Simionca Mărcăşan LI *et al.* (2022)
Notulae Botanicae Horti Agrobotanici Cluj-Napoca
Volume 50, Issue 4, Article number 13022
DOI:10.15835/nbha50413022
Research Article

The importance of assessing the population structure and biology of psylla species for pest monitoring and management in pear orchards

Leontina I. SIMIONCA MĂRCĂȘAN[1], Ionuţ B. HULUJAN[2*], Teodora FLORIAN[2], Peter A. SOMSAI[3], Mădălina MILITARU[4], Adriana F. SESTRAS[5*], Ion OLTEAN[2], Radu E. SESTRAS[1]

[1]*University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Department of Horticulture and Landscape, 3-5 Manastur St., 400372 Cluj-Napoca, Romania; leontina.marcasan@usamvcluj.ro; rsestras@usamvcluj.ro*
[2]*University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Department of Plant Protection, 3-5 Manastur St., 400372 Cluj-Napoca, Romania; ionut-bogdan.hulujan@usamvcluj.ro (*corresponding author); teodora.florian@usamvcluj.ro; ion.oltean@yahoo.com*
[3]*University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Horticulture Research Station, 5 Horticultorilor St., 400457 Cluj-Napoca, Romania; petersomsai@yahoo.com*
[4]*Research Institute for Fruit Growing Pitesti, 402 Mărului St., 117450 Mărăcineni, Romania; madamilitaru77@yahoo.com*
[5]*University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Department of Forestry, 3-5 Manastur St., 400372 Cluj-Napoca, Romania; adriana.sestras@usamvcluj.ro (*corresponding author)*

Abstract

The species of pear sucker, also called pear psylla or pear psyllid, which are destructive insects belonging to the genus *Cacopsylla* (Hemiptera: Psyllidae) cause substantial damage to pear tree plantations. Two consecutive years of research were conducted on the population structure and biological cycle of psylla in a small, elderly, and unmaintained pear orchard in northern Romania. Of the two identified species (*C. pyri* L. and *C. pyricola* Forster), *C. pyri* dominated the psylla population with a percentage of 77.8-80.1%. Adults of both species emerge from hibernation in the first part of March and produce three generations per year. First-generation adults emerge in the first decade of June, the second generation in the last decade of July, and the third generation in the first decade of September as they enter the hibernation phase. Larvae of the first generation appear in the second half of April, the second generation at the end of June - the beginning of July, and the third generation in the second decade of August. There have been reports of up to 11 adults and 27 larvae per leaf, 9 larvae per petiole, and 14 larvae per fruit. The number of adults captured on yellow sticky traps exposed on the southern side of the tree crown was significantly higher compared to the northern side. Following the intense attack, the well-known cv. 'Williams' was heavily affected, pear trees were badly defoliated, blackened, and aged prematurely. The climatic conditions of the two years did not influence the phenology of the pests, but the importance of monitoring psyllids is widely argued, considering that it remains the key to integrated protection programs in pear orchards.

Keywords: *Cacopsylla pyri* L.; *C. pyricola* Förster; climate; cultivar; fruit growing; integrated pest management (IPM); orchard; plant protection; psylla phenology; *Pyrus communis* L.

Received: 02 Sep 2022. Received in revised form: 25 Nov 2022. Accepted: 28 Nov 2022. Published online: 29 Nov 2022.
From Volume 49, Issue 1, 2021, Notulae Botanicae Horti Agrobotanici Cluj-Napoca journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

The common pear tree (*Pyrus communis* L.) is one of the most important fruit species in temperate climates, ranking second in fruit output in Europe, and is grown on more than 100,000 hectares, yielding over 2 million tonnes of pears in 2019 (Le Goff *et al*., 2021; Tougeron *et al*., 2021). Numerous insect species, psylla being the most significant, frequently severely reduce the output capacity of pear trees (Bell, 2015). Pear plantations are usually affected by three species of psylla: *Cacopsylla pyri* L., *C. pyricola* Forster, and *C. pyrisuga* Forster (Hemiptera: Psyllidae). The origin of these species is the European continent, although they are also widely distributed in North America and Asia (Nin *et al*., 2012). In North America, *C. pyricola* Forste is the only species present (Montanari *et al*., 2015; Le Goff *et al*., 2021), whereas in Europe all species are present, with *C. pyri* L. having the broadest distribution; in the more northern parts, *C. pyrisuga* Forster predominates (Erler and Cetin, 2007; Bell, 2015).

There is a wealth of specialised literature describing the morphological and biological characteristics of 'psylla' insects, which belong to a group of about 3000 species of small sap-feeding insects allied to aphids and whiteflies known collectively as 'psyllids' or 'jumping plant lice' (Hodkinson, 2009), as well as the application of proper pest management in pear orchards. The following section provides a synthesis of these particularities from many specialised contributions (e.g., Westigard and Zwick, 1972; Horton, 1999; Ahmed, 2007; Valle *et al*., 2017; Khan *et al*., 2020 etc.) and from our own experience (Straulea *et al*., 1992; Sestras *et al*., 1995, 2009).

Description. The adult *Psylla pyri* L. exists in two distinct sizes and hues. The winter or hibernating form is 2.6-3 mm in length, while the summer form is 2.1-2.7 mm (Nin *et al*., 2012). Hibernating adults have a reddish-brown body with red dots on the breast, a brown abdomen and transparent front wings, brown ribs, coloured markings towards the base, and dark-brown legs. The adults of the summer form have a lighter body colour with translucent wings, a yellow head and breast with orange markings, and a green abdomen with brown dots and stripes on the rear. Both types hold their wings like a canopy over the abdomen. The rear legs are designed for jumping. When laid, the egg is elliptical and creamy white; as it approaches hatching, it gradually turns from yellow to orange. The larvae undergo five stages of development. Young larvae are yellowish with red-violet eyes; as they mature, their colour changes to brown-violet or reddish-brown with white longitudinal stripes and black specks. Beginning in their third year, they begin to develop wing buds.

Hibernant adults of *C. pyricola* Förster have a body length of 2.9-3.2 mm. Initially, the head and chest are light yellow with orange spots, the abdomen green, the back with brown stripes and spots. Over time, the head, chest, and abdominal ribs become yellow, then dark brown. The head is wide, the eyes large and hemispherical. The antennas are long and thin, with 10 joints, yellow to black-brown at the tip. The upper trunk is bulging. The legs are long and strong, brown-yellow with black femurs. The hind legs feature black bristles and are adapted for jumping. The female abdomen is yellow-orange with black bristles. Adults belonging to the summer generation have a body length of 2.1-2.9 mm, are brown-green, with six orange longitudinal bands. The head is wide, with rounded frontal lobes. The eyes are red-brown and the antennae are 1.5 times longer than the width of the head. The tibias do not feature terminal thorns. Both forms have large, transparent wings with yellow ribs and a brown spot. The egg is elliptical, cream-white to yellow, turning yellow-orange as it develops, and has a pedicle that penetrates the substrate. The larva has a flat body, 0.1-0.4 mm long, light-yellow, with brown spots on the cephalic capsule and abdomen, and red eyes. In older larvae, the dorsal part of the abdomen shows wide, black spots.

Biology. All species produce 2-3 generations a year, even four generations during warmer years. Adults hibernate either under the thickened bark layers and in their respective cracks, or in moss beds, lichen formations or under fallen leaves. In spring, as early as March, when air temperatures reach 4.5-5.7 °C, hibernating adults become active. Phenologically, this is the time when fruit buds begin to swell, allowing fleas to feed on them and thrive on tree crowns for 80-85 days. After a short feeding period, copulation and egg-laying take place, with a span of up to 60-70 days. Eggs are deposited scattered apart at the base of buds and on young shoots, and in early tree varieties they are also laid on the fresh new leaves and even on blossoms (Nin *et al.*, 2012). Adults continue to lay eggs until blossoms fall. Incubation lasts about two weeks. Hatched larvae live close together, focusing around the buds, then spreading on shoots, leaves, and flowers. While feeding, insects excrete large amounts of sugary waste, which flood the attacked tree parts. The development of the spring generation of larvae lasts 35-40 days, after which they turn into nymphs. The larvae progress through 5 larval stages. After 6-10 days, adult insects appear. First-generation adults generally appear in May. After 7-8 days of feeding, copulation takes place and then egg laying. Eggs are deposited on the back of leaves, usually in rows and near ribs. One female lays up to 500-600 eggs (Stratopoulou *et al.*, 1992). Adults of the new generation live up to 60-65 days, and egg laying takes 25-30 days. The next generations evolve in a similar way, and they overlap (Montanari *et al.*, 2015). The adults of the last generation begin the inactive winter phase starting in September. Populations of these species can be controlled by useful entomofauna, of which 14 predatory species of the order Hemiptera are more commonly found, the Antocoridae, Miridae and Nabidae families, and two parasitic species of the order Hymenoptera, the Encyrtidae family (Ahmad *et al.*, 2020; Gajski and Pekár, 2021; Kocourek *et al.*, 2021; Le Goff *et al.*, 2021).

Host-plants and damage characteristics. Monophagous species infesting pear trees, the psylla causes significant damage to untended orchard plantations. The most affected pear trees are the dwarf varieties, as well as those supported by espaliers and young trees in nurseries (Tešanović *et al.*, 2016). Adults and larvae sting and draw cellular juice from buds, young shoots, flowers and leaves. As a consequence, attacked buds dry up and fall and flowers fail to bear fruit. Leaves, covered in excreted waste, stagnate in growth, wrinkle on the edges, twist and blacken with sooty mold, which makes them fall prematurely. Various pathogens (*Capnodium salicinum* Mont.) set in and prosper feeding on the sugary waste layer, sustaining the sooty mold that ultimately blocks photosynthesis (Montanari *et al.*, 2015). The attacked shoots curve, often wither, being unable to grow, with the average length of internodes significantly reduced (Youssef, 2016). Wood growth does not mature and annual progress will often freeze. Repeated attacks reduce crops, weaken trees and even dry them out (Nin *et al.*, 2012). Fruits are also attacked, becoming small, stained, deformed and falling early on. The commercial value of the fruit crop is reduced (Tešanović *et al.*, 2016). These psylla species are also vectors of some typical pear tree pathogens (Moreno *et al.*, 2021) such as the bacterium *Erwinia amylovora* Burrill, which causes fire blight (Hildebrand *et al.*, 2000), one of the most devastating pear diseases (Sestras *et al.*, 2008). It has also been confirmed that the pear psyllid is the vector transmitting the phytoplasma known as '*Candidatus* Phytoplasma pyri' that causes a serious disease known as 'pear decline' (Tešanović *et al.*, 2016; Riedle-Bauer *et al.*, 2022).

Management. In order to eliminate these pests, chemical treatments used to be the main method. It was found, however, that resistance to commonly used pesticides such as pyrethroids would rapidly set in (Buès *et al.*, 2003; Civolani *et al.*, 2014; Bell, 2015). Considering an integrated elimination approach, the use of genetic material that is more tolerant to pest attacks has been introduced (DuPont and John Strohm, 2020), as numerous studies have shown that some wild species of pear are genetically more resistant (Montanari *et al.*, 2015). The resistance may be due to the polyphenotic profile (Fotirić Akšić *et al.*, 2015) or the morphological and anatomical characteristics of the leaves (Fotirić Akšić *et al.*, 2021), but genetically, resistance to *C. pyri* has a polygenic inheritance (Perchepied *et al.*, 2016). Genetic resistance has been confirmed in many Asian varieties and interspecific hybrids, which can be used in genetic selection and breeding programs of pear (Nin *et al.*, 2012; Emami, 2019; Li *et al.*, 2022). Such a program was developed in Cluj-Napoca to produce the Haydeea pear variety that was considered tolerant to *Cacopsylla* sp. attack (Ghidra *et al.*, 1992; Sestras *et al.*, 1999, 2009).

C. pyri has 4-5 generations per year in Europe (Civolani, 2012), and the cultivar, rootstock, ecological circumstances, and management practises of the orchard, among other factors, can have a significant impact on how the assault manifests (Sestras *et al*., 2008, 2020; Nin *et al*., 2012, 2015; Shaltiel-Harpaz *et al*., 2018). However, thorough knowledge of a pest's life cycle is essential for improving pest control and management (Civolani, 2012). For this reason, in the current study, the population structure and biology of the psylla species were examined in a plantation with old trees and no phytosanitary treatments, from a traditional pear-growing region in Transylvania, Romania. In order to develop effective pest management in pear plantations, the study's goal was to track and collect new data and useful information.

Materials and Methods

Period, area of research and procedures

The studies on the structure of *Cacopsylla* species and the biological cycle of the pests were carried out during 2018-2019. The investigations were carried out in Cireșoaia, Bistrița-Năsăud County, Romania, a village having the following geographical coordinates: 47°8′33″N, 24°3′35″E and an elevation of 446 m, situated in an area where pear trees are cultivated on relatively large areas. In order to determine the structure of the *Cacopsylla* species, the sticky yellow-coloured traps (Figure 1) were used each year, with the catch reading taking place between March and August of each year. The catch was analysed in the laboratory and the species identification was carried out according to the external morphology aspects of the captured adults.

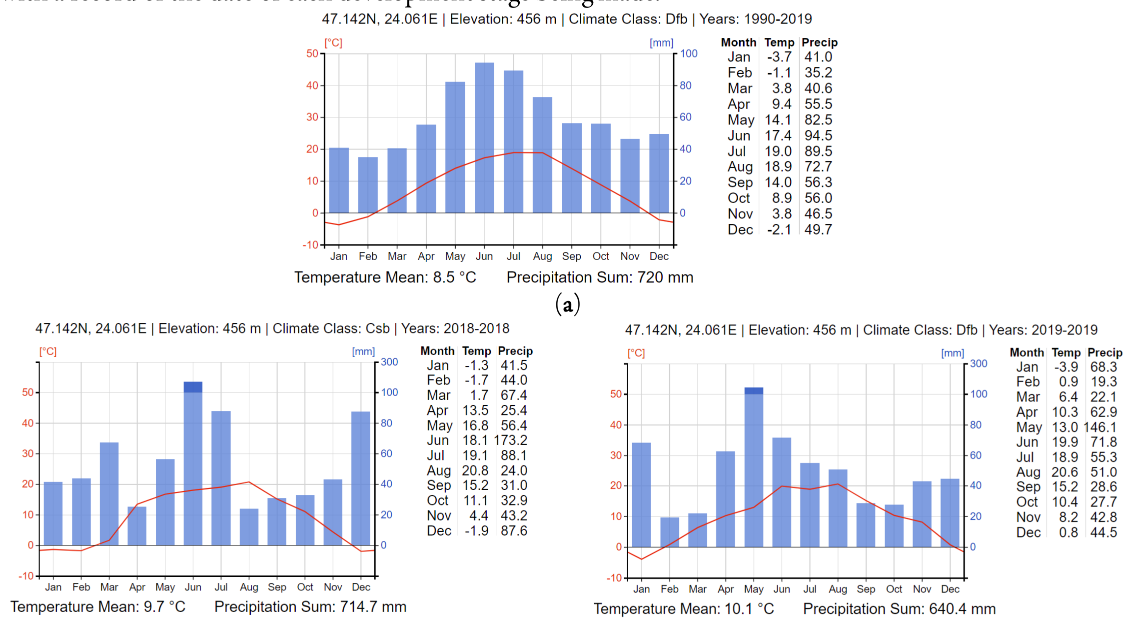
Figure 1. Catch of *Cacopsylla* spp. on the yellow sticky trap

Climatic conditions

The main climatic conditions of the study years, represented by the temperature and precipitation in the study area in the period 2018-2019, compared to the multiannual average of the period 1990-2019, based on ClimateCharts.net (Zepner *et al*., 2020) are presented in Figure 2. The average annual temperature for the period 1990-2019 was 8.5 °C, and the average annual amount of precipitation in the same period was 720 mm (Figure 2a). In 2018, precipitation was close to the multi-year average, but in 2019 it was less (640.4 mm). In the two years of observations, the monthly distribution was relatively uneven compared to the multiannual one. The least rainy months were April, August, and September in 2018 and February and March in 2019 (Figure 2b, c).

Observations and working procedures

In order to determine the biological cycle of the *Cacopsylla* species, observations were made annually on the pear trees in an area with many small private orchards, spread within the village or near it. The observations were made in a family garden, with old trees (about 30 years old), located near the house, belonging to the 'Williams' ('Bartlett') cultivar. 'Williams' is very well known and widespread in the area, being highly appreciated by the locals for many years. The time of emergence for hibernating adults was established both through direct observations on trees as well as with coloured traps. In order to determine the development sequence of the species, direct observations were made on-site. Samples of branches and leaves (100 samples per observation) were taken, from the second half of March to September, and were analysed in the laboratory, with a record of the date of each development stage being made.



(b) (c)

Figure 2. Climatic conditions in the study area: temperature and precipitation as multiannual averages (**a**) and in the two years of observations, 2018 (**b**) and 2019 (**c**)
Data taken from ClimateCharts.net (Zepner *et al.*, 2020)

Statistics

The variability of numbers of adult psylla per leaf, larvae per leaf, petiole, and fruit was presented with the help of boxplots, which represented minimum, lower quartile, median, mean, upper quartile, and maximum values of these traits. To compare the number of psyllids on a yellow sticky trap according to their position in the crown of pear trees, respectively exposure on the south or north side, the Mann-Whitney U test ($p < 0.05$) was applied, for the values resulting from every five traps per exposure. The differences between the two species of *Cacopsylla* for the traits were analyzed with the help of t-Test: Two-Sample Assuming Unequal Variances, at a significance level of $p < 0.05$. The same test and significance level was applied just in *C. pyri* to analyse if there is a statistically significant difference between generations I, II, and III, of the two different years (2018 and 2019). For the application of the test, the calendar data were transformed into days, counted from the first day and month of the start of the first stage of the biological cycle, and then cumulated according to the following stages. For a clear understanding and representation, the results were presented graphically, on the O-X axis noting the generation and the year, and on the O-Y axis the number of days, starting with the first day of each month in which the first stage of the respective biological cycle took place. Also, calculated P values were presented, knowing that for significant differences P must be less than 0.05. The statistical processing and graphic representations were carried out using Microsoft Excel software (Microsoft Corporation, 2018).

Results

Two species were reported in the existing pear tree plantations of the investigated area: *Cacopsylla pyri* L. and *C. pyricola* Förster. The species *C. pyrisuga* Förster was not identified during the two years of observations. Figure 3 shows the relative abundance of the *Cacopsylla* spp. species during the two years of study.

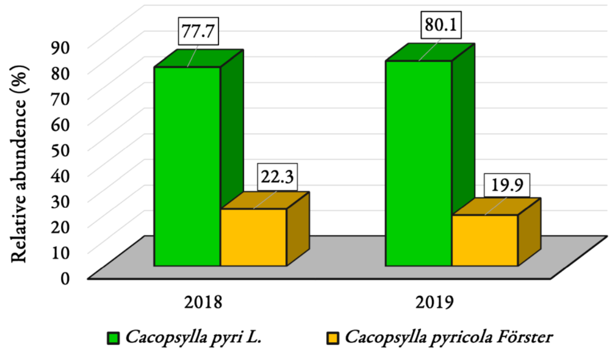


Figure 3. Relative abundance of the species *Cacopsylla* spp.

The dominant species was *C. pyri* L., which in 2018 accounted for 77.7% of all catches on the coloured traps, while in 2019 it was 80.1%. The relative abundance of the *C. pyrisuga* species was also close in the two years, 22.3% in 2018 and 19.9% in 2019. The biological cycle of the *C. pyri* species monitored during the two years of the study is presented in Table 1. Hibernating adults were reported in the first half of March (March 6, 2018, and March 12, 2019, respectively). Being species with a lower thermal threshold of about 5 °C, they have been observed feeding on buds. The feeding period for sexual maturation was between 13 and 17 days, after which copulation took place. After 7-9 days, egg laying began, marking the beginning of the first generation.

Table 1. Biological cycle of *C. pyri* L., 2018-2019

Development stage	Generation I		Generation II		Generation III	
	2018	2019	2018	2019	2018	2019
Hibernating adults	06.03	12.03	-	-		
Copulation	19.03	29.03	11.06	14.06	25.07	01.08
Egg depositing	26.03	07.04	17.06	19.06	02.08	05.08
Emergence of larvae	14.04	23.04	28.06	02.07	16.08	18.08
New generation adults	03.06	09.06	20.07	25.07	8.09	12.09
Total days/generation	73	70	33	36	37	39

Values are presented as day and month, i.e., "dd.mm" (for 'Hibernating adults' in 2018, '06.03' means March 03 etc.)

Eggs were first reported mainly at the base of buds, but as the leaves started appearing, they were laid on them as well and also on the flowers. Observations concluded that eggs were mainly deposited on the higher tree crown, on the southern and western side, with over 80% of the eggs being thus laid. Incubation took 19 days in 2018 and 16 days in 2019, so that the first larvae were reported on 14 April 2018 and 23 April 2019 respectively. Larval development took over 46-50 days and the first-generation adults appeared in the first decade of June. For the first generation, the development from egg to adult took 73 days in 2018 and 70 days in 2019 respectively. After a feeding period of 5-8 days, copulation took place and then eggs were deposited, evolving into the second generation. For this generation the incubation was 12-14 days, the larvae being reported on June 28 in 2018 and July 2 in 2019; the larval stage was 22-24 days, with adults being reported on

July 20, 2018 and July 25, 2019. The life span of this generation was 33 days in 2018 and 36 days in 2019. This was the largest generation, resulting in a very widespread attack. It has been confirmed that psyllids are strongly attracted to the colour yellow, and yellow sticky traps can be used effectively in monitoring them (Sagar and Balikai, 2013)). Thus, the number of adults captured on the yellow sticky traps was very high, showing a greater preference of the psyllids for the sun-exposed area of the crown of the trees (Figure 4a, b).

(**a**) (**b**)

Figure 4. Yellow sticky traps with catches of *Cacopsylla* spp. in the crown of pear trees of Williams cultivar: (**a**) – on the south side; (**b**) – on the north side

Therefore, comparing the number of adults of the second generation caught in the traps, a higher number was found on the traps that were placed on the southern exposure of the crown, compared to those on the northern exposure. During the flight period of the adults of the second generation, on the yellow sticky traps located on the southern side of the crown of the trees, the average number of adults captured was 18,207 adults/trap, and on those located on the northern side, 14,776 adults/trap. The Mann-Whitney U test showed that the mean number of psyllids caught on a sticky yellow trap, calculated from five traps, was significantly different ($p < 0.05$), depending on the position of the traps in the crown of trees, respectively southern or northern exposure (Figure 5).

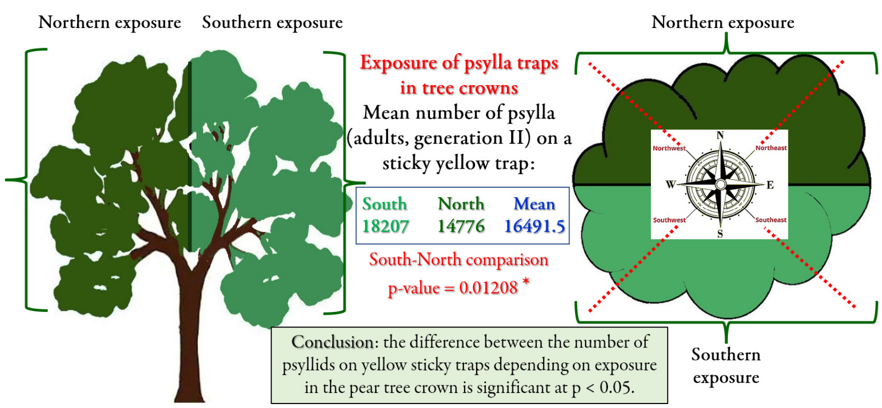


Figure 5. The average number of psyllids on a yellow sticky trap (average value calculated from five traps), according to their position in the crown of pear trees, respectively exposure on the southern or northern side; the Mann-Whitney U test was applied ($p < 0.05$)

Over 90% of the leaves had sooty mold and the attack affected shoots (Figure 6 a), leaves (Figure 6 b), leaf stalks (Figure 6 c) and fruits (Figure 6 d).

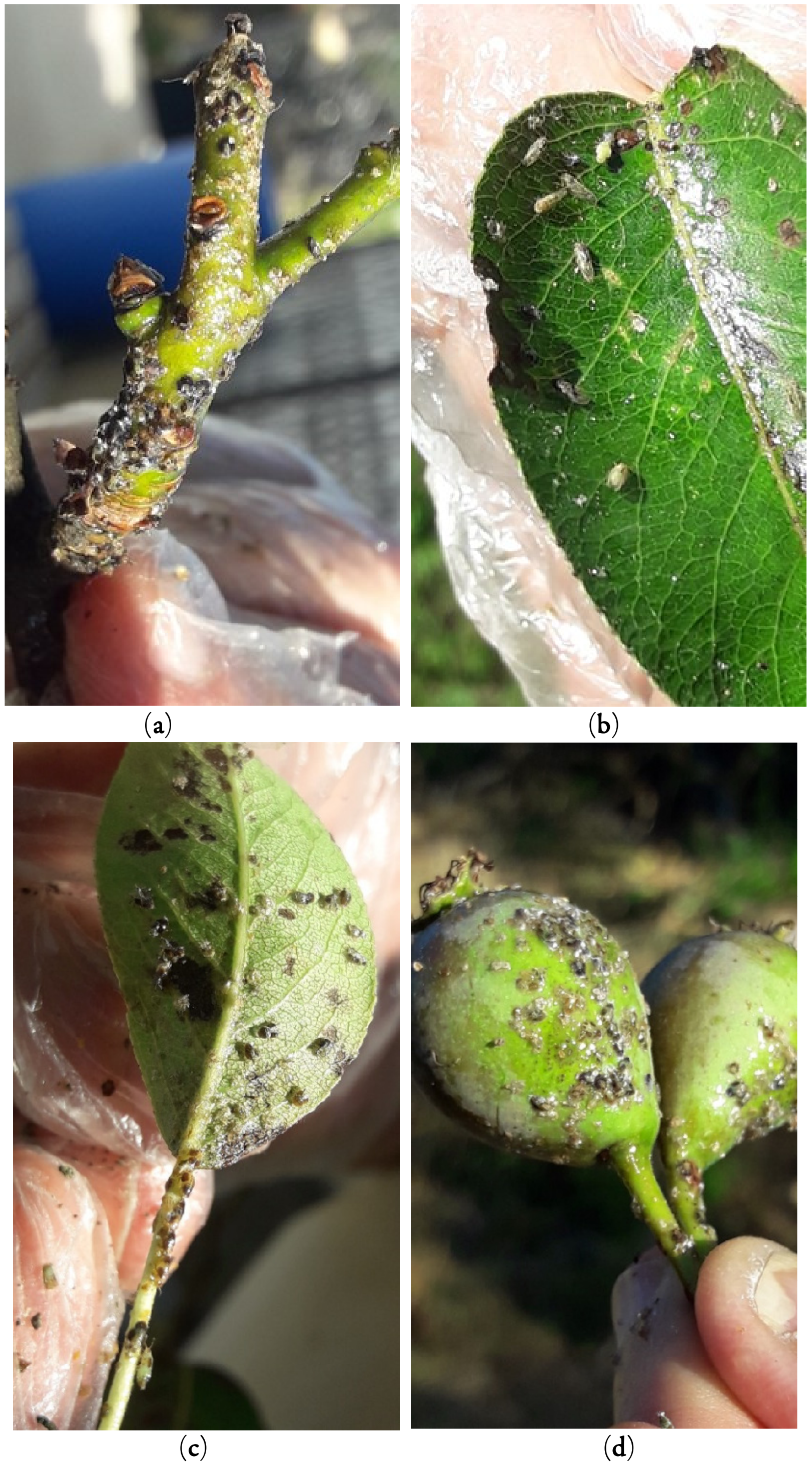


Figure 6. Attack of *Cacopsylla* spp.: (**a**) – on shoots; (**b**) – on leaves; (**c**) – on leaf stalks; (**d**) – on fruits

On a single leaf up to 27 larvae and 11 adults were reported. On the leaf stalk there were up to 9 larvae, and on the fruit up to 14 larvae. The third generation evolved from early August to the first half of September. Although in some orchards three treatments with synthetic pyrethroids were applied, in the autumn an extremely strong attack was reported, the trees being strongly defoliated and blackened with sooty mold caused by saprophytic fungi (Figure 7a, b).

(**a**) (**b**)

Figure 7. Attack of *Cacopsylla* spp. and the defoliation and weakening of the trees (**a**) and the appearance of sooty mold caused by saprophytic fungi (**b**)

At the end of September, the adults of this generation entered the winter pause. It is worth noting that the last two generations overlapped, and it is very likely that there was a partial fourth generation. Distinguishing between generations is very difficult as adults have a considerable life span as well as a long egg-laying period.

In the two years of the study (2018 and 2019), the t-Test with Two-Sample Assuming Unequal Variances revealed significant differences between the two species of *Cacopsylla* (*C. pyri* and *C. pyricola*) for the mean numbers of adult psylla per leaf, larvae per leaf, larvae per petiole, and larvae per fruit (Figure 8). When compared to *C. pyricola*, *C. pyri* showed better values for each of these traits. The variability of these attributes, including the minimum, lower quartile, median, upper quartile, and maximum values, was further illustrated by the boxplots.

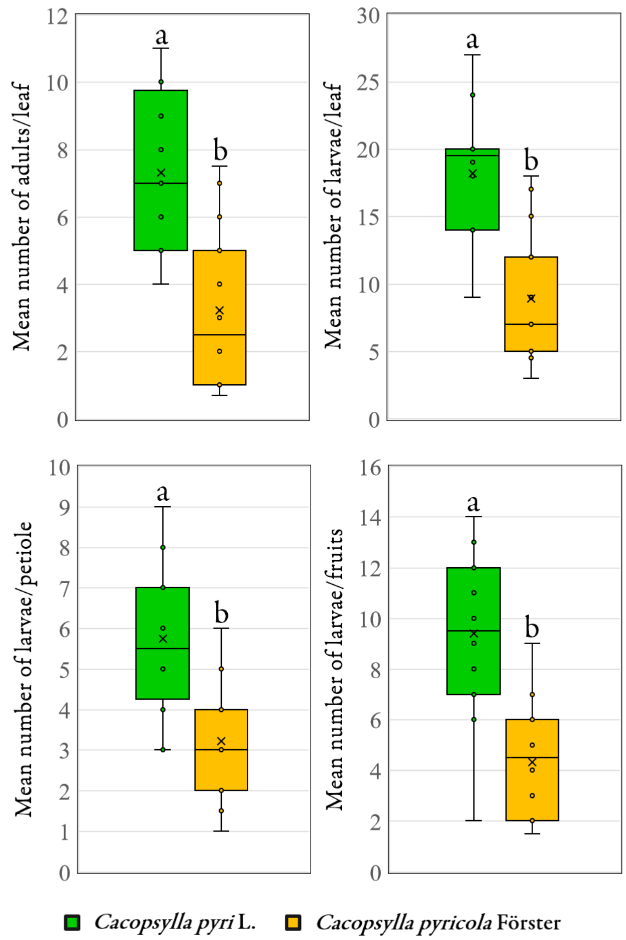
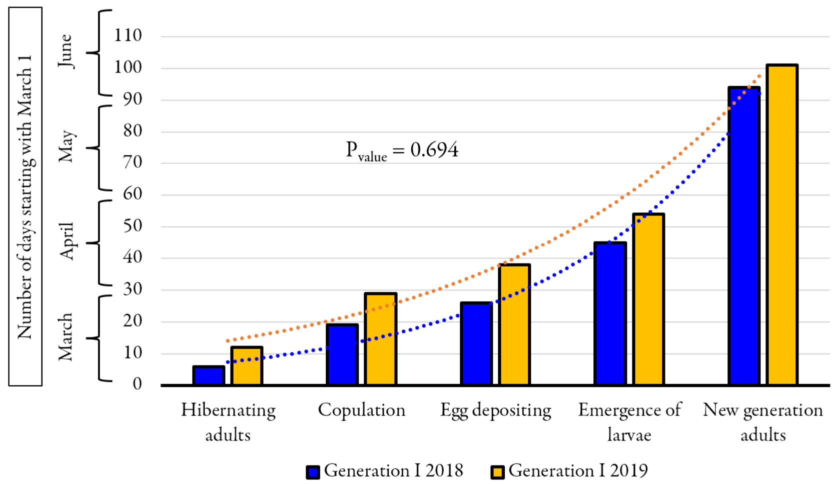
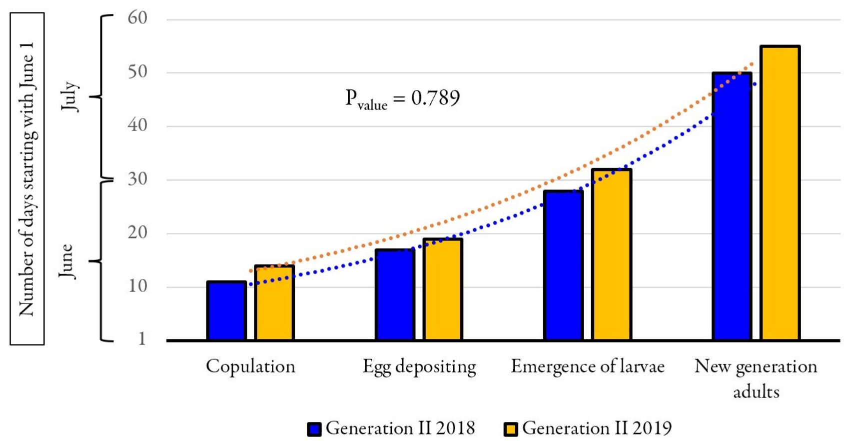


Figure 8. Numbers of psylla (adults and larvae) on the leaf, petiole and fruit as the mean (n = 20) in the two species of *Cacopsylla* (*C. pyri* and *C. pyricola*) and two years (2018 and 2019). Each box plot represents minimum, lower quartile, median, upper quartile, and maximum values; in addition, the mean of the data is symbolised with a '×' in the boxplot. Different letters among boxplots indicate statistically significant differences between the two species of *Cacopsylla*, at a significance level of $p < 0.05$ (t-Test: Two-Sample Assuming Unequal Variances)

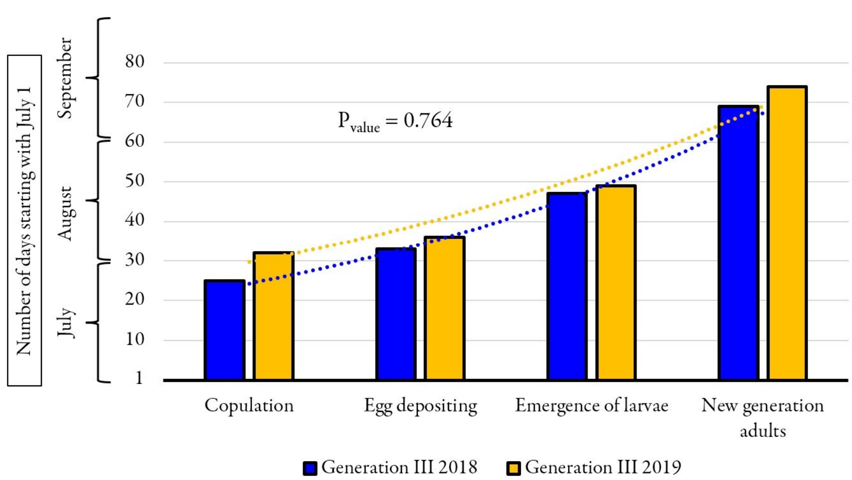
The application of the same t-test, based on two samples assuming unequal variances, revealed that the development of the main stages of the phenological cycle of the *C. pyri* species in generations I, II, and III in the two years of the study, 2018 and 2019, were not different significantly (Figure 9). The trend of the curves showing the comparative development of the phases of the first generation of psylla between 2018 and 2019 (Figure 9a) is relatively similar, even if, climatically, there were differences between the months of the study period in the two years analyzed. For example, the rainiest month in 2018 was June (173.2 mm), and in 2019 May (146.1 mm), and the months of April and May in 2018 recorded higher temperatures than in 2019 (13.5 and 16.8 C, compared to 10.3 and 13.0). However, the curvilinear allure of the biological cycle remains close in the two years. Finally, during the phases of the first generation, the calculated P value (P=0.694) indicated a non-significant influence of the years on the evolution of hibernating adults, copulation, egg depositing, the emergence of larvae and new generation adults in 2018 and 2019. Similar results were recorded for the second generation (Figure 9b) and third generation (Figure 9c).



(**a**)



(**b**)



(**c**)

Figure 9. The biological cycles of *C. pyri*, and t-Test: Two-Sample Assuming Unequal Variances for the investigation years 2018 and 2019, at the level of $\alpha = 0.05$, for the generation I (**a**), II (**b**) and III (**c**)

Discussion

The investigation offered interesting information about the phenology of the two psylla species and their generations over the course of two years under the research area's climatic circumstances. The relative abundance of *C. pyri* was found to be substantially higher than that of the species *C. pyrisuga*. No specimens of the third species present in pear orchards in Romania, *C. pyricola*, were identified. Also, the species *C. bidens* whose spread in Romania is referred to by several authors (Chireceanu, 2007; Shaltiel-Harpaz *et al.*, 2013; Valle *et al.*, 2017; Akbar *et al.*, 2018) has not been reported, even if in the neighbouring country, Serbia, it has been seen in many orchards and localities (Jerinić-Prodanović, 2011). Probably, *Cacopsylla bidens* (Šulc, 1907) = *P. pyricola* (Förster) as it appears in Hodkinson (1989). However, Burckhardt (2008) noted that according to Hodkinson (1989) "all records of *Cacopsylla pyricola* from South America probably refer to *C. bidens*". In our study, the slightly varied climatic circumstances between the two years had insignificant effect on the development of pest phenology and generations during the course of the year. Extending the study over a longer period could better highlight the influence of climatic conditions on the reaction of psyllids to environmental factors, especially to temperature. There is a clear tendency for temperature increase in the years of the study compared to the multi-year average of the last 30 years. The observations showed a large infestation of the Williams cultivar, which caused the appearance of honeydew on the organs of the trees and sooty mold which blemishing the fruits, as well as the appearance of premature aging of the trees. The study also highlighted the preference of the pests for the sunny areas of the crown of the trees. The number of psyllids on the southern, sunny side, was significantly higher than those on the shady, northern side.

In Romania, psylla is the most serious pest of pears, and the studies carried out on psyllid populations, as well as their evolution, must sustain proper monitoring and management. In this sense, the suggestions of Sagar and Balikai (2013) for the proper management of pear orchards remain relevant. As a result, caring for trees to promote healthy growth and optimum vegetative condition allows them to better endure and recover from pest attacks (i.e., balanced fertilization, without excess nitrogen to greatly stimulate vegetative growth of trees, could reduce psylla infestation – Khan *et al.*, 2020). Pest populations can be reduced by favouring natural predators or employing native and alien predators, parasitoids, and pathogens. Manipulation of biological control agents has the potential to improve their effectiveness against target pests and reduce also the use of pesticides. The most welcoming method would still be the pear breeding and development of genetically resistant genotypes, which would have economic and ecological implications as well as be helpful to the environment and fruit consumers' health.

Psylla pear pests produce significant harm, with an extraordinarily high destructive potential. Psylla can cause direct damage to trees by weakening them and decreasing fruit output and quality. It can also cause indirect damage by producing a significant amount of honeydew on which *Capnodium* fungi grow, as well as by transmitting phytoplasmas (Civolani, 2012). As the attack progresses, the fruits lose quality, remain small, and are covered by sooty mold that cause russeting. Strong infestations defoliate trees and diminish their vigour; trees must recover for several years or die as a result of psylla shock. As mentioned, in addition to these direct impacts, psylla is the carrier of a phytoplasma known as 'pear decline' disease, which can exacerbate dryness and, in some cases, death of the trees (Garcia-Chapa *et al.*, 2005; Civolani, 2012; Sestras *et al.*, 2020).

The nymphs are the most dangerous stages because of the vast amount of honey generated, particularly in spring and summer, which spills everywhere, on leaves, shoots, fruits, branches, and even on the tree stems during massive attacks. In addition to lowering the market value of the fruit, honey promotes the growth of sooty mold caused by saprophytic fungi, resulting in indirect plant harm. Sooty mold blankets the leaf apparatus, preventing photosynthesis, disrupting metabolism, weakening trees, and resulting in significant productivity and harvest quality losses. Prolonged attacks can cause severe tree weakening and, eventually, death (Straulea *et al.*, 1992; Civolani, 2012).

The control of pear psylla in orchards by phytosanitary treatments is difficult and frequently ineffectual, and the pests develop tolerance to insecticides (Riedl *et al*., 1981; Civolani, 2012; Jaworska *et al*., 2012; Nin *et al*., 2012; Sestras *et al*., 2020). The application of chemical treatments, especially those from the group of synthetic pyrethroids, causes a temporary decrease in the numerical density of pests for a few generations, but then the population recovers, and the numerical density can be at a much higher level (Janssen and van Rijn, 2021). In the area monitored by us, the treatments were applied after the emergence of the larvae of each generation, but honeydew reduced their effectiveness. Instead, the applied insecticides probably affected the populations of zoophagous species observed in the area, i.e., *Anthocoris nemoralis* F. (Hemiptera: Anthocoridae), *Forficula auricularia* L. (Dermaptera: Forficulidae) and *Chrysopa* spp. (Neuroptera: Chrysopidae). However, psylla can develop gradations at certain time intervals, a phenomenon reported in many pest species (Knorr *et al*., 2000; Alalouni *et al*., 2013). These variations in population density can be determined by the interaction between the dynamics of climatic factors and the activity of zoophages.

In some pear-growing regions, psyllid treatment costs account for more than half of all pest control expenditures (Horton, 1999). In new orchards, improved monitoring techniques and novel integrated pest management (IPM) techniques that protect the contribution of beneficial insects to the natural control of pear psylla are required (Horton, 1999; Civolani, 2012). Additionally, the introduction of psylla-resistant cultivars would drastically cut production costs (Bell, 1992; Nin *et al*., 2015). Consequently, the production of psylla-resistant cultivars remains a significant objective for pear breeders. In this way, the discovery and subsequent utilisation of specific genetic resources is crucial for the effectiveness of pear breeding (Benedek *et al*., 2010; Brewer and Palmer, 2011; Bell, 2015; Puskás *et al*., 2016; Brewer and Volz, 2019; Li *et al*., 2022).

The wild species, which are sources of genes of significant relevance for the adequate response of the trees to the attack of the most harmful diseases and pests, are genetic resources that must be taken into consideration similarly to those for the apple tree (Dan *et al*., 2015; Sestras *et al*., 2009, 2011). Very popular and well-known pear cultivars are frequently susceptible, if not extremely susceptible, to the effects of the most harmful biotic stressors. *Erwinia amylovora*, which causes fire blight, and psylla species are unquestionably among them. In studies where pear germplasm was evaluated, there were relatively few genotypes that had a favourable response to these two biotic stressors. For example, of the 365 genotypes represented by *Pyrus* species and cultivars, only 20.5% did not show fire blight under natural infection conditions (Sestras *et al*., 2008). In another study, among 160 European pear genotypes, only 8.1% were found to be highly tolerant or resistant to *C. pyri* attacks under natural infestation conditions (Nin *et al*., 2015). In the last study, 46.3% of the cultivars were qualified as susceptible. Well-known cultivars such as 'Conference', 'Doyenné du Comice', 'Highland', 'Curè' suffered moderate to heavy damage, and 'Williams' was considered highly susceptible. In addition, Quarta and Ruggioni (1985) identified only 12% genotypes with low susceptibility to *C. pyri* attack, from 93 cultivars and 43 selections grown near Rome, Italy.

Psyllids could be controlled by expanding pear cultivation of cultivars with the appropriate response to psylla attack (resistance or tolerance) and implementing moderate programmes of conventional pest management utilising phytosanitary treatments with broad-spectrum insecticides throughout the season. In the spring and early summer, conventional sprays suppress psylla, but abandoning biological control results in psylla outbreaks towards harvest (Nottingham *et al*., 2022). In addition, it is crucial to maintain a natural balance of entomofauna in pome tree ecosystems, thereby protecting psylla's natural predators to the greatest extent feasible. Some industrial products, such as kaolin clay and selective insecticides, do not interfere with biological control, but they are not alternatives for broad-spectrum insecticides (Nottingham *et al*., 2022).

Monitoring is particularly important for choosing strategies to fight and combat psyllids. The use of yellow sticky traps is useful for population analysis and pest monitoring. Bozkurt and Uğur (2022) found that sticky yellow traps strongly attracted *C. pyri* adults, but were insufficient for psyllid control. Instead, they may be useful for monitoring pest populations, especially in early spring when overwintering *C. pyri* adults are present and the beneficial population is inactive. To gather the information required to protect pear orchards from psylla, various types of traps can be deployed (Adams *et al*., 1983; Adams and Los, 1989). Psyllids can be monitored in the orchard using yellow sticky traps, particularly from the middle of summer until harvest time; however, the information obtained from these traps needs to be correlated with the effects of the weather on insects, natural enemies, and the pear genotypes' response to attack (Adams and Los, 1989). Due to insect activities and flight, which differ depending on sex, morphotype, reproductive state, time of year, time of day, weather, and other factors, sticky traps sometimes provide unexpected variations in insect dispersal, densities in the orchard, population age composition, and other factors (Horton, 1999). Nevertheless, the information obtained can be used in protection and pest control programs, including phytosanitary treatments with insecticides.

The timing of spray treatments is essential because advised insecticides are only effective at specific stages against the *C. pyri*. Pear psylla produces a number of summer-form generations throughout the growing season, and as the season progresses, generational overlap increases. Fruit tree farmers can evaluate the risk at the start of the second generation and determine that treatments primarily focus on the eggs and young larvae of the second generation (Schaub *et al*., 2005). Pear psylla population assessment is time-consuming and error-prone to observe. In order to help farmers, plan the time of monitoring and control activities, phenological models were created, which simulate and forecast the time of natural phenomena using driving variables, typically temperature. In order to possibly apply and improve the synchronization of monitoring and control methods in pear orchards, Schaub *et al*. (2005) adapted a similar model with simulated findings for the biological structure and parameter values of psylla populations. Prior to this, Morgan and Solomon (1993) developed simulation models by including a *C. pyricola* phenological model into a multipest forecasting system. They used historical data from pest populations in pear and apple orchards in south-east England in conjunction with autonomous climatic monitoring equipment. Their purpose was to offer a logical foundation for decisions regarding pest management.

The regular monitoring of the psyllids' developmental stages must serve as the foundation for the preventative calendar for the pest control effort, the deployment of pesticide treatments, as well as the selection of protective chemicals. One of the key factors in enhancing agricultural output is the use of pesticides, but its imbalanced and incorrect use has had detrimental impacts on both human and environmental health. There are numerous approaches for reducing pesticide residue in fruit crops, including precision farming, genetic methods (obtaining new resistant cultivars to pest attack through breeding works and introducing them into the culture), integrated pest management (IPM) and integrated nutrient management (INM), which are all applicable to pear orchards (Sinha *et al*., 2022). However, the management of pear orchards must ensure that pests do not become resistant to insecticides and that healthy crops and fruits are produced without the use of poisons or dangerous pesticide residues. In the study by Tomaš *et al.* (2022), the integrated protection programme treatment based on diflubenzuron, spirotetramat, abamectin, and acetamprid displayed the best effectiveness in battling psylla (2022). The kaolin treatment, on the other hand, was least successful in reducing psylla. The treatments' efficacy changed significantly from one year to the next, indicating that the year's climatic conditions had a significant impact on the success of phytosanitary spraying against psyllids. Preflowering or the period before the first egg oviposition is the best way to describe the first kaolin application. By doing this, both the quantity of the first generation and the requirement for pest control of the subsequent generations are decreased (Tomaš *et al*. (2022). Thiacloprid and diazinon are traditional chemical insecticides that can be employed against psylla, while diflubenzuron and lufenuron are biological insecticides. The biorational chemicals guaranteed the highest psyllid population mortality rate, making them an effective tool for controlling pear psylla populations (Emami, 2019; Sinha *et al*., 2022).

Plant protection specialists have the mission of ensuring the control of pests in pear orchards in the context of sustainable agriculture, protecting the environment and maintaining an appropriate ecological environment and obtaining fruits in the conditions of appropriate harvests, with quality and healthy fruits for consumers. This desideratum can be achieved through the exhaustive knowledge of the complex problems and aspects related to the response to attack of pear cultivars depending on their genetic endowment, climatic conditions, and culture technologies, etc. Ensuring integrated protection and control programs for crops becomes a priority in the current conditions of climate change, the economic and energy crisis, the growth of the world's population, and the need for food at the global level, etc.

Conclusions

C. pyri L. was the most common species of psylla found in the pear tree plantations in the Cireșoaia region, located in the northern part of Romania. The first half of March is when the adults of the generation that hibernates get up and begin their daily activities. Eggs are often laid by the adults in the upper section of the crown, as well as on the southern and western sides of the structure. The second half of April is when the larvae of the first generation appear in the plantation. The larvae of the second generation appear at the end of June and the beginning of July, and the larvae of the third generation appear in the second decade of August. There are three generations produced by this species every year: generation I (March-June), generation II (June-July), and generation III (August-March), which may or may not overlap. Plant protection experts can make efficient use of psylla population assessment and monitoring studies as well as in-depth understanding of pest phenology. Interest in tying the biological cycles of pests to climatic factors allows for projecting the expansion of psyllid populations and the escalation of attacks, depending on the weather evolution throughout the year. Under the guidelines of sustainable agriculture and the protection of the environment and fruit consumers, it is the responsibility of plant protection professionals to make the best choices for the efficient management of pests in pear orchards, assuring profitable harvests and high-quality fruit.

Authors' Contributions

Conceptualization: LIS and IO; Data curation: LIS, IBH and SPA; Formal analysis: LIS, MM, AFS and IO; Funding acquisition: LIS, MM and IO; Investigation: LIS, IBH, SPA and IO; Methodology: IO and RES; Resources: LIS and IO; Software: AFS; Supervision: AFS and IO; Validation: IO and RES; Visualization: TF, AFS and RES; Writing - original draft: LIS and IO; Writing - review and editing: MM, AFS, IO and RES.

All authors read and approved the final manuscript.

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The research was carried out in the framework of Doctoral School from the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca (USAMVCN) by L.I.S.M., as Ph.D. student.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Adams RG, Domeisen CH, Ford LJ (1983). Visual trap for monitoring pear psylla (Homoptera: Psyllidae) adults on pears. Environmental Entomology 12(5):1327-1331. *https://doi.org/10.1093/ee/12.5.1327*

Adams RG, Los LM (1989). Use of sticky traps and limb jarring to aid in pest management decisions for summer populations of the pear psylla (Homoptera: Psyllidae) in Connecticut. Journal of Economic Entomology 82(5):1448-1454. *https://doi.org/10.1093/jee/82.5.1448*

Ahmad MJ, Mohiudin S, Pathania SS, Mukhtar M (2020). Feeding potential of anthocorid bug, Blaptostethus pallescens (Poppius) (Hemiptera: Anthocoridae) against eggs of pear psylla, *Cacopsylla pyricola* (Foerster) (Homoptera: Psyllidae) on pear in Kashmir. Journal of Entomology and Zoology Studies 8(5):685-689.

Ahmed SA (2007). Description of the pear psyllid, *Cacopsylla* (=*Psylla*) *pyricola* (Foerster) (Hemiptera: Psyllidae), a new record in pear orchards in North Sinai and Ismailia Governorates, Egypt. Egyptian Journal of Biological Pest Control 17(1/2):159-160.

Akbar SA, Dar MA, Mahendiran G, Wachkoo AA (2018). The first record of pear psylla *Cacopsylla bidens* (Hemiptera: Psyllidae) from India along with notes on seasonal occurrence and some elements of its biology. Oriental Insects 52(1):101-111. *https://doi.org/10.1080/00305316.2017.1378598*

Alalouni U, Schädler M, Brandl R (2013). Natural enemies and environmental factors affecting the population dynamics of the gypsy moth. Journal of Applied Entomology 137(10):721-738. *https://doi.org/10.1111/jen.12072*

Bell RL (1992). Additional East European *Pyrus* germplasm with resistance to pear psylla nymphal feeding. HortScience 27(5):412-413. *https://doi.org/10.21273/HORTSCI.27.5.412*

Bell RL (2015). Effect of resistant and susceptible East European pears on development and mortality of the pear psylla, *Cacopsylla pyricola* (Förster). HortScience 50(5):661-665. *https://doi.org/10.21273/HORTSCI.50.5.661*

Benedek P, Szabó T, Soltész M, Szabó Z, Konrád-Németh C (2010). Susceptibility of European pear genotypes in a gene bank to pear psylla damage and possible exploitation of resistant varieties in organic farming. International Journal of Horticultural Science 16(3):95-101. *https://doi.org/10.31421/IJHS/16/3/904*

Bozkurt V, Uğur A (2022). Using yellow sticky traps in control to *Cacopsylla pyri* (L.)(Hemiptera: Psyllidae) on pear trees. Plant Protection Bulletin 62(2):36-42. *https://doi.org/10.16955/bitkorb.1056343*

Brewer L, Volz R (2019). Genetics and Breeding of Pear. In: Korban S (Ed). The Pear Genome. Compendium of Plant Genomes. Springer, Cham. *https://doi.org/10.1007/978-3-030-11048-2_4*

Brewer LR, Palmer JW (2011). Global pear breeding programmes: goals, trends and progress for new cultivars and new rootstocks. Acta Horticulturae 909:105-119. *https://doi.org/10.17660/ActaHortic.2011.909.10*

Buès R, Boudinhon L, Toubon JF (2003). Resistance of pear psylla (*Cacopsylla pyri* L.; Hom., Psyllidae) to deltamethrin and synergism with piperonyl butoxide. Journal of Applied Entomology 127(5):305-312. *https://doi.org/10.1046/j.1439-0418.2003.00740.x*

Burckhardt D (2008). Psylloidea. In: Claps LE, Debandi G, Roig-Juñent S (Eds). Biodiversidad de Artrópodos Argentinos 2:189-199.

Chireceanu C (2007). Species diversity of insects in pear ecosystem in Băneasa-Bucharest. Entomologica Romanica 12:243-249.

Civolani S (2012). The past and present of pear protection against the pear psylla, Cacopsylla pyri L. In: Perveen FK (Ed). Insecticides – Pest Engineering. InTech, Croatia pp 385-408.

Civolani S, Peretto R, Caroli L, Pasqualini E, Chicca M, Leis M (2014). Preliminary resistance screening on abamectin in pear psylla (Hemiptera: Psyllidae) in Northern Italy. Journal of Economic Entomology 100(5):1637-1641. *https://doi.org/10.1093/jee/100.5.1637*

Dan C, Sestras AF, Bozdog C, Sestras RE (2015). Investigation of wild species potential to increase genetic diversity useful for apple breeding. Genetika 47(3):993-1011. *https://doi.org/10.2298/GENSR1503993D*

DuPont ST, John Strohm C (2020). Integrated pest management programmes increase natural enemies of pear psylla in Central Washington pear orchards. Journal of Applied Entomology 144(1-2):109-122. *https://doi.org/10.1111/jen.12694*

Emami MS (2019). Field evaluation of the relative susceptibility of six pear varieties to the pear psylla (*Cacopsylla pyricola* (Foerster, 1848)). Acta Agriculturae Slovenica 114(1):47-52. *http://dx.doi.org/10.14720/aas.2019.114.1.5*

Erler F, Cetin H (2007). Effect of kaolin particle film treatment on winterform oviposition of the pear psylla *Cacopsylla pyri*. Phytoparasitica 35(5):466-473. *https://doi.org/10.1007/BF03020605*

Fotirić Akšić M, Cerović R, Radošević R, Oparnica Č, Meland M (2021). Morphological and anatomical leaf characteristics of some European and Asian pear cultivars. Acta Horticulturae 1303:63-70. *https://doi.org/10.17660/ActaHortic.2021.1303.10*

Fotirić Akšić MM, Dabić DC, Gašić UM, Zec GN, Vulić TB, Tešić ZL, Natić MM (2015). Polyphenolic profile of pear leaves with different resistance to pear psylla (*Cacopsylla pyri*). Journal of Agricultural and Food Chemistry 63(34):7476-7486. *https://doi.org/10.1021/acs.jafc.5b03394*

Gajski D, Pekár S (2021). Assessment of the biocontrol potential of natural enemies against psyllid populations in a pear tree orchard during spring. Pest Management Science 77(5):2358-2366. *https://doi.org/10.1002/ps.6262*

Garcia-Chapa M, Sabaté J, Laviña A, Batlle A (2005). Role of *Cacopsylla pyri* in the epidemiology of pear decline in Spain. European Journal of Plant Pathology 111:9-17. *https://doi.org/10.1007/s10658-004-1981-y*

Ghidra V, Ardelean M, Oltean I, Sestras R (1992). Comportarea unor soiuri şi elite de păr la atacul produs de puricele melifer (*Psylla pyri* L.) [The response of several pear varieties and selections to psylla (*Psylla pyri* L.) attack] (in Romanian). Buletin USACN A-H 46(2):83-90.

Hildebrand M, Dickler E, Geider K (2000). Occurrence of *Erwinia amylovora* on insects in a fire blight orchard. Journal of Phytopathology 148(4):251-256. *https://doi.org/10.1046/j.1439-0434.2000.00504.x*

Hodkinson ID (1989). The Biogeography of the neotropical jumping plant-lice (Insecta: Homoptera: Psylloidea). Journal of Biogeography 16(3):203-217. *https://doi.org/10.2307/2845257*

Hodkinson ID (2009). Life cycle variation and adaptation in jumping plant lice (Insecta: Hemiptera: Psylloidea): a global synthesis. Journal of Natural History 43(1-2):65-179. *https://doi.org/10.1080/00305316.2017.1378598*

Horton DR (1999). Monitoring of pear psylla for pest management decisions and research. Integrated Pest Management Reviews 4:1-20. *https://doi.org/10.1023/A:1009602513263*

Janssen A, van Rijn P C (2021). Pesticides do not significantly reduce arthropod pest densities in the presence of natural enemies. Ecology Letters 24(9):2010-2024. *https://doi.org/10.1111/ele.13819*

Jaworska K, Olszak R, Łabanowska B, Korzeniowski M (2012). Efficacy of spirotetramat in the control of pear psylla (*Cacopsylla pyri* L.) on pear trees in Poland. Journal of Fruit and Ornamental Plant Research 20(2):91-106. *https://doi.org/10.2478/v10290-012-0019-3*

Jerinić-Prodanović D (2011). Jumping plant-louse *Cacopsylla* (Hepatopsella) *bidens* (Šulc, 1907) (Hemiptera, Psyllidae) new pest on pear in Serbia. Pesticidi i Fitomedicina 26(2):147-157. *https://doi.org/10.2298/PIF1102147J*

Khan AA, Kundoo AA, Nissar M, Mushtaq M (2020). Sucking pests of temperate fruits. In: Omkar (Ed). Sucking Pests of Crops. Springer, Singapore pp 369-409. *https://doi.org/10.1007/978-981-15-6149-8_12*

Knorr IB, Bashev AN, Alekseev AA, Naumova EN (2000). Effect of population density on ecological characteristics of the grass moth *Loxostege sticticalis* L. (Lepidoptera: Pyralidae) in the gradation cycle. Biology Bulletin 27(1):63-70.

Kocourek F, Holý K, Řezáč M, Sopko B, Stará J (2021). The effects of various pest control regimes on the community structure and population dynamics of selected natural enemies of *Cacopsylla pyri* in pear orchards. Biocontrol Science and Technology 31(6):632-651. *https://doi.org/10.1080/09583157.2021.1877615*

Le Goff GJ, Berthe J, Tougeron K, Dochy B, Lebbe O, Renoz F, Hance T (2021). Effect of the instar of the pear psyllid *Cacopsylla pyri* (Hemiptera: Psyllidae) on the behaviour and fitness of the parasitoid *Trechnites insidiosus* (Hymenoptera: Encyrtidae). European Journal of Entomology 118:279-287. *https://doi.org/10.14411/eje.2021.028*

Li J, Zhang M, Li X, Khan A, Kumar S, Allan AC, … Wu J (2022). Pear genetics: Recent advances, new prospects, and a roadmap for the future. Horticulture Research 9:uhab040. *https://doi.org/10.1 093/hr/uhab040*

Microsoft Corporation (2018). Microsoft Excel. Retrieved from *https://office.microsoft.com/excel*

Montanari S, Guérif P, Ravon E, Denancé C, Muranty H, Velasco R, … Durel CE (2015). Genetic mapping of *Cacopsylla pyri* resistance in an interspecific pear (*Pyrus* spp.) population. Tree Genetics and Genomes 11:74. *https://doi.org/10.1007/s11295-015-0901-y*

Moreno A, Miranda MP, Fereres A (2021). Psyllids as major vectors of plant pathogens. Entomologia Generalis 41(5):419-438. *https://doi.org/10.1127/entomologia/2021/1289*

Morgan D, Solomon MG (1993). PEST-MAN: a forecasting system for apple and pear pests 1. EPPO Bulletin 23(4): 601-605. *https://doi.org/10.1111/j.1365-2338.1993.tb00556.x*

Nin S, Ferri A, Sacchetti P, Picardi E, Cantini C, Giordani E (2015). Susceptibility of European pear germplasm to *Cacopsylla pyri* under Mediterranean climatic conditions. Scientia Horticulturae 185:151-161. *https://doi.org/10.1016/j.scienta.2015.01.031*

Nin S, Giordani E, Sacchetti P, Ferri A (2012). Pear resistance to psilla (*Cacopsylla pyri* L.): a review. Advances in Horticultural Science 26(2):59-74. *http://digital.casalini.it/10.1400/207287*

Nottingham LB, Orpet RJ, Beers EH (2022). Integrated pest management programs for pear psylla, *Cacopsylla pyricola* (Förster) (Hemiptera: Psyllidae), using kaolin clay and reflective plastic mulch. Journal of Economic Entomology 115(5):1607-1619. *https://doi.org/10.1093/jee/toac121*

Perchepied L, Guérif P, Ravon E, Denancé C, Laurens F, Robert P, Bouvier L, Lespinasse Y, Durel CE (2016). Polygenic inheritance of resistance to *Cacopsylla pyri* in a *Pyrus communis* × *P. ussuriensis* progeny is explained by three QTLs involving an epistatic interaction. Tree Genetics & Genomes 12:108. *https://doi.org/10.1007/s11295-016-1072-1*

Puskás M, Höfer M, Sestras RE, Peil A, Sestras AF, Hanke MV, Flachowsky H (2016). Molecular and flow cytometric evaluation of pear (*Pyrus* L.) genetic resources of the German and Romanian national fruit collections. Genetic Resources and Crop Evolution 63(6):1023-1033. *https://doi.org/10.1007/s10722-015-0298-3*

Quarta R, Ruggioni D (1985). Survey on the variety susceptibility to pear psylla. Acta Horticulturae 159:77-86. *https://doi.org/10.17660/ActaHortic.1985.159.10*

Riedl H, Westigard P, Bethell R, DeTar J (1981). Problems with chemical control of pear psylla. Hilgardia 35(9):7-9. *DOI:10.3733/ca.v035n09p7*

Riedle-Bauer M, Paleskić C, Schönhuber C, Staples M, Brader G (2022). Vector transmission and epidemiology of '*Candidatus* Phytoplasma pyri' in Austria and identification of *Cacopsylla pyrisuga* as new pathogen vector. Journal of Plant Diseases and Protection 129(2):375-386. *https://doi.org/10.1007/s41348-021-00526-y*

Sagar D, Balikai RA (2013). Psyllid pests of horticultural and forage crops: taxonomy, biology and their management. Journal of Experimental Zoology 16(1):1-18.

Schaub L, Graf B, Butturini A (2005). Phenological model of pear psylla Cacopsylla pyri. Entomologia Experimentalis et Applicata 117(2):105–111. *https://doi.org/10.1111/j.1570-7458.2005.00339.x*

Sestras AF, Pamfil D, Dan C, Bolboaca SD, Jäntschi L, Sestras RE (2011). Possibilities to improve apple scab (*Venturia inaequalis* (Cke.) Wint.) and powdery mildew [*Podosphaera leucotricha* (Ell. et Everh.) Salm.] resistance on apple by increasing genetic diversity using potentials of wild species. Australian Journal of Crop Science 5(6):748-755.

Sestras AF, Sestras RE, Barbos A, Militaru M (2008). The differences among pear genotypes to fire blight (*Erwinia amylovora*) attack, based on observations of natural infection. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 36(2):97-103.

Sestras AF, Somsai P, Militaru M, Mitre V, Ercişli S, Sestras RE (2020). The response of pear cultivars and wild species of *Pyrus* to *Psylla* sp. attack, depending on genotype, based on eggs' and nymphs' presence on the leaves, before and after the treatment with insecticide. Acta Horticulturae 1289:79-90. *https://doi.org/10.17660/ActaHortic.2020.1289.12*

Sestras R, Ardelean M, Ghidra V, Oltean I (1999). Pear breeding for resistance to pear psylla (*Psylla* sp.) at Cluj-Napoca. Bulletin USAMV 53:21-24.

Sestras R, Botez C, Ardelean M, Oltean I, Sestras A (2009). Response of pear genotypes to psylla sp. attack in central Transylvania, Romania. Acta Horticulturae 814:845-850. *https://doi.org/10.17660/ActaHortic.2009.814.144*

Sestras R, Ghidra V, Straulea M (1994). Haydeea – un nou soi de par creat la SCPP Cluj ['Haydeea' – a new pear cultivar obtained at Fruit Research Station Cluj] (in Romanian). Horticultura 1:17-18.

Sestras R, Oltean I, Ghidra V, Raureanu V (1995). Observatii generale privind biologia si controlul in livada al puricilor meliferi ai parului (Psylla sp.) in conditiile din zona Clujului [Observations about biology and monitoring of psylla species (Psylla sp.) in Cluj-Napoca conditions] (in Romanian). Protectia Plantelor 5(17):51-60.

Sestras R, Pamfil D, Ardelean M, Botez C, Sestras A, Mitre I, Dan C, Mihalte L (2009). Use of phenotypic and MAS selection based on bulk segregant analysis for study of genetic variability induced by artificial hybridization on apple. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 37(1):273-277.

Shaltiel-Harpaz L, Gerchman Y, Ibdah M, Kedoshim R, Rachmany D, Hatib K, … Holland D (2018). Grafting on resistant interstocks reduces scion susceptibility to pear psylla, *Cacopsylla bidens*. Pest Management Science 74(3):617-626. *https://doi.org/10.1002/ps.4745*

Shaltiel-Harpaz L, Soroker V, Kedoshim R, Hason R, Sokalsky T, Hatib K, … Holland D (2013). Two pear accessions evaluated for susceptibility to pear psylla Cacopsylla bidens (Šulc) in Israel. Pest Management Science 70(2):234-239. *https://doi.org/10.1002/ps.3543*

Sinha A, Chaudhuri T, Arora L (2022). Residue free farming of fruit crops. The Pharma Innovation Journal SP-11(9):2999-3009.

Stratopoulou ET, Kapatos ET (1992). Distribution of population of immature stages of pear psylla, *Cacopsylla pyri*, within the tree and development of sampling strategy. Entomologia Hellenica 10:5-10. *https://doi.org/10.12681/eh.13997*

Straulea M, Ardelean M, Ghidra V, Sestras R (1992). Gradul de uscare a pomilor in urma atacului de purici meliferi (*Psylla* sp.) [Scorching rate of pear trees following infestation with melliferous flea (*Psylla* sp.)] (in Romanian). Buletin USAMV A-H 46(2):91-97.

Tešanović D, Spasić R, Prodanović DJ (2016). Psyllid species (*Cacopsylla* spp.) in pear orchards of East Sarajevo. Agroznanje Agro-knowledge Journal 17(1/4):81-89. *https://doi.org/10.7251/AGREN1601081T*

Tomaš V, Mihaljević I, Vuković D, Viljevac Vuletić M, Galić V, Tomeš V, … Zdunić Z (2022). Comparative effect of different insecticides and processed kaolin on *Cacopsylla pyri* L. population reduction. Poljoprivreda 28(1):3-10. *https://doi.org/10.18047/poljo.28.1.1*

Tougeron K, Iltis C, Renoz F, Albittar L, Hance T, Demeter S, Le Goff GJ (2021). Ecology and biology of the parasitoid *Trechnites insidiosus* and its potential for biological control of pear psyllids. Pest Management Science 77(11):4836-4847. *https://doi.org/10.1002/ps.6517*

Valle D, Zoppolo R, Burckhardt D, Mujica V, Morelli E (2017). The occurrence of the pear psyllid, *Cacopsylla bidens* (Šulc, 1907) (Insecta: Hemiptera: Psyllidae), in Uruguay. Check List 13(2):2088. *https://doi.org/10.15560/13.2.2088*

Westigard PH, Zwick RW (1972). The pear psylla in Oregon. Oregon Agricultural Experiment Station Technical Bulletin 122, p. 22.

Youssef AS (2016). Morphological and histological changes in pear trees due to the infestation with *Cacopsylla pyricola* (Foerster) (Hemiptera: Psyllidae). Egyptian Journal of Agricultural Research 94(1):17-24. *https://dx.doi.org/10.21608/ejar.2016.150656*

Zepner L, Karrasch P, Wiemann F, Bernard L (2020). ClimateCharts.net – an interactive climate analysis web platform, International Journal of Digital Earth 14(3):338-356. *https://doi.org/10.1080/17538947.2020.1829112*