was treated with 1.0 l/ha of teflubenzuron (NOMOLT 15SC).

Spiders were collected by tapping the branches with a slender stick, covered with hard

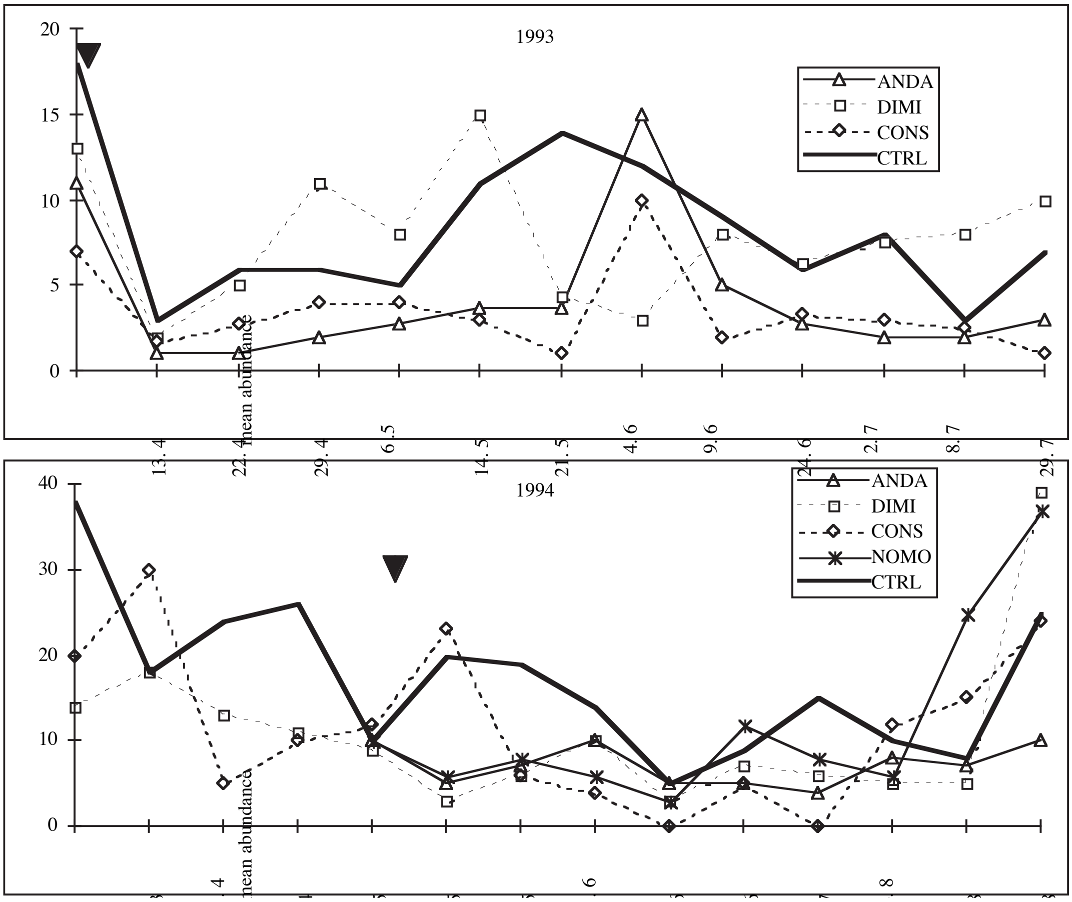

Fig. 1: Seasonal population dynamics (mean abundance) of crown-inhabiting spiders under various insecticide practices in 1993 and 1994. Arrows mark the dates of insecticide applications.

rubber, over a 0.25 m^2 cloth tray. Single branches were tapped on 25 trees, in 3 replications. The sampling was carried out usually at one week intervals between April and August in 1993, and March to September in 1994.

Numbers of spiders (collected during five weeks after application) were transformed by $l_{n(x+1.0)}$ and then subjected to partial redundancy analysis (Ter Braak, 1987) with replications as covariables, as the standard MANOVA could not be performed due to restrictions on the number of response variables.

Results

In total, 588 spiders were collected in 1993 (Table 1). The effect of insecticide applications was analysed in two periods: within 5 weeks of application (until the late-spring peak) and for the rest of the season (Fig. 1). During the first five weeks after application, significantly higher abundance ($P < 0.015$; Kruskal-Wallis ANOVA) was observed in CTRL and DIMI than in CONS and ANDA plots (Table 2). The abundances in the latter plots reached a level of CTRL six weeks after application. Ordination by redundancy analysis helped to distinguish particular differences between treatments (Fig. 2). According to RDA results, numbers of ambush spiders (*Philodromus cespitum* and *P. rufus*) were most reduced in the ANDA plot, while abundance of orb-web spiders (*Araniella cucurbitina*, *Mangora acalypha*, *Aculepeira ceropegia*) in the CONS plot. Most of the

	1993		1994	
	22 April–4 May	**9 May–19 August**	**17 May–30 June**	**14 July–20 Sept**
ANDA	2.2 (SD = 1.3)	5.0 (SD = 5.0)	7.4 (SD = 2.5)	6.8 (SD = 2.4)
DIMI	7.5 (SD = 4.8)	6.6 (SD = 2.7)	6.2 (SD = 3.3)	14.0 (SD = 16.7)
CONS	3.0 (SD = 1.2)	3.8 (SD = 3.6)	8.3 (SD = 10.1)	11.2 (SD = 9.3)
NOMO	–	–	6.6 (SD = 2.6)	17.6 (SD = 13.1)
CTRL	7.5 (SD = 4.1)	7.5 (SD = 3.0)	13.6 (SD = 6.3)	14.3 (SD = 7.8)

Table 2: Mean abundance (and standard deviation) of spiders during five weeks after application and for the rest of the season.

spiders were most abundant in the DIMI and CTRL plots. The Monte Carlo permutation test (significance of axis 1, $\lambda_1 = 0.41$) showed that the community of spiders in studied plots after insecticide applications was significantly different ($F = 5.6$, $P < 0.01$). During the rest of the experiment the abundance of spiders in the ANDA and CONS plots become almost equal to that in CTRL. However, the late-summer peak was lower in ANDA and CONS plots than in DIMI and CTRL plots (Fig. 1). The Shannon-Weaver indices of diversity (Odum, 1977), in contrast, were higher for DIMI and CONS plots than for CTRL (Table 3).

In 1994, 1511 spiders were collected. Unlike the previous year, the abundance of spiders in treated plots within five weeks after application (Fig. 1) was not significantly lower ($P < 0.05$, Kruskal-Wallis ANOVA) in comparison with CTRL, except for the DIMI plot (Table 2). The ordination diagram (Fig. 3) shows that spiders were most adversely affected on ANDA, followed by the CONS and DIMI plots. Frame-web spiders (*Theridion impressum*, *T. varians* and *T. bimaculatum*) and some ambush spiders (*Philodromus rufus* and *P. cespitum*) were most reduced in ANDA and CONS plots. *Araniella cucurbitina*, *Misumenops tricuspidatus* and *Clubiona pallidula* were negatively affected in DIMI. The community of spiders in the NOMO plot most resembled the CTRL. The Monte-Carlo permutation test ($\lambda_1 = 0.29$) revealed that application of insecticides affected the community of spiders differently, though less significantly ($F = 4.1$, $P < 0.04$) than in the previous year. Abundances in treated plots during the rest of the season attained a level similar to the CTRL, but in NOMO and DIMI plots the late-summer peak reached higher magnitude than in CTRL and CONS plots. ANDA, again, had the lowest late-summer peak. Diversity indices were a little higher for CTRL, DIMI and CONS (Table 3).

Discussion

The detrimental effect of the insecticides was mainly apparent during the first five weeks after application, though it could also be detected during the rest of a season. Immediately after application the treatment clearly resulted in reduced abundance and, subsequently, in a delayed late-spring peak. In the rest of a season, the magnitude of the late-summer peak was particularly affected. The late-spring peak is due to the occurrence of *Theridion varians*, *T. impressum* and *Philodromus cespitum* adults, whereas the late-summer one is mostly the result of hatching of *Theridion bimaculatum* and *Araniella cucurbitina* spiderlings. The insecticide application suppressed populations of adults but did not affect late-summer emergence of juveniles. It is not yet known whether spiders were directly affected by an insecticide or were influenced by the reduction of prey. This might be resolved by examining the known characteristics of these insecticides.

Flucycloxuron is used for control of mites, whereas teflubenzuron and hexaflumuron are used against a wide variety of other pests, such

	1993	1994
ANDA	0.82	0.89
DIMI	0.98	0.93
CONS	0.97	0.97
NOMO	–	0.87
CTRL	0.69	1.00

Table 3: Shannon-Weaver Index of diversity (H_S) of plots in 1993 and 1994.

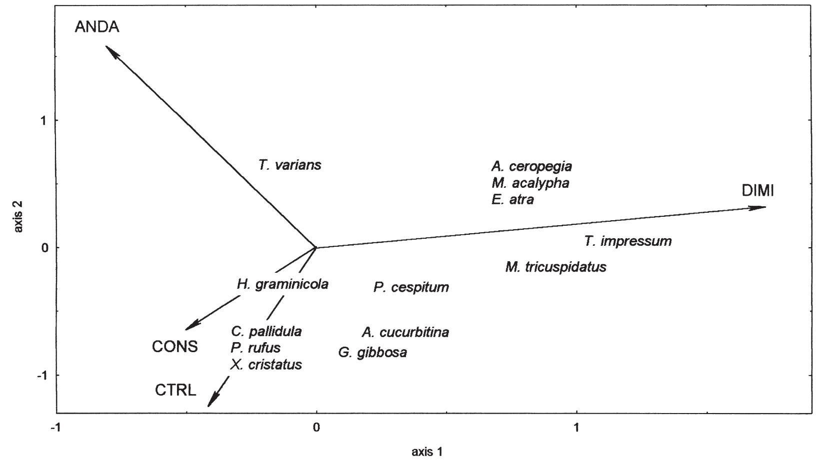

Fig. 2: Ordination diagram based on partial redundancy analysis of spiders with respect to plots (ANDA, DIMI, CONS, CTRL) during five weeks after application in 1993.

as moths, Colorado beetles and caterpillars. According to the List of Registered Pesticides (Kužma, 1997), only hexaflumuron (applied on CONS) is classified as toxic to honey-bees, whereas other insecticides are considered less harmful. Hassan *et al.* (1987) observed that diflubenzuron was harmless to natural enemies (e.g. *Syrphus vitripennis*, *Coccinella septempunctata*, *Anthocoris nemoralis*, *Amblyseisus potentillae*) and less harmful for *Chrysopa carnea*; they therefore recommended it for orchards. According to Mansour & Nentwig (1988), acaricides are highly toxic to spiders.

The results of this experiment suggest that hexaflumuron (in CONS) and teflubenzuron (in NOMO) caused lower damage to spider populations than flucycloxuron (in ANDA). In contrast, diflubenzuron (in DIMI) caused negligible to no damage. Hexaflumuron and teflubenzuron were most efficient against *Psylla pyri* (Teplý, 1997), whereas flucycloxuron and diflubenzuron failed in psyllid control. Though the spiders showed an inconsistent response over the two years, RDA results suggest that numbers of ambush and wandering spiders (Thomisidae, Philodromidae, Salticidae) were most depressed after flucycloxuron application. It seems that this insecticide reduced not only abundance of spiders but also that of mites, and that this led to a decline of frame-web spiders (it is known that *Theridion* species feed on mites). The other insecticides (teflubenzuron, diflubenzuron and hexaflumuron) reduced pests (e.g. pear psyllid) but, as these are not an

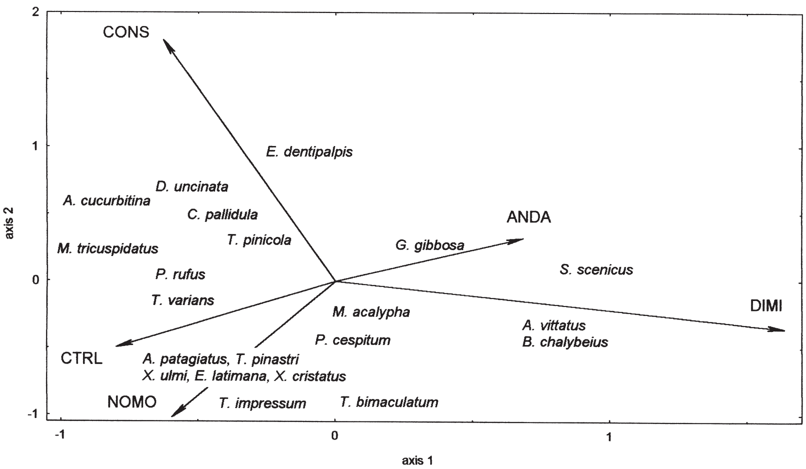

Fig. 3: Ordination diagram based on partial redundancy analysis of spiders with respect to insecticide treatments (ANDA, DIMI, CONS, NOMO, CTRL) during five weeks after application in 1994.

exclusive prey of spiders, the overall effect was not so clear.

In investigations on the effect of non-selective pesticides, authors used to stress that there was a decrease of diversity (Chant, 1956; Mansour *et al*., 1980). The effect of non-selective insecticides, such as formothion, carbaryl (Mansour, 1987), azinphos-metyl, methidathion (Mansour *et al*., 1981) on spiders was apparently very drastic. However, selective insecticides do not cause such strong supression. Therefore, diversity is not an appropriate measure of a disturbance. In this study, the Shannon-Weaver Index of diversity failed to show apparent differences between treatments, because the treatments decreased density (of principal species in particular), which in fact increased the diversity index. The insecticidal effect is, therefore, better determined according to the abundance of the principal species rather than on the absence of the rare ones.

Ambush and wandering spiders are more susceptible to insecticides than orb- or frame-web spiders because webs can efficiently accumulate droplets of applied chemicals. Specht & Dondale (1960) observed reduction of hunting spiders in a sprayed orchard. In contrast, Mansour & Nentwig (1988) found out that an ambush spider (*Philodromus aureolus*) was competely resistant to about 30 pesticides. According to RDA ordination, both *P. cespitum* and *P. rufus* were affected only after flucycloxuron and hexaflumuron applications.

The arachnofauna of the studied pear orchard was found to be a little poorer in species in comparison with apple (e.g. Olszak *et al*., 1992). This seems to be a result of non-selective insecticides applied in the previous years, since the mean abundance as well as number of species increased in 1994, i.e. one year after "selective" management. In this pear orchard, an ambush spider, *Misumenops tricuspidatus*, was one of the dominant species. Apple, in contrast, was dominated by *Theridion* species. This is probably a response to type of prey: the apple was rich in mites (*Tetranychus urticae* Koch), the pear in pear psyllid.

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