Bulletin of Insectology ***61*** *(1): 25-30, 2008*
ISSN 1721-8861

Effectiveness of some pesticides against *Cacopsylla pyri* and impact on its predator *Anthocoris nemoralis* in pear-orchards

Constantinos Souliotis[1], Theodoros Moschos[2]
[1]*Department of Entomology and Agricultural Zoology, Laboratory of Agricultural Entomology, Benaki Phytopathological Institute, Kifissia, Athens, Greece*
[2]*Regional Center of Plant Protection and Quality Control of Magnesia, Toroutzia-Nikolaidi, Pedion Areos-Volos, Greece*

Abstract

During 2001-2002, in the scope of an IPM programme, a research was carried out on the impact of treatment with broad spectrum and selective insecticides on the population dynamics of the pear psyllid *Cacopsylla pyri* (L.) (Homoptera Psyllidae) and its predator *Anthocoris nemoralis* (F.) (Heteroptera Anthocoridae) in a pear orchard of the variety "Krystalli", near Koropi in Attica, Greece. At the same time the beneficial insect fauna on the wild vegetation edging the orchard was recorded and its role as natural ecological resource and dynamic source of beneficial insect populations was estimated. A programme of treatments with the broad spectrum insecticides (deltamethrin, amitraz) effectively controlled *C. pyri*. However, these were also highly toxic to *A. nemoralis*, the most predator in the area under survey, whose active period and population dynamics coincide with those of the psyllid. In contrast, a program of treatments with insect growth regulators (diflubenzuron, fenoxycarb) and potassium salts was equally effective against *C. pyri* but showing less toxic activity on *A. nemoralis* that at times was found in higher densities than the psyllid. On the four plant species of which the wild vegetation at the edge of the orchard was composed, 12 predator species, belonging to three families, were recorded. Out of these, *A. nemoralis* with a relative frequency of 61% in average prevails by far over the other species. It occurs mainly (73% in average of all records) on *Cercis siliquastrum* L.

Key words: *Anthocoris nemoralis*, *Cacopsylla pyri*, integrated pest management, insecticides, predators, pear-orchard.

Introduction

Over the last decades the culture of pear in Greece has gained great interest with respect to cultivation and economics. Therefore, ever better varieties are grown and cultivation and protection measures in orchards are steadily improved, so as to ensure better quality and a competitive produce through a modern integrated production system.

The common pear psyllid *Cacopsylla pyri* (L.) (Homoptera Psyllidae) is the most important pest in pear culture in Greece (Broumas *et al*. 1989; Stratopoulou and Kapatos, 1992; 1995; Souliotis and Broumas, 1998), as in other European countries (Hodkinson, 1984; Mathias, 1984; Pollini *et al*., 1992; Tremblay, 1995; Milenkovic *et al*., 1998; Champagne and Bylemans, 1999; Jenser *et al*., 1999; Schaub *et al*., 1999; Mourik, 2003). The pest completes 4-7 generations annually and a significant number of beneficial insects, mainly predators of the family Anthocoridae [*Anthocoris nemoralis* (F.), *Orius* sp.] and Chrysopidae considerably conduce to the fluctuation of it's population density (Atger, 1979; Fauvel and Atger, 1981; Deronzier, 1984; Mathias, 1984; Rieux and D'Arcier, 1984a; 1984b; Broumas *et al*., 1989; Souliotis and Broumas, 1998; Stratopoulou and Kapatos, 1992). The psyllid is particularly harmful during summer, causing serious problems (inferior quality of the fruits), while it is also exceedingly difficult to control (Stratopoulou and Kapatos, 1992; 1995; Souliotis, 1999). Pear orchards are usually repeatedly treated with selective and broad spectrum conventional insecticides often leading to progressive resistance of the pest and destruction or decrease of predator populations (Harries and Burts, 1965; Delorme, 1985; Bués *et al*., 1999; 2003). Surveys carried out in Greece and in other countries (Nicoli *et al*., 1989; Nguyen and Merzoug, 1994; Rieux *et al*., 1994; Souliotis and Broumas, 1998; Souliotis, 1999; Pasqualini *et al*., 1999a; 1999b; 2001), indicated that by "proper management" of its wild populations the predator *A. nemoralis* (Heteroptera Anthocoridae) could be the "key" to successful conservation biological control of the psyllid.

There is a tendency to reduce, wherever possible, the use of broad spectrum insecticides within the framework of an IPM programme. This may be achieved by using more environment friendly selective formulations with improved application techniques. Evaluation of the sensitivity of plant feeding and beneficial arthropods to the formulations used in the crop concerned, in particular to those most frequently applied, is a fundamental condition for their introduction into an IPM programme seeking high toxicity against the harmful insect and at the same time affecting as little as possible the beneficial insect fauna, man and environment in general.

The aim of this survey was to provide more information for evaluation and comparison of the direct and indirect effects of the use of various broad spectrum and selective insecticides against *C. pyri* on the population dynamics of *A. nemoralis* in relation to population densities of psyllid in a representative pear orchard in Greece. It is worth mentioning that such information, where available, from other areas and countries always bears limited relevance and should not be generalised, as often a different kind and frequency of treatment, different climate conditions and a different beneficial insect fauna are concerned.

At the same time an attempt was made to evaluate the role of the wild vegetation surrounding the pear orchard as natural ecological reserve and potential source of beneficial insects.

Table 1. Insecticides applied in the experimental orchard at Koropi-Attiki in 2001 and 2002.

Category of insecticides	Active compound	Commercial name	Dose L $^{-1}$
Classic insecticides	deltamethrin	Decis	60 ml 100 l^{-1} water
"	amitraz	Mitac	150 ml 100 l^{-1} water
Insect growth regulators (IGR)	fenoxycarb	Insegar	100 gr 100 l^{-1} water
"	diflubenzuron	Dimilin	100 ml 100 l^{-1} water
Other insecticides	potassium salts fatty acids	Savona	100 ml 100 l^{-1} water

Materials and methods

Experimental orchard

The survey was made during 2001 and 2002 at Koropi, Attiki region, in a pear orchard of 1.4 ha comprising 174, trees of the variety "Krystalli", approximately 14 year old. The orchard was surrounded by wild vegetation, horticultural crops (open-grown and under glass), olive, grapevine and pistachio, the main culture in the area. The climate in the region is warm and dry. In both years of the survey the same cultivation measures were carried out (figure 1).

Design of the survey and pesticides used

For the survey the orchard was split into three sections: section A (60 trees) was treated with broad spectrum insecticides, section B (53 trees), serving as control, was not treated at all and section C (60 trees) was treated with selective and natural products (figure 1). The insecticides applied per section, the dose and date of application are shown in tables 1 and 2. Insecticides commonly applied in pear orchards of the region were chosen for the experiment. Doses applied are as indicated by the manufacturer for the crop concerned. Treatments were given at peak densities of *C. pyri* (all biological stages), as determined by successive sampling. When dates of treatment coincided with sampling dates the samples were taken before spraying the trees. All treatments were applied with a conventional high pressure spray motor and hand spray gun.

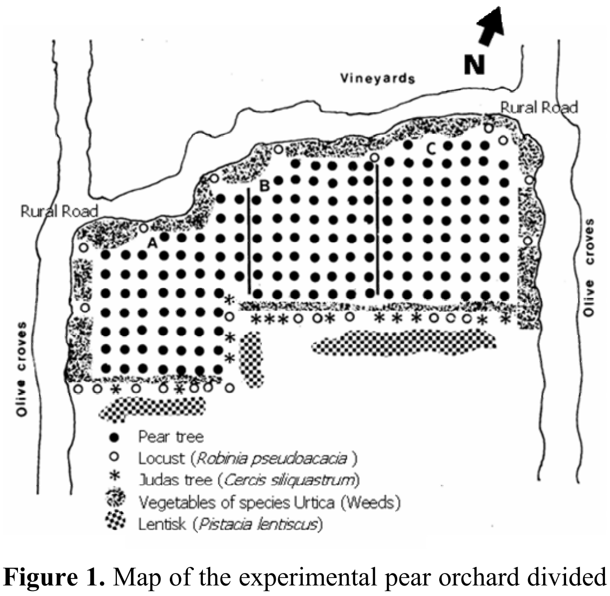

Figure 1. Map of the experimental pear orchard divided in section (A, B, C) and surrounding areas.

Table 2. Insecticide treatments per year and experimental section.

Year	Section	Insecticide	date
2001	A	deltamethrin	2/5, 1/10
	A	amitraz	23/5, 17/6, 2/8
	B	-	-
	C	diflubenzuron+fenoxycarb 50/50 a.i.	16/4
	C	diflubenzuron	16/5, 9/7
	C	potassium salts	27/8
2002	A	deltamethrin	30/4, 25/9
	A	amitraz	21/5, 2/7, 2/8
	B	-	-
	C	diflubenzuron+fenoxycarb 50/50 a.i.	10/4
	C	diflubenzuron	9/5
	C	potassium salts	28/7, 15/8

Estimation of the population density

To allow comparative researches into the impact of the chemical and natural preparations on the population dynamics of the plant pest, *C. pyri*, and its predator, *A. nemoralis*, 10 trees per section were chosen randomly and sampled weekly from the beginning of April till the end of October. Four twigs of 15-20 cm length each, carrying 12 to 18 leaves, were cut from every tree (one twig from each direction; amounting to 40 twigs per plot in total) for monitoring the psyllid larval stages. The samples were examined under the stereoscope and the immature stages of the psyllid were recorded. As pear psylla over the year develops on different plant organs (flower and leaf buds, young shoots), the samples checked varied according to season. At the same time, the beating tray (frappage) method (Burts and Brunner, 1981) was applied on another randomly chosen 10 trees per section to record the adults of *C. pyri* and the adults and larvae of its predator *A. nemoralis*. Four branches per tree received a double abrupt hit with a rod covered with styrofoam and the insects were collected in a 50x50 cm cotton fabric container. Beating of the branches was applied in the morning hours, when the activity of the adults is generally low. The method was also used to determine the appearance of the winter form of the pear psyllid adults and their proportion in the total adult population during the autumn. Sampling and beating tray method was done at man's height, preferably from the exterior part of the crown. Effort was made for the trees sampled to be of comparable vegetative growth and infestation level.

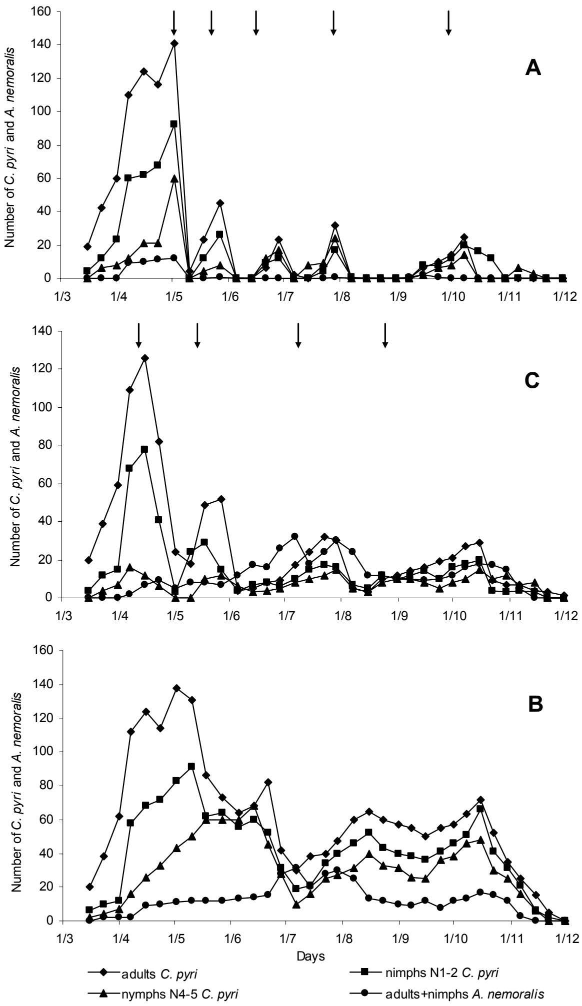

Figure 2. Population dynamics of *C. pyri* and *A. nemoralis* affected by conventional insecticides (A) and growth regulators (C) as compared to the control (B) in 2001. Arrows indicate the treatments.

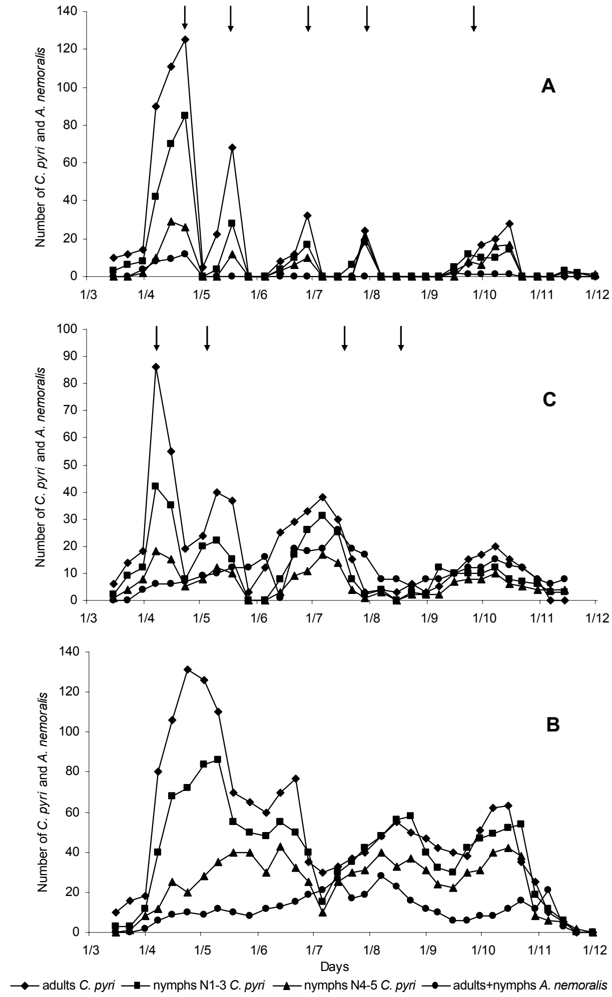

Figure 3. Population dynamics of *C. pyri* and *A. nemoralis* affected by conventional insecticides (A) and growth regulators (C) as compared to the control (B) in 2002. Arrows indicate the treatments.

At the same time an attempt was made at evaluating to what extent the lush wild vegetation edging the orchard (trees and shrubs mainly to the south and annuals, mainly *Urtica* spp., at the other sides) (figure 1), may be a "dynamic source" of beneficial insects, in particular of the predator *A. nemoralis*. To record and evaluate the population densities of the various predator species, the beating tray method was applied for every plant species separately, at the same dates of sampling the orchard, during the entire growing season.

Results and discussion

The survey showed *C. pyri* to be the only harmful species present among the insects frequently found on pear in the orchard at Koropi over the period 2001-2002.

The population dynamics of *C. pyri* and its predator *A. nemoralis* per section and per year are presented in the figures 2 and 3. *C. pyri* is shown to appear from mid March (beginning of the oviposition period of the winter form pear psyllid adult) and remain in the orchard over the entire growing season till late November (emergence of the last winter form adults) even if numbers may be rather low. Counts in the control section (B) showed that the pest appears in greatest density in spring (mid April-middle May) giving evidence for its interrelation with young foliage. During the summer, till middle October it occurred in lower, but equally significant, slightly fluctuating, densities. There was a sharp drop in density after October 10, mainly caused by migration of the insects in search of a suitable site on the trees for hibernation.

Monitoring and evaluation of the beneficial arthropods showed *A. nemoralis* to be a constant and predominant presence in the orchard. The predator apparently occurs on the trees at the same time as *C. pyri*, its population dynamics, with lower deflections, closely following that of the pest (figures 2 and 3), thus revealing the high degree of interrelation between predator and pest. In addition, population dynamics of *A. nemoralis* in the control section indicated summer to be the best time for its growth and predatory activity during both years of the survey. This is in agreement with previous observations

(Stratopoulou and Kapatos, 1995; Souliotis and Broumas, 1998; Souliotis, 1999), considering summer the best time for intervention to control the psyllid.

In section A, where broad spectrum insecticides were used, pyrethrin applied twice per year (table 2), was shown to cause a drastic drop in numbers of pest and predator immediately after treatment (figures 2 and 3). Noteworthy was in both years a slight but abrupt and permanent recovery of the *C. pyri* population after the first treatment, notwithstanding the effectiveness of the preparation. In contrast, after the second treatment, adults of the pest suddenly disappeared almost completely and the development of the L_{1-3} and L_{4-5} instar larvae was delayed for 10 till 15 days. As far as *A. nemoralis* is concerned, the second treatment of pyrethrin was to almost identical effect as the first application. However, the predator occurred on the trees till the end of November, notwithstanding its low numbers.

The amitraz preparation, three times per year applied also in section A (table 2), caused both years a drastic drop in number of all biological stadiums of pest and predator, almost immediately after each treatment, as compared to the control (figures 2 and 3). *A. nemoralis* remained very sparse, almost nil, during the whole period of treatment and started to reappear on the trees a month after the last application. In contrast, the *C. pyri* population (adults and larvae L_{1-3} and L_{4-5}) made a quick recovery after each application but each time at a much lower level. Apart of its effect on the pest, noteworthy is the high mortality that amitraz causes in *A. nemoralis* as well, particularly when it is applied repeatedly during the growing season, as in the present case, when it was applied three times within 10 weeks. The toxicity of the preparations deltamethrin and amitraz especially to *A. nemoralis* has been indicated also by others and has been rated from moderate to high, depending on the way of evaluation (laboratory, field, combination with other compounds and frequency of application) (Priore *et al*., 1988; Milenkovic *et al*., 1998; Champagne and Bylemans, 1999; Pasqualini *et al*., 1999; Schaub *et al*., 1999; 2002). Nevertheless, besides the laboratory bioassays, the toxicity of various insecticides in particular for predators, will have to be studied also in the field under various climatic conditions, allowing for the isolation and evaluation of specimens resistant to the active compounds applied so frequently. Moreover, the present research on *A. nemoralis* will be continued in the area under survey in future in that direction.

In section C, treated with specific and more environment friendly insecticides than the neurotoxicants, an immediate and significant drop in population density was observed in the pest *C. pyri* (adults, larval instars), both years after every treatment, comparable to that in section A after respective treatments with broad spectrum insecticides (figures 2 and 3). After the second application already densities of *C. pyri* remained low till the end of the growing season without particular outbreaks occurring. In contrast, treatment with the IGR_s and potassium salts did not have any toxic affect on the predator *A. nemoralis*. Both years, population dynamics of the predator in section C developed undisturbed and was comparable with that in the control (section B). After the second treatment already population dynamics of pest and predator developed along a parallel course and at certain times (early June till middle August and second half of October in 2001, mid July till beginning of September in 2002) densities of the predator were even higher than the pests. Thus, timely treatments (especially in spring) with IGRs (in mixture and applied alone) significantly reduced the initial population of the psyllid. The specific activity of the insecticides mentioned above and the mild effect of the potassium salts allowed for the unhindered predatory activity of *A. nemoralis* that apparently contributed decisively in keeping the densities of *C. pyri* at very low levels till the end of the growing season. The above results are in agreement with those of others concerning treatments with diflubenzuron and fenoxycarb (Milenkovic *et al*., 1998; Pasqualini *et al*., 1999a; 2001).

In Greece, as in other countries, the monitoring of the psyllid population dynamics and studying the various factors that have an impact on it, adds decisively to proper management of the pest. However, such a control strategy has to be based equally on data on the population dynamics of the beneficial insects, in particular predators, in order to ensure their activity and profit by it (Broumas *et al*., 1989; Souliotis and Broumas, 1998; Souliotis, 1999). It thus appears that the use of selective insecticides, such as IGR_s and their mixtures at least at the time of greatest activity of the psyllid (April-June) and, if necessary, application of low toxic potassium salts mainly before harvest time will allow to profit by predatory activity, in particular of *A. nemoralis.*

Concerning the role of the wild vegetation south of the orchard as natural ecological infrastructure and dynamic source of beneficial arthropods, in the two year period of the survey 12 predator species from different families were recorded (table 3). *A. nemoralis* with relative frequency of 64% and 58.3% in 2001 and 2002 respectively is by far the predominant species. It is followed by two species at much lower, but between themselves comparable levels: *Orius* sp. (7.9% and 14.7%) and *Chrysoperla carnea* (Stephens) (11.4% and 9.3%).

The remaining species, with relative frequency varying between 0.4% and 3% depending on species and year, apparently are no potential assets to the beneficial insect fauna in the orchard. Nevertheless their predatory activity may be supplementary to that of the predominant species, mainly *A. nemoralis*, limiting the *C. pyri* population increase.

Given that *A. nemoralis* was the most abundant predator species, its relative frequency on the plant species edging the experimental pear orchard was investigated (table 4). Out of the four wild annual and perennial plant species, the greatest relative frequency of the predator was recorded both years on *Cercis siliquastrum* L. (Judas tree) (72% and 74% respectively). Both years its frequency was approximately 23% on the annual *Urtica* spp., while on locust tree (*Robinia pseudoacacia* L.) it was 5% in 2001 and 2.6% in 2002 respectively. The frequency of *A. nemoralis* on lentisc (*Pistacia lentiscus* L.) did not exceed 0.4% either year and may therefore be considered a casual event. This is in agreement with earlier observations (Souliotis and Broumas,

Table 3. Quantitative record of predator species in the wild vegetation at the southerly fringe of the orchard.

species/family	2001		2002	
	No. of insects	% of insects	No. of insects	% of insects
Coccinellidae				
Scymnus subvillosus (Goeze)	92	3.11	75	2.46
Scymnus suturalis Thunberg	77	2.61	76	2.49
Harmonia axyridis (Pallas)	61	2.06	73	2.38
Propylea quatuordecimpunctata (L.)	55	1.92	68	2.22
Coccinella septempunctata L.	42	1.42	32	1.04
Chrysopidae				
Chrysoperla carnea (Stephens)	332	11.42	285	9.30
Chrysopa pallens (Rambur)	73	2.47	61	1.99
Dichochrysa zelleri (Schueider)	63	2.13	87	2.86
Dichrochrysa prasina (Burmeister)	25	0.84	42	1.37
Anisochrysa flavifrons Brawer	12	0.40	29	0.94
Anthocoridae				
Anthocoris nemoralis (F.)	1886	63.96	1785	58.29
Orius sp.	231	7.83	449	14.66
Total	2949	100.00	3062	100.00

Table 4. Relative frequency of the predator *A. nemoralis* per plant species in the wild vegetation at the south border of the orchard.

Plant species	2001		2002	
	No. *A. nemoralis* per plant species	% *A. nemoralis* per plant species	No. *A. nemoralis* per plant species	% *A. nemoralis* per plant species
Robinia pseudoacacia L. (locust)	145	4.92	81	2.64
Cercis siliquastrum L. (judas tree)	2117	71.79	22664	73.93
Urtica spp. (stinging nettle)	617	22.89	709	23.17
Pistacia lentiscus L. (lentisc)	12	0.40	8	0.26
Total	2949	100.00	3062	100.00

1998; Souliotis, 1999). The relative frequency of the predator on stinging nettle confirms records made earlier in other orchards (Broumas *et al*., 1989; Souliotis and Broumas, 1998; Souliotis, 1999). Plants of this genus belong to the few annuals hosting beneficial arthropods (insects and mites) and are characterized in international literature as “dynamic sources of natural ecological reserves”. It has indeed been supported that certain plants, such as *Castanea sativa* Miller (chestnut), *Rubus* sp. (bramble), *P. lentiscus*, *Alnus* sp. (alder), *Cornus sanguinea* L. (dogwood), *Sambucus nigra* L., *Sambucus* sp. (elder), *Urtica* spp. (stinging nettle), *Malva* sp. (mallow), *Amaranthus retroflexus* L. (pigweed) and others, not only just host several beneficial arthropod species, but that some may even be colonized by dense populations. In addition, an important role in the extent of colonization of host plants by beneficial arthropods is attributed to morphological characters of the leaves such as shape, pubescence and waxiness (Solomon, 1981; Walter and O’Dowd, 1992; Papaioannou-Souliotis *et al*., 2000).

The data obtained in the present two year survey clearly indicate, confirming the views of others, that certain annuals and perennials composing the hedges around orchards, may form "natural ecological reserves and dynamic sources" of populations at least for some beneficial arthropods, particularly under conditions favouring their migration to and for the protected crop (Nguyen and Merzoug, 1994; Nicoli, 1995).

Conclusions

C. pyri in the area near Koropi in Attica is the pest causing severe problems to the fruit quality of pear. It is most abundant in spring and early summer (April–mid July).

Concerning the crop protection protocol applied in the orchard, the use of the active compounds deltamethrin and amitraz (this a.i. is not allowed in many countries) must be limited in programs of integrated control, because when applied once or twice, even in early spring, the survival and growth of populations of *A. nemoralis*, the predominant predator, is not guaranteed. In contrast, repeated application of the new generation preparations diflubenzuron and fenoxycarb and combination of those and potassium salts, guarantee the population growth of *A. nemoralis,* while at the same time reducing and keeping the plant feeding *C. pyri* in check at low density levels during the whole growing season.

Out of the 12 predatory insects species recorded on the wild annual and perennial plants in the hedge at the south side of the orchard, *A. nemoralis* was found to be most abundant, its densities varying per plant species. *C. siliquastrum* is an indicator for a “natural ecological reserve and dynamic source” of populations of *A. nemoralis* especially under favourable conditions allowing for the passive flow of the predators to and for the orchard.

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Authors' addresses: Constantinos SOULIOTIS (corresponding author, p.soulioti@bpi.gr), Department of Entomology and Agricultural Zoology, Laboratory of Agricultural Entomology, Benaki Phytopathological Institute, GR 14561 Kifissia, Athens, Greece; Theodoros MOSCHOS (moschosth@hotmail.com), Regional Center of Plant Protection and Quality Control of Magnesia, Toroutzia-Nikolaidi, GR 38334 Pedion Areos-Volos, Greece.

Received March 1, 2007. Accepted January 24, 2008.