CONTROLLING PEAR PSYLLIDS BY MASS-RELEASING *Anthocoris nemoralis* AND *A. nemorum* (Heteroptera: Anthocoridae)

Lene Sigsgaard, Peter Esbjerg and Holger Philipsen

Dept. of Ecology, Royal Veterinary and Agricultural University
Thorvaldsensvej 40, DK-1871 Frederiksberg, DENMARK
e-mail: les@kvl.dk

(Received November 7, 2005/Accepted March 14, 2006)

A B S T R A C T

The most common pear psyllid in Denmark is *Cacopsylla pyri* L. (Homoptera: Psyllidae). The effectiveness of anthocorids in controlling pear psyllids was evaluated in a series of experiments conducted from 2002 to 2004. The anthocorids tested were *Anthocoris nemorum* (L.) and *A. nemoralis* F. In 2002, two preliminary studies were conducted with adult anthocorids under sleeve cages. In 2003, a more detailed study was carried on releasing *A. nemoralis* in two orchards. Females were allowed to lay their eggs under sleeve cages. The effectiveness of their young offspring in controlling pear psyllids was evaluated. In 2004, second, third and fourth instar nymphs of *A. nemoralis* were released on naturally infested trees in three orchards. In 2002, *A. nemoralis* reduced the number of psyllids by 54%, and *A. nemorum* reduced the number of psyllids by 31% in only two days. Later that year, another experiment was carried out in which one of the following combinations was placed in each cage:

- one male and one female of *A. nemorum;*
- one male and one female of *A. nemoralis;* or
- one male and one female of *A. nemorum* and one male and one female of *A. nemoralis* together.

Psyllid populations were reduced by 72 to 92% compared to the control. In 2003, the psyllid population fell by 94 to 95% on branches treated with *A. nemoralis*, and by 89 to 90% on untreated control branches in four or five weeks. The treatments were effective, although natural mortality was high. In 2004, *A. nemoralis* nymphs were released in three orchards naturally infested with pear psyllids. Psyllid populations were reduced by up to 40%. Because of dispersal and because of the fact that *A. nemoralis* nymphs can be produced cheaper than adults, releasing nymphs may be a more practical and cost effective way to control pear psyllids than releasing adults.

Key words: anthocorid, pear psyllid, inoculation, inundation, augmentation, biological control

INTRODUCTION

Pear psyllids are an increasing problem for pear growers in Denmark. Insecticides are no longer effective in controlling pear psyllids in Denmark and other European countries. A more promising control strategy is to promote the establishment of healthy populations of natural enemies in orchards and surrounding hedgerows by reducing the use of pesticides (Horton et al., 2003; Fitzgerald and Solomon, 2004). However, this strategy is not always enough to keep infestation at an economically acceptable level. An alternative strategy is to introduce mass-produced anthocorids early in the growing season.

Anthocoris nemorum (L.) and *A. nemoralis* F. are important predatory insects in orchards. *A. nemorum* preys on a wide variety of arthropods, including aphids, mites, psyllids and lepidopteran eggs and young larvae. *A. nemoralis* can also to prey on a wide variety of prey, but has a strong preference for pear psyllids, especially *Cacopsylla pyri* L. (Homoptera: Psyllidae), which is the most common pear psyllid in Denmark (Hill, 1957; Anderson, 1962ab; Collyer, 1967; Solomon et al., 1989 and 2000; Scutareanu et al., 1999; Dempster, 1963; Fauvel et al., 1984; Hodgson and Aveling, 1988).

A. nemoralis is currently mass-produced by companies specialized in biological pest control. The recommended release rate is 1000 to 1500 adults per hectare at five or six release points. In Italy, however, trial releases of *A. nemoralis* adults at similar densities were ineffective (Beninato and la Morella, 2000). In the Netherlands, a trial release of 1200 adults at 36 release points per hectare was also ineffective (M. Kers, personal communication). In Southern France, trial releases of 17,000 to 24,000 adults per hectare were effective regardless of the initial infestation level (D'Arcier et al., 2001). Spring releases at rates of 2,600 to 7,200 adults were more or less effective, depending on the timing of the release and pesticide use. However, it is difficult to interpret the results of these trials because no controls were apparently carried out.

In France, releasing *A. nemoralis* eggs was effective, but labor intensive. Mortality was also high (Rieux et al., 1994). In the United States, releasing nymphs was also effective at a increased release rate of 300 nymphs per tree (Unruh and Higbee, 1994).

The aim of this study was to evaluate the effectiveness of anthocorids in controlling pear psyllids.

In 2002, two preliminary studies were conducted with adult anthocorids under sleeve cages.

In 2003, a more detailed study was carried on releasing *A. nemoralis* in two orchards. Females were allowed to lay their eggs under sleeve cages. The effectiveness of their young offspring in controlling pear psyllids was evaluated.

In 2004, second, third and fourth instar nymphs of *A. nemoralis* were released on naturally infested trees in three orchards.

MATERIAL AND METHODS

Females of *A. nemorum* were collected in the field. *A. nemoralis* was provided by EWH BioProduction, which specializes in raising *A. nemoralis* in the laboratory. Both species were raised following the procedure described by Sigsgaard (2005b).

For five to seven days before the experiments, both the *A. nemorum* females collected from the field and the newly emerged *A. nemoralis* adults were allowed to mate and were fed on eggs of the grain moth *Sitotroga ceralella* Olivier (Lepidoptera: Gelechidae).

All experiments were conducted on pear trees of the cultivar 'Clara Friis', the variety most widely cultivated in Denmark.

The sleeve cages used in 2002 and 2003 were constructed of very fine mesh and measured 30 × 50 cm. The sleeve cages covered approximately 35 cm of the apical part of the branches, leaving room for shoot growth.

In 2004, small cardboard boxes each containing ten *A. nemoralis* nymphs were placed on the trees. The boxes measured about five cm on each side.

In June 2002, sleeve cages were placed over individual branches of pear trees growing the pometum belonging to the Royal Veterinary and Agricultural University. Adult *C. pyri* were placed in the cages and allowed to lay their eggs. After ten days, the adult psyllids were removed. One adult female of either *A. nemorum* or *A. nemoralis* was then placed in each cage. After two days, the anthocorids were removed and the remaining psyllid eggs and nymphs were counted in the laboratory.

In August, 2002, anthocorids were placed in sleeve cages on branches heavily infested with pear psyllids in an orchard on the island of Fejø. One of the following combinations was placed in each cage:

- one male and one female of *A. nemorum;*
- one male and one female of *A. nemoralis;* or
- one male and one female of *A. nemorum* and one male and one female of *A. nemoralis* together.

After two weeks, the branches were cut off and examined in the laboratory.

In 2003, sleeve cages were placed on pear branches in an orchard on the island of Funen and at the university pometum. Adult *C. pyri* were placed in the cages during the first week of May on Funen and during the third week of May at the pometum. The psyllids were allowed to lay eggs in the upper twenty centimeters of the sleeve cages. After a week, the adult psyllids were removed. Two gravid *A. nemoralis* females were placed in the lower, sealed-off ten to fifteen centimeters of some of the sleeve cage and allowed to lay

their eggs. No *A. nemoralis* females were placed in the rest of the sleeve cages, which served as a control. The females were provided with an ample supply of *S. ceralella* eggs and sucrose solution. The two females were allowed to lay eggs for a week, during which they laid an average of eleven eggs. After a week, the sleeve cages were removed, exposing the shoots to natural conditions. The numbers of arthropods detected on each shoot were recorded every week for five weeks on Funen and for four weeks at the pometum. The branches were then cut off and examined in the laboratory under a stereomicroscope.

In the first week of May, 2004, second, third and fourth instar nymphs of *A. nemoralis* were released in three orchards. The first orchard was near Oure on the island of Funen, the second near Vejstrup on the island of Funen, and the third on the island of Fejø. In each orchard, two replicates of ten trees each were subjected to one of three different treatments:

- 30 nymphs per tree;
- 10 nymphs per tree;
- zero nymphs per tree (control).

The treatments were repeated after two weeks. The boxed were half filled with buckwheat husks. *S. ceralella* eggs were also placed in the boxes. Every week for six weeks, leaf samples were collected and the branches were beaten over trays in order to assess the number of arthropods.

Data were statistically elaborated using ANOVA. Data were transformed if necessary, and the transformation best fitting a normal distribution and with the most even variances was used for further analysis.

RESULTS

In 2002, there was an average of 129.5 psyllid eggs and young nymphs on each experimental branch. *A. nemoralis* reduced the number of psyllids by 54%, significantly more than *A. nemorum*, which reduced the number of psyllids by 31%. In the control treatment, slightly more psyllid eggs and nymphs were found at the end of the experiment (4%). This was probably due to the higher precision in final counts under the stereomicroscope. The effect of the treatment was highly significant (Proc GLM $F_{2.49} = 20.4$, $P < 0.0001$).

In August, 2002, the natural infestation level had risen from 0.8 eggs and less than 0.01 nymphs per leaf to 10.8 eggs and 0.8 nymphs per leaf over a two-week period. This matches the densities found in the control sleeve cages at the end of the experiment. There were significantly more eggs and nymphs in the control cages than in the cages in which anthocorids had been placed. The effect of treatment was highly significant (Proc GLM, $F_{3.43} = 11.7$, $P < 0.0001$) (Fig. 1).

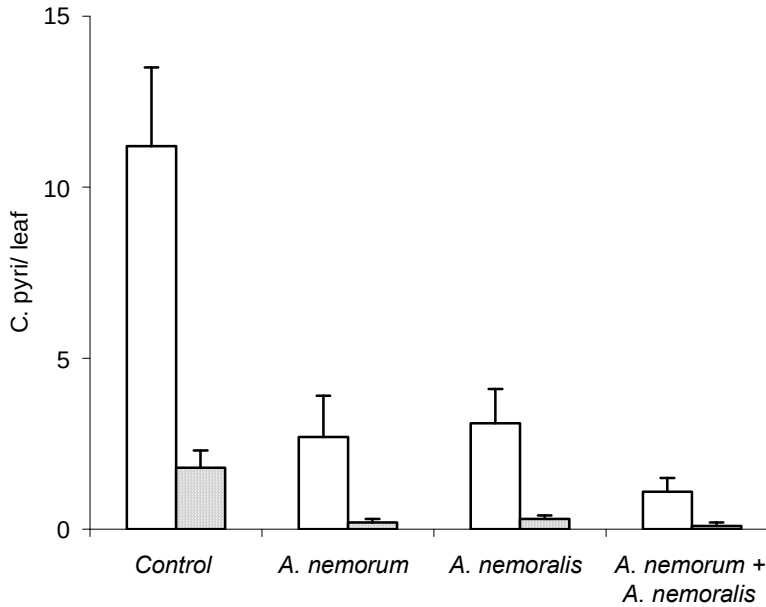

Figure 1. *Cacopsylla pyri* eggs (white) and nymphs (grey) remaining per leaf in the control, and treatments with release of a) two *A. nemoralis,* b) two *A. nemorum* or c) two *A. nemoralis* and two *A. nemorum* on existing *C. pyri* infestation in August 2002

At the beginning of the experiment in 2003, the level of natural *C. pyri* infestation was low. There was an average of 172.3 eggs in each cage in the orchard on Funen, and an average of 122.3 eggs in each cage at the pometum. At the end of the experiments, the offspring of the psyllids introduced at the beginning of the experiment had reached the middle to late instar stages. On treated branches, a significantly smaller proportion of the psyllids introduced at the beginning of the experiment had reached the middle to late instar stages (Proc Mixed, $F_{1.114} = 6.34$, $P = 0.013$). Results from the two orchards were not significantly different. On Funen, 5.1% of the middle and late instar nymphs remained on the treated branches, and 11.1% on the untreated branches. At the pometum, 6.0% of the middle and late instar nymphs remained on the treated branches, and 9.7% on the untreated branches. The treatments were effective, although natural mortality was high. Naturally occurring anthocorids were detected from the fourth week onwards.

In 2004, cool weather delayed *C. pyri* infestation. In the third week, there was still only an average of 0.3 *C. pyri* eggs and nymphs per leaf in the controls. Then the numbers started to increase. At the end of the experiment, there was an average of 4.7 *C. pyri* per leaf in the controls. The increase in the number of *C. pyri* in the two treatments and the control is presented in Figure 2. The effect of the treatment was significant (Proc Mixed $F_{2.48} = 5.6$, $P <$

0.007), as was the effect of the orchard ($F_{2.6}$ = 5.7, P = 0.04). The effects of the treatments were significantly different from the control, but not from each other. On the basis of samples collected by beating the branches, the density of anthocorids was very low at the beginning of the experiment and increased as the season progressed. At the beginning of the experiment, the density of anthocorids ranged from 0 to 10 anthocorids per plot. At the end of the experiment, the density of anthocorids ranged from 2 to 30 anthocorids per plot, with the lowest numbers recorded in the controls.

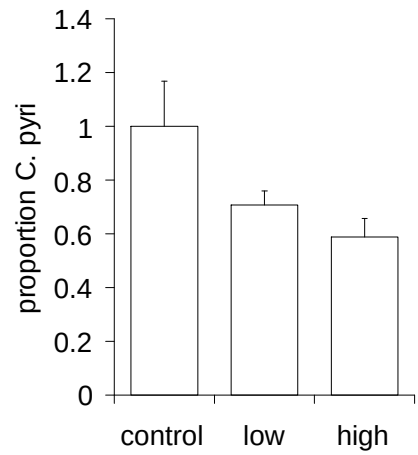

Figure 2. Relative increase in *Cacopsylla pyri* eggs and nymphs from third to sixth week in a) control (set to 1), b) two releases of ten *Anthocoris nemoralis* per tree in early and mid May or c) two releases of thirty *A. nemoralis* per tree in early and mid May

DISCUSSION

Both anthocorid adults and nymphs effectively reduced the number of pear psyllids in all experiments. In the experiment at the pometum in 2002, *A. nemoralis* was more effective than *A. nemorum* in reducing the number of pear psyllid eggs and young nymphs. On the other hand, in the experiment conducted in the late summer in 2002, *A. nemoralis* and *A. nemorum* reduced were equally effective in reducing the number of pear psyllids. In laboratory experiments, *A. nemoralis* preferred to feed on *C. pyri* rather than on aphids, and preferred to lay its eggs on pear trees rather than on apple trees. *A. nemorum*, on the other hand, preferred to feed on aphids than on *C. pyri,* and preferred to lay its eggs on apple trees rather than on pear trees (Sigsgaard 2004, 2005a). For this reason, we chose to concentrate on *A. nemoralis* in the later trials.

At the end of experiments in 2003, the psyllid eggs released at the beginning of the experiment had developed into middle and late instar nymphs. In both orchards, the proportion of the psyllids remaining was significantly lower on treated branches than on untreated branches. Anthocorids were ineffective against psyllid eggs laid toward the end of the experiment, probably because of the reduction in the number of young anthocorids due to dispersal and mortality, and because of the influx of gravid adult psyllid females. Because the experimental plots were small in relation to the orchards, the mass influx of *C. pyri* from surrounding orchards onto the experimental plots was a risk. This influx was especially evident in the orchard at Oure. Analysis had to be restricted to the population introduced at the beginning of the experiment. In a larger scale experiment, the influx of adult psyllids from nearby trees would likely be less of a problem.

In 2004, releasing *A. nemoralis* nymphs effectively reduced the number of pear psyllids in all orchards in spite of the fact that May was cold and windy, and few psyllids were detected at the beginning of the experiment, especially at Vejstrup and Fejø. As in 2003, influx reduced the effectiveness of *A. nemoralis* on the small experimental plots more than would be expected in a large-scale field release.

The instar stage of the nymphs when they are released is an important factor determining the effectiveness of mass releases. In the experiments in 2002, adult anthocorids effectively reduced the number of psyllids. In theory, adult psyllids are especially effective not only because they control psyllids by themselves, but also because they can produce numerous offspring. Releasing as few as 1500 adults per hectare should be enough to ensure effective control. Assuming that half of the adults released are females, and that each female lays one hundred eggs in her month-long lifetime, a release of 1500 adults should result in the production of 75,000 offspring. At a tree density of 2500 trees per hectare, this would mean a density of 30 *A. nemoralis* eggs per tree. In reality, however, the number of eggs laid per female is like to be less, and the highly mobile adults are likely to disperse. Dispersal may explain why trial releases of adults in Europe have not been effective (Beninato and la Morella., 2000; M. Kers, personal communication). However, this cannot be confirmed, because dispersal was not taken into account in these trials. Releasing adults in higher numbers may ensure effective control, although further study is needed (D'Arcier et al., 2001).

The experiment in 2003 mimicked a situation in which two females would stay and lay their eggs on a single tree for a week. The females in this experiment produced at total of 11 offspring a week. Under laboratory conditions, a female usually lays one or two eggs a day, which translates into 14 to 28 eggs for two females per week. Therefore, if the weather had been warmer, the females in this experiment could have laid more eggs. In the experiment in 2003, the *A. nemoralis* offspring reduced the psyllid population to half the size of the population in the controls. However, they were ineffective in controlling the later flush of psyllid eggs.

Releasing nymphs, as was done in 2004, is more effective than releasing adults because dispersal is less of a problem. In modern orchards with trees planted close to each other within the rows, nymphs can still spread along the rows. Nymphs probably have to be released in higher numbers than adults, but cost lest per individual than adults. The survival of nymphs can be enhanced by providing an alternative source of food such as *S. ceralella*, even though *A. nemoralis* prefers to feed on pear psyllids (Sigsgaard, unpublished).

Repeated releases ensure that the population of predators remains high enough to be effective. During the last weeks of the experiment in 2004, the number of psyllids increased in all treatments, which means that a third release may have been justified.

When beneficial insects are mass released in the field, the natural populations of arthropods with which they will interact has to be taken into account. In the experiments conducted in 2003, natural predation substantially increased mortality in *A. nemoralis.* Mass releasing anthocorids may help offset the losses due to natural predation to the point at which effective psyllid control is still possible.

Because of dispersal and because of the fact that *A. nemoralis* nymphs can be produced cheaper than adults, releasing nymphs may be a more practical and cost effective way to control pear psyllids than releasing adults.

Acknowledgements. The authors wish to thank Howard Thistlewood, Canada, for valuable discussions and to Christine Kastrup for practical assistance. Thanks to Birgitte Petersen, Fejø experimental orchard and to growers Møller Voigt-Petersen, Oure, Niels Mortensen, Vejstrup and Finn Sloth, Fejø for their positive collaboration and support. Also thanks to Svend Ramborg, the Danish agricultural advisory service, for sharing his long experience in orchard systems. Research was funded by the Danish Directorate for Food, Fisheries and Agri Business.

REFERENCES

Anderson N.H. 1962a. Growth and fecundity of *Anthocoris* spp. reared on various prey (Hetroptera: Anthocoridae). ENT. EXP. APPL. 5: 40-52.

Anderson N.H. 1962b. Bionomics of six species of *Anthocoris* (Heteroptera: Anthocoridae) in England. TRANS. ENT. SOC. LONDON 114: 67-95.

Beninato S., la Morella S. 2000. Control of Cacopsylla pyri with massive releases of *Anthocoris nemoralis* in pear orchards. GIORNATE FITOPATOLOGICHE, PERUGIA 1: 367-372.

Collyer E. 1967. On the Ecology of *Anthocoris nemorum* (L.) (Hemiptera: Heteroptera). PROC. ENT. SOC. LONDON 42: 107-118.

Dempster J.P. 1963. The natural prey of three species of *Anthocoris* (Hetroptera: Anthocoridae) living on broom (*Sorothamnus scoparius*). ENT. EXP. APPL. 6: 149-155.

D'Arcier F.F., Millot P., Belzunces L.P. 2001. Lâchers inoculatifs d'*Anthocoris nemoralis* F en verger de poiriers. PHYTOMA 544: 76-78.

Fauvel G., Thiry M., Cotton D. 1984. Progress towards the artificial rearing of *Anthocoris nemoralis* F. BULL. OILB SROP 7: 176-183.

Fitzgerald J.D., Solomon M.G. 2004. Can flowering plants enhance numbers of beneficial arthropods in UK apple and pear orchards? BIOCONTROL SCI. TECHNOL. 14: 291-300.

Hill A.R. 1957. The biology of *Anthocoris nemorum* (L.) in Scotland (Hemiptera: Anthocoridae). TRANS. ENT. SOC. LONDON 109: 379-394.

Hodgson C., Aveling C. 1988. Anthocoridae. In: A.K. Minks, P. Harrewijn (eds.), Aphids, their biology, natural enemies and control, vol 2B, pp. 279-292.

Horton D.R., Broers, D.A., Lewis R.R., Granatstein D., Zack R.S., Unruh T.R., Moldenke A.R., Brown J.J. 2003. Effects of mowing frequency on densities of natural enemies in three Pacific Northwest pear orchards. ENT. EXP. APPL. 106: 135-145.

Rieux R., Fauvel G., Faivre D.A., Fournage G., Lyoussoufi A. 1994. Study of biological control against *Cacopsylla pyri* (L.) in pear orchards by experimental release of *Anthocoris nemoralis* F. in the egg stage. II. – Results and discussion. BULL. OILB SROP 17: 120-124.

Scutareanu P., Lingeman R., Drukker B., Sabelis M.W. 1999. Cross-correlation analysis of fluctuations in local populations of pear psyllids and anthocorid bugs. ECOL. ENT. 24: 354-362.

Sigsgaard L. 2004. Oviposition preference of *Anthocoris nemorum* and *A-nemoralis* for apple and pear. ENT. EXP. APPL. 111: 215-223.

Sigsgaard L. 2005a. Prey preferences of *A. nemoralis* and *A. nemorum* (Heroptera: Anthocoridae) and their predation behaviour towards Pear psyllid, *Cacopsylla pyri*. IOBC-WPRS BULL. 28(7): 225-228.

Sigsgaard L. 2005b. Oviposition preference of *Anthocoris nemoralis* and *A. nemorum* (Heteroptera: Anthocoridae) on pear leaves affected by leaf damage, honeydew and prey. BIOCONTROL SCI. TECHNOL. 15: 139-151.

Solomon M.G., Cranham J.E., Easterbrook M.A., Fitzgerald J.D. 1989. Control of the pear psyllid, *Cacopsylla pyricola*, in South East England by predators and pesticides. CROP PROTECT. 8: 197-205.

Solomon M.G., Cross J.V., Fitzgerald J.D., Campbell C.A.M., Jolly R.L., Olszak R.W., Niemczyk E., Vogt H. 2000. Biocontrol of pests of apples and pears in northern and central Europe – 3. Predators. BIOCONTROL SCI. TECHNOL. 10: 91-128.

Unruh T.R., Higbee B.S. 1994. Releases of laboratory reared predators of pear psylla demonstrate their importance in pest suppression. OILB SROP, pp. 146-150.

ZWALCZANIE MIODÓWEK GRUSZOWYCH RZEZ MASOWE WPROWADZANIE *Anthocoris nemoralis* I *Anthocoris nemorum* (Heteroptera: Anthocoridae)

Lene Sigsgaard, Peter Esbjerg i Holger Philipsen

STRESZCZENIE

Najpowszechniej występującą miodówką na gruszach w Danii jest *Cacopsylla pyri* L. (Homoptera: Psyllidae). W latach 2002-2004 przeprowadzono serię badań nad efektywnością pluskwiaków drapieżnych z rodziny dziubałkowatych (Anthocoridae) w zwalczaniu miodówek na gruszach. Testy przeprowadzono z dwoma gatunkami pluskwiaków *Anthocoris nemorum* (L.) i *Anthocoris nemoralis* F. Dwa wstępne testy z owadami dorosłymi dziubałków przeprowadzono w roku 2002 w cienkich izolatorach nakładanych na pędy. W 2003 roku przeprowadzono dokładniejsze obserwacje z wypuszczaniem *A. nemoralis* w dwóch sadach. Umieszczone w izolatorach samice złożyły jaja, a następnie oceniano efektywność młodych larw *A. nemoralis* w wyniszczaniu miodówek. Z kolei w roku 2004 w trzech sadach na drzewa zasiedlone przez miodówki wypuszczono larwy drugiego, trzeciego i czwartego stadium rozwojowego *A. nemoralis*. W roku 2002 w ciągu 2 dni *A. nemoralis* zredukował liczbę miodówek o 54%, a *A. nemorum* o 31%. W późniejszym okresie tego roku przeprowadzono w izolatorach inny eksperyment, w którym zastosowano następujące kombinacje:

- 1 samica i 1 samiec *A. Nemorum*;
- 1 samiec i 1 samica *A. Nemoralis*;
- 1 samiec i 1 samica *A. nemorum* + 1 samiec i 1 samica *A. nemoralis* razem.

Populacja miodówek została zredukowana o 72 do 92% w porównaniu do kontroli. W 2003 roku populacja miodówek zmniejszyła się w ciągu 4-5 tygodni o 94-95% na gałęziach z *A. nemoralis* i o 89 do 90% na gałęziach bez drapieżcy. W 2004 larwy *A. nemoralis* wypuszczone w trzech sadach zasiedlonych przez miodówkę zredukowały jej populację o 40%. Biorąc pod uwagę mniejszą dyspersję larw i niższy koszt hodowli larw niż owadów dorosłych, wykorzystanie larw jest bardziej praktycznym i ekonomicznie uzasadnionym sposobem w zwalczaniu miodówek niż wykorzystanie owadów dorosłych tego gatunku.

Słowa kluczowe: zwalczanie miodówek, *Cacopsylla pyri,* Psyllidae, *Anthocoris nemoralis, Anthocoris nemorum*, Anthocoridae