ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

Research Article/Araştırma Makalesi

Determination of Variation in Egg Hatching and Prey Consumption Rates of Different Biological Stages of *Anthocoris nemoralis* (Hemiptera: Anthocoridae) Exposed to Different Insecticides

Baboo Ali*

Canakkale Onsekiz Mart University, Faculty of Agriculture, Department of Field Crops–17100/Canakkale, Turkey
*Corresponding author: babooali@comu.edu.tr

Received: 28.08.2020 Accepted: 21.12.2020

Abstract

This research has been carried out to determine the prey consumption of different biological stages (3rd and 5th nymphal instars + male and female individuals) as well as the egg hatching rate of the predatory insect, *Anthocoris nemoralis* (F.) (Hemiptera: Anthocoridae) of *Cacopsylla pyri* (Hemiptera: Psyllidae), occurred at three different time periods (24, 48 and 72 hours) under four different insecticide (Spinetoram, Chlorpyrifos ethyl, Diflubenzuron and Spirotetramat) treated conditions. According to the results of this research, the average per day prey consumption (eggs of *Ephestia kuehniella*) rates of different biological stages of *A. nemoralis* in an insecticide treated environment was determined highest as 27.70% in female individuals and lowest as 18.44% in 3rd nymphal instars of the predatory insect. The highest prey consumption rate was noted in control (distilled water) treatments with 30.83% and the lowest (20.56%) was recorded in spirotetramat treated experiments when taken into account the average per day prey consumption rate of different biological stages depending on applied insecticides. The average prey consumption of biological stages of predatory insect correlated to different treated insecticides was found to be 27.81%. As a result of keeping *A. nemoralis* under insecticide treated environments for five days, it was observed that there was no egg hatching at the end of 1st day (24 hours) and 2nd day (48 hours), however, egg hatching rate increased to 21.71% at the end of 3rd day (72 hours), to 49.11% at the end of 4th day (96 hours) and to 58.11% on the 5th day (120 hours) after the conduction of research experiments. At the end of the 5th day, highest egg hatching rate (32.43%) was determined in control treatment followed by diflubenzuron with 30.35%, while the lowest egg hatching rate (14.70%) has been recorded in chlorpyrifos ethyl according to the average insecticide application.
Keywords: *Anthocoris nemoralis*, egg hatching, insecticide, prey consumption, biocontrol.

Farklı İnsektisitlere Maruz Bırakılan *Anthocoris nemoralis* (Hemiptera: Anthocoridae)'in farklı Biyolojik Dönemlerindeki Av Tüketim ve Yumurta Açılış Oranındaki Değişiminin Belirlenmesi

Öz

Bu araştırma armut psillidi (*Cacopsylla pyri*) (Hemiptera: Psyllidae)'nin avcı böceği olan *Anthocoris nemoralis* (F.) (Hemiptera: Anthocoridae)'in farklı biyolojik dönemlerinin (3. ve 5. nimf ile dişi ve erkek bireyleri) 4 farklı insektisitli (Spinetoram, Chlorpyrifos Ethyl, Diflubenzuron ve Spirotetramat) ortamda 3 farklı zamanda (24, 48 ve 72 saat) ortaya çıkan av tüketim ile yumurta açılış oranlarını tespit amacıyla yürütülmüştür. Araştırma sonuçlarına göre insektisitli ortamda *A. nemoralis*'in farklı biyolojik dönemlerinin bir günlük ortalama av tüketim oranı en fazla (*Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) yumurtaları) %27.70 ile dişi avcı böcek, en az ise %18.44 ile 3. nimf döneminde belirlenmiştir. Av tüketim oranının biyolojik dönemlerine bağlı olarak uygulanan insektisitlerin ortalamalarına bakıldığında en yüksek av tüketim oranı %30.83 ile kontrol (saf su) grubunda, en düşük ise Spirotetramat uygulamasında (%20.56) tespit edilmiştir. Farklı insektisit ve biyolojik dönemlerinin ortalama av tüketim oranı %27.81 olduğu ortaya çıkmıştır. *A. nemoralis*'in farklı insektisitli ortamlarda 5 gün boyunca tutulması sonucunda 1. (24 saat) ve 2. gün (48 saat) sonunda hiç yumurta açılışının olmadığı gözlenmiştir. Fakat 3. gün (72 saat) sonunda yumurta açılış oranı %21.71, 4. gün (96 saat) sonunda %49.11 ve 5. günde (120 saat) ise %58.11'e yükselmiştir. Beşinci gün sonunda insektisit ortalamalarına göre yumurta açılış oranı en fazla kontrol uygulamasında (%32.43) belirlenmiştir. Kontrol uygulamasını %30.35 ile diflubenzuron izlemiştir. En düşük yumurta açılış oranı (%14.70) ise chlorpyrifos ethyl uygulamasında kaydedilmiştir.
Anahtar Kelimeler: *Anthocoris nemoralis*, yumurta açılışı, insektisit, av tüketimi, biyolojik mücadele.

ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

Introduction

Pesticides have long been used to control harmful insect pests, plant diseases and weeds (Bernardes, et al., 2015). Agricultural product losses of approximately 30-35% could be experienced per annum if weeds, diseases, and insect pests are not kept under control in plant production. These losses can reach up to 100% if the above-mentioned harmful entities cause epidemic. The main goal of chemical control practices against insect pests, diseases, and weeds are to reduce or minimize the product losses which will occur in plants. Moreover, it is aimed to realize environment-friendly agriculture that does not endanger the health of human beings as well as other living things in the ecosystem while carrying out chemical control practices. The main purpose in pest control is to prevent the agricultural product losses and on the other hand to make sure a sustainable agriculture system by causing the least possible damage to environment, agroecosystem, biodiversity and human health with the appropriate insect pest, disease and weed control methods to be selected.

In Turkey, it creates negative effects in human health, environment, ecology and economy sectors due to intensive and untimely usage of pesticides, particularly, in the fields of viticulture, and pomology (Kaymak and Serim 2014). In this regard, one of the most obvious examples is experienced in pear production. Many important plant protection problems are faced in pear production and *Cacopsylla pyri* (L.) (Hemiptera: Psyllidae) is one of them (Winfield et al. 1984; Gençer and Kovancı, 2000). Pear psylla is perhaps the most serious insect pest in pear orchards (Sigsgaard, 2010). Nymphal and adult stages of pear psylla cause economic damage by feeding on green leaves and shoots of pear trees (Önuçar, 1983). Growth and development of pear trees stop in those orchards where the pear psylla population is found dense. Furthermore, fruit deformities can also occur along with the shedding of leaves and fruit before maturity. Pear psylla has gained tremendous resistance against several insecticides due to the intensive and unconscious usage of pesticides in the control of harmful insect pests, diseases, and weeds in pear orchards. That is why, the consumption of insecticides has been increasing day by day depending on pesticide resistance in *C. pyri*. As a result, alternative control methods should be introduced against the influence of *C. pyri* in pear orchards. Among these control methods, priority should be given to biological control.

The most important predatory insect, *Anthocoris nemoralis* (F.) (Hemiptera: Anthocoridae) that keeps *C. pyri* under control in the natural field conditions, comes first among the biocontrol agents (Fauvel and Atger, 1981; Hodgson and Mustafa, 1984; Er and Uğur, 1999; Gençer and Kovancı, 2000). *A. nemoralis* is a polyphagous predatory insect feeds on eggs, nymphal and adult stages of pear psylla in pear orchards and can be reared by feeding on the fresh eggs of *E. kuehniella*, *Ephestia cautella*, *Plodia interpunctella*, etc., under laboratory conditions.

This study has been carried out to determine the variation in prey consumption rates of 3rd and 5th nymphal instars as well as the male and female biological stages along with the egg hatching rate of the *A. nemoralis* when exposed to different insecticide treated environments under laboratory conditions while feeding on the fresh eggs of *E. kuehniella*. Therefore, this study will contribute to the determination of Integrated Pest Management (IPM) strategies which are primarily used in biological control of pear psylla in pear orchards in our country. Moreover, the results of this research also help our farmers and pear producers in the selection of the appropriate insecticide that could be suitable for using in the IPM programme of *C. pyri* with releasing the different biological stages of the *A. nemoralis* in pear orchards against the nymphal and adult stages of pear psylla.

Materials and Methods

Different biological stages such as 3rd and 5th nymphal instars as well as the male and female individuals of *Anthocoris nemoralis* (F.) (Hemiptera: Anthocoridae) along with the fresh eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) were used as living materials in this research. The active ingredients i.e., Chlorpyrifos ethyl, Spirotetramat, Spinetoram and Diflubenzuron insecticides (Table 1.) were used for the purpose to determine their side-effects on egg hatching and prey consumption rates of *Anthocoris nemoralis*. Firstly, the samples of adult stages of *A. nemoralis* were collected from the neglected, wild, and unsprayed pear trees situated in the District of Çubuk from Ankara Province, Turkey. Secondly, the collected live insect samples have been brought to the biological control laboratory of the Department of Plant Protection, Faculty of Agriculture in Ankara University. Later, the collected live insect specimens have been reared in an incubation room

ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

constituted with 25±1 °C temperature, 70±10% relative humidity, 16:8 hrs. (L:D) exposure period and 2500 lux light intensity. The individuals were fed on the fresh eggs of *E. kuehniella*, and tagged them as 'Çubuk Culture'.

Table 1. Insecticides their side-effects were examined on egg hatching and prey consumption of the *Anthocoris nemoralis* under laboratory conditions.

Active ingredients	**Trade names**	**Applied doses**	**Company names**	**Formulations**
Chlorpyrifos ethyl	Dursban 4	100 ml/100 lt water	Dow AgroSciences	EC
Spirotetramat	Movento 100	100 ml/ 100 lt water	Bayer CropScience	SC
Spinetoram	Delegate 250	40 ml/ 100 lt water	Dow AgroSciences	WG
Diflubenzuron	Dimilin 48	25 ml/ 100 lt water	Certis & Chemtura	SC

Firstly, the insecticide concentrations were prepared and secondly, they were sprayed with the help of a spraying tower (Potter, 1952) with an amount of 2 ml/petri dish before transferring the insects into them. After that, insecticide treated empty petri dishes were left to dry for 30-45 minutes. Later, the newly emerged (0–24 hrs.) individuals of *A. nemoralis* were selected randomly from the stock culture (Çubuk Culture), and then 1 individual from each biological stage (3rd and 5th nymphal instar + adult male and female) was transferred to per insecticide treated petri dish for determining to prey consumption rate. During the entire research, the fresh eggs of *E. kuehniella*, which were adhered on black cardboard strips (1×1 cm) with the help of distilled water and kept them at -4ºC for 72 hrs., before presented to *A. nemoralis* as food. The fresh eggs of *E. kuehniella* were presented to the individuals of the predatory insect every 24 hours during the experiment. Experimental trials were established using 6 replications for each insecticide along with a control treatment, and 1 insect individual (3rd and 5th nymphal instar + adult male and female) has been placed in each replication (insecticide treated petri dish). The experimental trials have been carried out separately each for 3rd and 5th nymphal instars as well as the adult male and female individuals of *A. nemoralis*.

Effects of insecticides on prey consumption of *Anthocoris nemoralis* (F.)

During the research, the fresh eggs of *E. kuehniella*, which were adhered on black cardboard strips with the help of distilled water and kept them at -4ºC for 72 hours before presented to the 3rd and 5th nymphal instars along with the adult male and female individuals of the predatory for determining the prey consumption rates of different biological stages of the *A. nemoralis*. For this purpose, white blotting paper was placed on the bottom of each petri dish before transferring the eggs of *E. kuehniella* and a single predator of the required stage was then allowed to feed on the eggs of *E. kuehniella*. After 24 hours of the conduction of experiments, the consumed eggs of *E. kuehniella* by the 3rd and 5th nymphal instars as well as the male and female individuals of *A. nemoralis* were counted separately under binocular microscope and then recorded. Within the period of 24 hours, if any individual of *A. nemoralis* from any petri dish died, a newly emerged individual from insect stock was taken and added to its place. The method for recording the prey consumption rate of different stages of the predatory insect was followed as described by Taleb and Sardar (2007).

Effects of insecticides on egg hatching of *Anthocoris nemoralis* (F.)

Ivy geranium, *Pelargonium peltatum* (L.) (Gereniales: Geraniaceae) has been grown under greenhouse conditions for obtaining the fresh eggs of *A. nemoralis* required for the conduction of experimental trials regarding to determine the side-effects of four different insecticides on egg hatching of *A. nemoralis*. For this purpose, the greenhouse, possesses the conditions of 25-35ºC temperature and 50-70% relative humidity, was used. Rearing technique of *A. nemoralis* and the usage of the leaves of ivy geranium as the oviposition substance described by Samsoe-Petersen et al. (1989). The females of *A. nemoralis* could lay eggs on *P. peltatum* leaves by transferring one leaf to 100 ml transparent plastic insect rearing containers with the capacity of an approximate of 20 males and 20

ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

females *A. nemoralis*. Excess eggs were eliminated with the help of a needle under binocular microscope when the number of laid eggs on each leaf of ivy geranium exceeds 30. A total of three ivy geranium leaves, one egg-containing leaf in each replicate for each insecticide (including control), were used in this experiment. The leaves of ivy geranium containing 30 newly laid eggs (0-24 hrs.) of *A. nemoralis* onto them were sprayed using the applied dose of the required insecticide by a spraying tower (Potter 1952). The number of hatched eggs were started to count 24 hours after the conduction of experiments once after every 24 hours, and the experiments regarding egg hatching under insecticide treated environment have been ended after 5 days (120 hours). The obtained data regarding egg hatching of *A. nemoralis* were recorded and then analyzed. All these experiments have been carried out under 25±1 °C temperature and 70±10% relative humidity in the biocontrol laboratory. Data regarding the egg hatching of *A. nemoralis* under four different insecticide treated conditions were analyzed by applying 'Analysis of Variance' and "Tukey" test with the help of SPSS program.

Results

Effects of insecticides on prey consumption rate of *Anthocoris nemoralis* (F.)

Per day prey consumption rates of 3rd and 5th nymphal instars as well as the adult male and female stages of *A. nemoralis* under four different insecticide treated environments were statistically found non-significant (Ffemale = 2.32, Pfemale = 0.128, Fmale = 0.85, Pmale = 0.524, F3rd = 2.91, P3rd = 0.078, F5th = 1.24, P5th = 0.356). According to the results of four different insecticides, the highest prey consumption rate has been observed in the control treatment of female containing experiment with 34.44% followed by diflubenzuron treated female experiment with the rate of 33.33%. The lowest prey consumption rate was recorded in the 3rd nymphal instars treated with spirotetramat active ingredient with 11.11% followed by diflubenzuron treated experiments again containing the same nymphal instar of *A. nemoralis* with 12.22% (Table 2.). So, the obtained data, regarding the prey consumption rates of four different biological stages of *A. nemoralis* under four different insecticide treated conditions, show that the female individuals can easily feed on prey (*E. kuehniella*'s eggs) in the presence of the effect of diflubenzuron active ingredient, and it further shows that there is not a big difference between the prey consumption rates of *A. nemoralis* under diflubenzuron treated condition and control treatment.

Table 2. Prey consumption rates of biological stages of *Anthocoris nemoralis* (F.) under insecticide treated conditions*

Active ingredients	Mean±SE			
	3rd nymph	5th nymph	Female	Male
Chlorpyrifos ethyl	17.78±5.09 a	24.44±8.38 a	20.74±10.00 a	28.89±1.92 a
Spirotetramat	11.11±5.09 a	18.89±8.39 a	25.56±10.18 a	26.66±3.33 a
Diflubenzuron	12.22±6.94 a	28.89±8.39 a	33.33±10.00 a	25.55±1.92 a
Spinetoram	22.22±5.09 a	25.55±5.09 a	24.44±5.09 a	26.55±3.85 a
Control	28.89±5.09 a	32.22±8.39 a	34.44±5.09 a	27.78±3.85 a

*: The difference between different letters in the same column is significantly important (Tukey, P≤0.05).

Egg hatching rate of *Anthocoris nemoralis* (F.) under insecticide treated conditions

The difference between the egg hatching rate of *A. nemoralis* depending on the exposure period to four different insecticides was found statistically significant, except the exposure period for 72 hours (F72= 1.08, P72= 0.416), which showed non-significant difference between the exposure time to insecticides and the egg hatching rates (F24=0.000-P24=0.000, F48=0.000-P48=0.000, F96=6.12-P=0.009 and F120=15.56-P=0.000) of *A. nemoralis* shown in Table 3. In addition to the exposure periods, egg hatching rate of *A. nemoralis* has been found statistically significant with the application of four different insecticides (Fdur=31.66-Pdur=0.000, Fmov=82.42-Pmov=0.000, Fdim=109.57-

ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

Pdim=0.000, Fdel=30.78-Pdel=0.000, Fcont=86.35-Pcont=0.000). The highest egg hatching rate of *A. nemoralis* was determined as 80.44% in the control treatment after 120 hours of exposure time. This was followed by the 120 and 96 hours of exposure period with the egg hatching rates of 61.78% and 57.78%, respectively, treated with diflubenzuron active ingredient. According to the overall obtained data, there was no egg hatching observed after 24 and 48 hours of the application of four different insecticides including control (distilled water) treatment. Table 3 shows that there was no egg hatching recorded in the first two days of the application of four different insecticides. However, newly emerged nymphs from the insecticide treated eggs of *A. nemoralis* from 3rd to 5th day of experiments were recorded. There was no further egg hatching observed after the fifth day (120 hrs.) of conduction of the experiments. After waiting for three days more without observing any egg hatching then the experiments were given an end.

Table 3. Effects of different insecticides on egg hatching rates of *Anthocoris nemoralis* (F.)*

Active ingredients	N	Mean±SE				
		24 hours	48 hours	72 hours	96 hours	120 hours
Chlorpyrifos ethyl	3	00.00±0.00 C – a	00.00±0.00 C – a	00.17±0.07 B – a	36.67±0.00 A – b	36.67±0.03 A – b
Spirotetramat	3	00.00±0.00 C – a	00.00±0.00 C – a	25.56±0.04 B – a	51.11±0.03 A – ab	57.11±0.04 A – b
Diflubenzuron	3	00.00±0.00 D – a	00.00±0.00 D – a	32.23±0.03 C – a	57.78±0.04 B – a	61.78±0.04 A – a
Spinetoram	3	00.00±0.00 C – a	00.00±0.00 C – a	23.33±0.04 B – a	45.56±0.05 A – ab	54.56±0.06 A – b
Control	3	00.00±0.00 D – a	00.00±0.00 D – a	27.28±0.03 C – a	54.44±0.03 B – a	80.44±0.05 A – a

*: The difference between different letters in the same column is significantly important (Tukey, P≤0.05).
N: number of replicates

Discussion

In this research, we observed that the prey consumption rates of the 3rd and 5th nymphal instars along with the adult male and female stages of *A. nemoralis*, exposed to four different insecticides, were found statistically non-significant. Table 2 describes that the highest prey consumption has been reported in the control treatments (28.89-34.44%) of all biological stages of *A. nemoralis*, except the male stage. Prey consumption rate has been found high (28.89%) in adult male stage of *A. nemoralis* treated with chlorpyrifos ethyl insecticide. According to the obtained results of this study, the average highest prey consumption rate (27.7%) in terms of all applied insecticides to the different biological stages of *A. nemoralis* was determined in female individuals followed by male stage, 5th and 3rd nymphal instars with the average prey consumption rate of 27.10%, 26.00% and 18.40%, respectively.

A similar study was conducted to determine the side-effects of chlorpyrifos ethyl, diazinon and fenitrothion on a predatory insects of *Andrallus spinidens* Fabricius (Hemiptera: Pentatomidae). In the experiment, five different densities (2, 4, 8, 16 and 32 larvae) of the larval stages of *Chilo suppressalis* Walker (Lepidoptera: Pyralidae) were presented to *A. spinidens* as food at 25±2 °C temperature, 60±10 % relative humidity and 16:8 (L: D) hours of lighting conditions. As a result of this study, it was determined that there was a decrease in the prey consumption rate of predatory insect depending on the application of insecticides. In addition, the side-effects of chlorpyrifos ethyl on the predatory insect was significantly lower than that of other two insecticides (diazinon and fenitrothion). In this study, the side-effects of applied insecticides were found higher on the prey consumption rate of *A. spinidens* as compared to control treatment (Gholamzadeh-Chitgar et al., 2015).

In another study, the side-effects of three different concentrations (LC_{10}, LC_{20} and LC_{30}) of fenpropathrin and abamectin active ingredients on prey consumption of female and larval stages of *Scolothrips longicornis* (Priesner) (Thysanoptera: Thripidae) were investigated when fed on the eggs of *Tetranychus urticae* (Koch)(Acari: Tetranychidae). All of three different concentrations of these two active ingredients (fenpropathrin and abamectin) significantly reduced the prey consumption rate

ÇOMÜ Zir. Fak. Derg. (COMU J. Agric. Fac.)
2020: 8 (2): 319–326
ISSN: 2147–8384 / e-ISSN: 2564–6826
doi: 10.33202/comuagri.787125

of female thrips. According to results of this study, fenpropathrin showed a higher effect on prey consumption of thrips as compared to abamectin active ingredient (Pakyari and Enkegaard, 2015). In another study, the impact of cypermethrin active ingredient on the functional response, predatory and mating behaviour of the adult stages of *Acanthaspis pedestris* (Hemiptera: Reduviidae) were examined. it was determined that as the number of prey per treatment increased then the prey capturing time and the rate of prey discovery also proportionally increased, but the attacking rate of the predatory insect reduced in control treatments (Claver et al., 2003). Similar results are also obtained by Khan (2000). Another study was conducted to determine the prey consumption rates of the female and nymphal instars of *Phytoseius plumifer* (Canestrini & Fanzago)(Acari: Phytoseiidae), which was fed with *T. urticae* exposed to subletal effects with four different concentrations of fenpyroximate and three different concentrations of abamectin. The all applied concentrations of the two acaricides (fenpyroximate and abamectin) strongly affected the prey consumption of female mites. On the other hand, female mites those exposed to fenpyroximate showed an extreme reduction in prey consumption as compared to those individuals which exposed to abamectin (Hamedi et al., 2009).

The difference between the egg hatching rates of *A. nemoralis* depending on different exposure periods in insecticide treated environments was found to be statistically significant in all treatments, except 72 hours of exposure period shown in Table 3. In this study, insecticide treated eggs of *A. nemoralis* started to hatch in all treatments from the 3rd day (72 hours) of the conduction of experiments. Later on, the egg hatching rate increased with the passage of time. As a matter of fact, we observed that there was no egg hatching on the 1st and 2nd days of the experiment in all treatments. Egg hatching occurred at the rate of 21.71%, 49.11% and 58.10% on the 3rd, 4th and 5th day of experiment, respectively. It was observed the average highest egg hatching in the control (distilled water) treatment with the rate of 34.40% followed by diflubenzuron with 30.40% and spirotetramat with 26.80%, while the lowest egg hatching rates were determined with 24.70% in spinetoram and 14.70% in chlorpyrifos ethyl treatments. In another study, subletal dose of methoprene ($C_{19}H_{34}O_3$) and Malathion ($C_{10}H_{19}O_6PS_2$) were applied to the female fourth instar larvae of *Culex quinquefasciatus* (Diptera: Culicidae). It has been observed that the application of insecticides reduced egg hatching by 36% in females compared with control treatments (Robert and Olson, 1989). In a similar study, it was observed that the subletal doses of the above mentioned insecticides shorten the life span and also reduced the egg hatching in insects (Moriarty, 1969).

Serin (2009) investigated the side-effects of 0.001, 0.01 and 0.1 ppm concentrations of Dichlorvos ($C_4H_7Cl_2O_4P$), an organophosphorus insecticide, on egg hatching of *Pimpla turionellae* L. (Hymenoptera: Ichneumonidae). All of the subletal concentrations negatively affected the egg hatching of *P. turionellae* and relatively reduced the rate of egg hatching to control treatment. Higbee et al. (1995) reported that the pyriproxyfen ($C_{20}H_{19}NO_3$) and fenoxycarb ($C_{17}H_{19}NO_4$) active ingredients reduced the egg hatching rate of *Cacopsylla pyricola* Foerster (Hemiptera: Psyllidae) for one week after exposure. An approximate of similar results have also been obtained by Ding et al. (2002) and they demonstrated that the pyriproxyfen and methoprene active ingredients have a clearly lethal effect on egg hatching of *Liposcelis entomophila* (Psocoptera: Liposcelididae).

Conclusions

In conclusion, the average per day highest prey consumption rate of different biological stages (3rd and 5th nymphal instars, adult female and male individuals) of *A. nemoralis* was determined as 27.70% in adult females under four different insecticide treated environments along with a control treatment, whereas, the average per day lowest prey consumption rate was recorded as 18.44% in the 3rd nymphal instar of *A. nemoralis*. The highest prey consumption rate was observed in control treatment with 30.83%, while the lowest (20.56%) was recorded in spirotetramat active ingredient when considering the average prey consumption rate of different biological stages of *A. nemoralis* depending on four different applied insecticides. The average prey consumption rate of different biological stages correlated to insecticides was found to be 27.81%. As a result of keeping the eggs of *A. nemoralis* under four different insecticide environments for 5 days, it observed that there was no egg hatching till the end of 1st (24 hrs.) and 2nd (48 hrs.) days of experiment. However, *A. nemoralis* egg hatching rate increased, under insecticide treated conditions, to 21.71%, 49.11% and 58.11% on the 3rd (72 hrs.), 4th (96 hrs.) and 5th (120 hrs.) days, respectively. According to the overall average

insecticide results, the egg hatching rate was determined highest in control (32.43%) treatment, which is followed by diflubenzuron treated eggs of the predatory bug with 30.35%; while the eggs of *A. nemoralis*, treated with chlorpyrifos ethyl active ingredient, had the lowest egg hatching rate of 14.70% at the end of the 5th day of experiments. It is concluded that the application of four active ingredients significantly affect the prey consumption as well as the egg hatching of *A. nemoralis*.

Acknowledgements: Author is very grateful to the Scientific and Technological Research Council of Turkey (TÜBİTAK-2215-Doctoral Fellowship Award) for financially supported this research work. Moreover, this research article is a part of the PhD dissertation of the author of this article.

Literature

Bernardes, M.F.F., Pazin, M., Pereira, L.C., Dorta, D.J. 2015. Impact of pesticides on environmental and human health. Book: Toxicology studies-cells, drugs and environment, Intech, 1-39 pp.

Claver, M.A., Ravichandran, B., Khan, M.M., Ambrose, D.P. 2003. Impact of cypermethrin on the functional response, predatory and mating behaviour of a non-target potential biological control agent *Acanthaspis pedestris* (Stål) (Heteroptera: Reduviidae). J. Appl. Ent., 127, 18-22.

Ding, W., Shaaya, E., Wang, J.J., Zhao, Z.M., Gao, F. 2002. Acute lethal effect of two insect growth regulators on *Liposcelis entomophila* (Psocoptera: Liposcelididae). Zoological Research, 23: 173–176.

Er, H., Uğur, A. 1999. Ankara ilinde *Cacopsylla pyri* (L.) (Homoptera: Psyllidae)'nin doğal düşmanları ve populasyon değişimleri üzerinde araştırmalar. Türkiye IV. Biyolojik Mücadele Kongresi, 295-307 s., Adana.

Fauvel, G., Atger, P. 1981. Study on the build-up of insect predators and their relation to the pear psyllid (*Psylla pyri* L.) and the red spider-mite (*Panonychus ulmi* Koch) in two orchards in southeastern France in 1979. Agronomie, 1(9): 813-820.

Gençer, N.S., Kovancı, B. 2000. Bursa ilinde armutlarda zararlı *Cacopsylla pyri* (L.) (Homoptera: Psyllidae)'nin biyolojisi. Türkiye IV. Entomoloji Kongresi, 101-110 s., Aydın.

Gholamzadeh-Chitgar, M., Hajizadeh, J., Ghadamyari, M., Karimi-Malati, A., Hoda, H. 2015. Effects of sublethal concentration of diazinon, fenitrothion and chlorpyrifos on demographic and some biochemical parameters of predatory bug, *Andrallus spinidens* Fabricius (Hemiptera: Pentatomidae) in laboratory conditions. International Journal of Pest Management, 61(3):204-211.

Hamedi, N., Fathipour, Y., Saber, M., Garjan, A.S. 2009. Sublethal effects of two common acaricides on the consumption of *Tetranychus urticae* (Prostigmata: Tetranychidae) by *Phytoseius plumifer* (Mesostigmata: Phytoseiidae). Systematic and Applied Acarology, 14(3): 197–205.

Higbee, B.S., Horton, D.R., Krysan, J.L. 1995. Reduction of egg hatch in pear psylla (Homoptera: Psyllidae) after contact by adults with insect growth regulators. J. Econ. Entomol., 88(5): 1420–1424.

Hodgson, C.J., Mustafa, T.M. 1984. Aspect of chemical and biological control of *Psylla pyricola* Förster in England. SROP/WPRS Bull., 7(5): 330-353.

Kaymak, S., Serim, T.A. 2014. Pestisit sektöründe araştırma ve geliştirme. Meyve Bilimi, 2(1): 27-34.

Khan, M.M. 2000. Impact of cypermethrin and neemgold on a non-target potential biocontrol agent *Acanthaspis pedestris* (Stål) (Insecta: Heteroptera: Reduviidae). M.Sc. Thesis. St. Xavier's College, Palayankottai, India.

Moriarty, F. 1969. The sublethal effects of synthetic insecticides on insects. Biological Reviews, 44(3): 321–356.

Önuçar, A. 1983. İzmir ve çevresinde bitkilerde zararlı Psyllid (Homoptera: Psyllinea) türlerinin tanınmaları, konukçuları ve taksonomileri üzerinde araştırmalar. T.C. Tarım ve Orman Bakanlığı, Zirai Mücadele ve Zirai Karantina Genel Müdürlüğü, İzmir Bölge Zirai Mücadele Araştırma Enstitüsü Müdürlüğü, Araştırma Eserleri Serisi No: 44, 122 s., Ankara.

Pakyari, H., Enkegaard, A. 2015. Sublethal effects of abamectin and fenpropathrin on the consumption of *Tetranychus urticae* eggs by *Scolothrips longicornis*. Journal of Systematic and Applied Acarology, 20, 357–365.

Potter, C., 1952. An improved laboratory apparatus for applying direct sprays and surface films with data on the electrostatic charge on atomized spray fluids. *Annals of Applied Biology*, 39, 1–28.

Robert, L.L., Olson, J.K. 1989. Effects of sublethal dosages of insecticides on *Culex quinquefasciatus*. J. Americ. Mosq. Control Assoc., 5(2): 239–246.

Samsoe-Petersen, L., Bigler, L., Bogenshütz, H. et al. 1989. Laboratory rearing techniques for 16 beneficial arthropod species and their prey/hosts. Z. Pflanzenkrankh., Pflanzensch, 96, 289-316.

Serin, M.E. 2009. Diklorvos'un subletal dozlarının Pimpla turionellae (L.)'nin yumurta açılımına etkisi. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü (Yüksek Lisans Tezi), s; 36.

Sigsgaard, L. 2010. Habitat and prey preferences of the two predatory bugs *Anthocoris nemorum* (L.) and *A. nemoralis* (Fabricius) (Anthocoridae: Hemiptera-Heteroptera). Biological Control, 53(1): 46-54.

Taleb, M.A., Sardar, M.A. 2007. Predation efficiency of insect predators in suppressing red mite, *Tetranychus bioculatus* attacking marigold. J. Agric. Rural Dev., 5(1&2): 98-104.

Winfield, A.L., Hancock, M., Jackson, A.W., Hommon, R.P. 1984. Pear sucker (*Psylla pyricola*) in Southeast England. SROP/WPRS Bull., 7(5): 45-54.