PhD thesis

Faunistical and structural investigations on cicada (Auchenorrhyncha) assemblages in apple and pear orchards

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The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.

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1. The antecedents of the study and aims

Cicadas (Auchenorrhyncha) are insects feeding on plant sap, occurring in high density in most terrestrial ecosystems, including agricultural areas. Many species are regarded as pests of cultivated plants and can be also vectors of different plant diseases. Nevertheless, only few surveys have been carried out in Hungarian agricultural areas on cicadas. These studies were confined mainly on vegetable and arable cultures. Investigations on phytoplasma vector cicadas were conducted by Hegab (1981) and Sáringer (1984) in apple orchards and by Elekesné et al. (2005) in vineyards in Hungary. Detailed studies were carried out by Dér et al. (2003) in apricot orchards. There have not been any comprehensive studies on cicada communities up to now in Hungarian apple orchards. Several studies have been carried out in Great Britain, however these were limited to dominant species only.

The aims of the study were:

- Faunistical survey and analysis of quantitative relationships of cicada assemblages of Hungarian apple and pear orchards and their surroundings.
- Determination of characteristic species of the orchards and their potential connection to apple
- Investigation of the relationship between the orchards and their surroundings
- Comparison of effectiveness and characteristics of different sampling methods
- Investigation of life cycle of cicadas occurring most frequently in apple orchards
- Faunistical and quantitative investigation of cicada assemblages of apple orchards in Great-Britain
- Investigation of effects of different plant protection treatments on cicadas in an experimental apple orchard in Great-Britain, with special interest to a new pest management approach: ‘zero pesticide residues’ Integrated Pest Management programme
- Investigation of vertical distribution of cicadas in the canopy of apple orchards, structure of assemblages in the canopy and herb layer
- Parasitization level of cicadas occurring in apple orchards
- Resistance of apple varieties against cicadas

2. Material and methods

2.1. Investigations in Hungary

2.1.1. Place of investigations and sampling methods

The investigations between 1999 and 2001 took place in 7 locations of Hungary, in 10 apple and 3 pear orchards. Three different plant management programs were applied in the orchards. Additional samplings were done in two abandoned orchards. In Szigetcsép, Tura, Vámosmikola and Györgytarló broad spectrum pesticides, mainly organophosphorous and piretroids were applied (conventional orchards). The samplings in Újfehértó took place in a conventional, an integrated – using basically selective insecticides – and in an abandoned apple orchard. An abandoned apple orchard was investigated in Kecskemét. In the organic apple orchard in Nyírtura pesticides, permitted in organic production containing copper and sulphur and *Bacillus thuringiensis* were applied.

Three sampling methods were applied. In four apple and three pear orchards cicadas were collected by beating from the canopy and sweep netting in the herb layer. In seven apple orchards Malaise traps were placed. Each sampling methods were used simultaneously in Szigetcsép.

2.1.2. Faunistical and quantitative investigations in the orchards and their environments

Regular beating and sweep net samplings were applied to observe the faunistical composition of the orchards. Samples from the canopy were taken using Winkler-type beating net (d = 0.7 m). Samplings in the herbaceous layer were carried out with a sweep net (d = 0.3m). Beating and sweep net samples in Szigetcsép were collected biweekly, from early May to early October. In Györgytarló, Tura and Kecskemét collecting was carried out three times a year (in spring, summer and autumn). The cicadas collected by Malaise traps were also involved into the faunistical survey.

2.1.3. Investigation of the relationship between the orchards and their surroundings

To investigate the relationship between the orchards and their surroundings samples were collected by Malaise traps. Malaise trap (Townes, 1972) is a tent with four open sides, which is suitable for collection of flying insects. The height of the open sides was approximately 180 cm. In Szigetcsép, in the two orchards in Vámosmikola, and in Nyírtura Malaise traps were placed into the orchards, into the shrub layer of neighbouring forest and into the open, bushy edge between the orchard and the forest. In Újfehértó the traps were placed into the three differently treated orchards. The traps were operated continuously from late April or early May to October, and were emptied three times a week.

2.2. The investigations in Great-Britain

2.2.1. Place of investigations and sampling methods

Investigations between April and November in 2001 and 2002 took place in an experimental apple orchard of Horticulture Research International at East Malling and in two organic apple orchards: in Marden and Oakwood.

The experimental orchard at East Malling was divided into 12 plots to compare the effects of different plant protection systems: conventional, ‘zero pesticide residues’ Integrated Pest Management programme and untreated control treatment. In conventional plots broad spectrum pesticides, mainly fungicides were applied. Insecticides were used between April and beginning of July. In ‘zero pesticide residue’ plots selective fungicides and pesticides were used. Insecticides were applied in the beginning of the growing season only, before fruit set. The untreated plots were not equivalent with those in Hungary. As these control plots were treated with the same agrotechnical and herbicide programme as the treated plots.

In the orchard at East Malling in 2001 and 2002 samples from the canopy were collected by yellow sticky traps and beating. In the herb layer sweep netting was applied. The yellow sticky traps, sticky on both sides were of 20 x 20 cm size. Two traps in each plot were hanged into the lower third of the canopy during the vegetation period. The traps were changed every two weeks. Beating samplings in the canopy were carried out biweekly and sweep netting in the herb layer monthly.

Additional samplings were done in untreated plots with yellow sticky traps for observing vertical distribution of cicadas and resistance of different apple varieties against cicadas. Varieties Discovery, Ahra, Fiesta, Queen Cox and Saturn were involved.

In Marden and Robertsbridge less intensive investigations were conducted in the canopy. Each year in spring, summer and autumn beating samples were collected. In 2002 yellow sticky traps were applied too.

2.3.Indices and statistical analyses applied for evaluation of the data

The incidence of the cicada species in the orchards was described in three ways: (1) by proportion of individuals of the species in the total catch (2) by the sum of the scores, (3) by the distribution.

Column diagrams were used to represent the effects of the environment, location and plant protection treatments onto the abundance and species richness of cicada assemblages in Hungarian orchards. As generally only the male individuals were identifiable on species level, the analyses were based on the males.

For the comparison of different plant protection treatments at East Malling statistical tests were carried out. After the logarithmic (ln(x+1)) transformation of the raw data, the equality of theoretical means was analysed by robust ANOVA, applying Welch- and James tests. When significant difference was observed, Tukey-Kramer comparison among the means was performed. The data of the two sexes were evaluated separately. The statistical analysis was performed by Ministat 3.3 software package (Vargha, 1999).

The comparison of parasitization levels between treatments and sexes was analysed by robust two-way ANOVA: the difference between treatments and sexes by Welch-test, the interaction of these two factors by Johansen-test. When the difference between treatments was significant, the pairwise comparison of means was performed by Games-Howell test.

Life cycle diagrams of the most frequently occurring species were represented.

Relation of the most frequent cicada species to the different canopy levels was investigated after logarithmic (ln(x+1)) transformation of the raw data, by robust two-way ANOVA, when the grouping factors were the two investigated years (2001 and 2002), and the replicating factors were the three vertical levels (lower, middle, upper). Thus the samples collected within the canopy of one tree were treated as coherent. For testing the group effect of the years Welch-test, for testing the effects of vertical levels variance analysis was used with Huynh-Feldt correction. The pairwise comparison of vertical levels was done by Tukey test.

To compare the different apple varieties two analyses were made separately, as only Discovery was found in all of the four untreated plots, while Fiesta and Queen Cox were together only in two plots and similarly Saturn and Ahra in another two plots.

Metric ordination, principal coordinates analysis (PCoA), based on Jaccard and Horn similarity indices (Krebs, 1989) was applied to compare the composition of cicada assemblages of differently treated plots using Syntax 2000 statistical package (Podani, 1993). Evaluation of the row data was performed after logaritmic (log10) transformation too.

Rényi-diversity values were calculated from the samples collected in each treatment and were compared by t-test using Divord 1.09 program package (Tóthmérész, 1996, 1997).

3. Results

3.1. Investigation of cicada assemblages in Hungarian apple and pear orchards and their environment

3.1.1. Faunistical and quantitative investigations

In Hungarian apple and pear orchards altogether 15 686 individuals have been found belonging to 114 cicada species, representing approximately 20% of the cicada fauna of Hungary. In the investigated orchards and their surroundings altogether 145 species have been detected, which is about 25% of the Hungarian cicada fauna. The species richness of the orchards varied between 9 and 59. The average species richness was 35.

The characteristic species occurring in the canopy of Hungarian apple orchards were *Empoasca decipiens*, *Eupteryx atropunctata*, *Edwardsiana rosae*, *Zyginidia pullula*, *Eupteryx calcarata*, *Ribautiana tenerrima*, *Kybos virgator*, *Kybos populi*, *Cicadella viridis* and *Edwardsiana crataegi.* The following species can be important in the herb layer of apple and pear orchards: *Empoasca solani, Eupteryx atropunctata*, *Empoasca decipiens*, *Laodelphax striatellus*, *Psammotettix alienus*, *Zyginidia pullula*, *Philaenus spumarius*, *Emelyanoviana mollicula*.

Some of the species collected were rare in Hungary, or interesting in respect of faunal research: *Rhoananus hypochlorus, Metalimnus formosus*, *Mocuellus metrius*, *Ossiannilssonola callosa, Enantiocephalus cornutus Phlogotettix cyclops* and *Macrosteles sardus,* which was recently recorded as new for the Hungarian fauna (Dér and Orosz, 2002).

3.1.2. Relation of certain cicada species to apple

According to the Malaise trap collections *Edwardsiana crataegi, Kybos virgator* and *K. populi* were the species found most frequently inside of the apple orchards. *Edwardsiana rosae, Ribautiana tenerrima, Edwardsiana lamellaris* and *Eurhadina kirschbaumi* were most abundant mainly on the edges, but occurred in significant numbers inside of the orchards too. *Empoasca decipiens, Eupteryx atropunctata, Laodelphax striatellus* and *Empoasca solani* were found in notable amounts in all habitats. *Eupteryx calcarata, E. cyclops, E. stachydearum* and *Eupteryx collina* were detected in high numbers in the traps placed into the shrub layer of the forests. The species dominant in apple orchards belonged to one of the groups mentioned above, thus the cicada assemblages of the orchards and their environments did not differ from each other significantly.

3.1.3. Observation of life cycle diagrams

There were detectable not so distinct peaks in species richness three times a year.
It could be assessed that cicadas occur in high species richness in the orchards during the vegetation period. Altogether 32 life cycle diagrams of 11 species were represented. Three peaks at *Edwardsiana rosae* and *Empoasca decipiens*, and two peaks at *Edwardsiana crataegi* and *Ribautiana tenerrima* were detected in Hungary.
The adults of *Kybos populi* and *K. virgator* were detectable already in May and had three peaks during the vegetation period.

3.1.4. Effect of the regions and environment on cicada assemblages of apple orchards

The species richness of cicada assemblages in conventional orchards was mostly lower compared to the edges and probably the Rényi diversity of the assemblages inside of the orchards was often lower than on the edges. However, opposite tendency could be experienced in certain years and orchards.

Observing the similarity in species composition of cicada assemblages by metric ordination it could be concluded, that the regions with clayey (Vámosmikola) and sandy (Szigetcsép, Nyírtura, Újfehértó) soil differed from each other principally. Additional difference was detected between the regions in Szigetcsép and Újfehértó.

Within the certain regions, the species richness and dominance relations of the catches of the traps placed into the different habitats (the orchards, the edges and the forests) did not differ from each other significantly.

3.1.5. Effect of different plant protection treatments on cicada assemblages

The investigations carried out in Hungarian orchards showed, that the cicada assemblages of less intensely managed orchards were more diverse and larger in number of individuals. Highest species and individual numbers could be observed in abandoned (Újfehértó, abandoned orchard) and in organic (Nyírtura) orchards. Least values were detectable in most intensively managed orchards (Újfehértó and Vámosmikola, conventional orchards). However, only the application of integrated pest management system did not cause significant increase in number of species and individuals.

3.2. Investigations in apple orchards in Great-Britain

3.2.1. Faunistical and quantitative investigations

As a result of faunistical surveys in apple orchards in Kent, Great-Britain in all of the three investigated orchards (East Malling, Marden and Oakwood) 27 425 individuals were collected altogether belonging to 77 species.

The most frequent species were similar in all of the three orchards, with differences in their relative abundance values depending on sampling places and methods. Independently from the sampling methods the 7 and 14 most frequent species give more than 70% and 80% of the total catch. The following 63 species had minor importance in composition of cicada assemblages of apple orchards. The two most common species occurring in the canopy of apple orchards were *Edwardsiana rosae* and *Empoasca decipiens.* They were followed by *Ribautiana debilis*, *Edwardsiana crataegi*, *Empoasca vitis, Philaenus spumarius* and *Tachycixius pilosus.* All of these species are frequent and widely distributed in Great-Britain. The dominant species were different in certain sampling places: *Empoasca decipiens* at East Malling, *Ribautiana debilis* in Marden and *Empoasca vitis* in Oakwood. As a result of the collections a species, new to the Auchenorrhyncha fauna of the British Isles was found: *Zyginella pulchra* Löw.

3.2.2. Effect of different plant protection treatments on cicada assemblages

In the experimental apple orchard at East Malling the highest abundance values and species numbers were detectable in untreated control plots. The values of conventional and zero pesticide residue plots were similar to each other.

Observing the common species or the males and females separately different results could be detected. The males of *Edwardsiana rosae, Edwardsiana crataegi, Ribautiana debilis, Zygina flammigera, Empoasca vitis* and *Alnetoidia alneti* appeared tendentiously in highest abundance in untreated plots. The values in zero pesticide residue plots were slightly higher or similar as in conventional plots.

However, the males of *Empoasca decipiens* appeared in high numbers in treated plots too, with higher or similar abundance values in conventional plots, compared to the two other treatments. On the contrary, the females of the genus *Empoasca*, which belonged mainly to the species *E. decipens* occurred in significantly higher numbers in untreated plots. The effect of pesticide treatments in herb layer had little effect on the densities of cicadas, according to the sweep net samplings.

3.2.3. Investigation of life cycle and changes in the proportion of males and females

Two peaks in life cycle diagrams of *E. rosae, E. decipiens* and *R. debilis* were detectable. In the case of the frequent species differences were shown in the abundance values of males and females in different stages of the vegetation period. The females of *E. rosae* and *R. debilis* appeared in higher amounts in the first, while the males in the second half of the vegetation period. The males of *E.*

decipiens also occurred in significantly higher abundances in the second half of the vegetation period. In the second half of the vegetation period, in the case of the genus *Edwardsiana* and in both parts in the case of the genus *Empoasca* the proportion of males increased with the insecticide load.

3.2.4. Vertical distribution of cicadas in the canopy

Cicadas occurred in significantly higher abundances in the lower part of the canopy compared to the middle and upper parts. The abundance values of the males and females of *Empoasca decipiens, Zygina flammigera, Alnetoidia alneti, Edwardsiana crataegi* and *Zyginidia scutellaris* the numbers decreased in upper levels. *Ribautiana debilis* was most frequent in the middle part. The females of the subfamily Typhlocybinae (supposedly belonging mainly to the species *E. rosae*) were connected tendenciously to lower, while the males to the upper part of the canopy.
According to metric ordination the connection of cicada assemblages between the lower part of the canopy and the herb layer was not notable.

3.2.5. Parasitization of the cicadas in the canopy

Some of the cicadas collected by us were infected by parasitoids, mainly by ectoparasitoids. The parasitization level of the males was a bit higher than that of the females in 2001. The proportion of parasitised cicadas in untreated plots was significantly ($p<0.05$) higher than in treated plots. There was not significant difference between the parasitization of males and females in the subfamily *Typhlocybinae* (mainly E. rosae, some *E. crataegi* and *A. alneti*). The parasitisation in untreated plots was significantly ($p<0.05$) higher at both sexes. The parasitization level at the genus Empoasca was lower, with no significant differences between the sexes and treatments.

At the genus *Edwardsiana* in 2002 the parasitization of both sexes increased significantly (14%) in the second half of the vegetation period. The parasitization level in untreated plots was remarkably and significantly ($p<0.05$) higher than in treated plots.

At the genus *Empoasca*, on the contrary to the genus *Edwardsiana*, the proportion of parasitized individuals was higher in the first half of the vegetation period. The parasitization level of the females in the first half of the vegetation period was significantly higher in conventional plots ($p<0.05$), than in untreated ones, values of zero pesticide residue plots were between them.
Vertical distribution of the parasitized specimens did not differed essentially from the characteristics observed at non parasitized individuals.

3.2.6. Cicada assemblages of different apple varieties

Five apple varieties were investigated: Discovery, Saturn, Ahra (varieties resistant against venturia and powdery-mildew) and the sensitive Queen Cox and Fiesta. Less number of cicadas could be observed on the resistant Saturn, while most of the specimens could be detected on the sensitive Queen Cox. Varieties Ahra, Discovery and Fiesta did not differ from each other significantly. Differences were detectable according to the cicada species. In the case of the species of *Edwardsiana* genus the values were not significantly lower on Saturn than on Ahra and Discovery.

3.3. Methodological investigations

In Hungarian orchards 7797 individuals have been collected altogether by Malaise traps, 7770 by sweep netting and only 119 specimens by beating. In Szigetcsép, the number of species collected by sweep netting was 42 and by Malaise traps 32. Number of species collected by both methods was 16. The dominant and subdominant species differed from each other according to sampling methods.

Average proportion of males in Malaise trap samples (81.6%) was nearly two times higher than in sweep net samples (43.8%).

In Great-Britain number of cicadas was highest on yellow sticky traps and smallest in beating samples. There were remarkable differences in beating and sweep net samples between the two investigated years and the two methods. The beating samples were dominated by females, while yellow sticky trap samples by males. Proportion of males was about 30-40% in beating samples and 60-80% in sweep net and yellow sticky trap samples.

The higher proportion of males in Malaise traps and on yellow sticky traps can be connected with stronger migrating activity of the males.

3.4. New scientific results

1. Cicada assemblages of Hungarian apple and pear orchards was first determined. In apple orchards 104 species, in pear orchards 60 species were detected. In apple and pear orchards altogether 115 species were collected. It was determined, that the species richness of cicada assemblages in Hungarian apple- and pear orchards can be approximately 40-80. Faunistical characterisation of surrounding vegetation of apple orchards was conducted. Altogether 77 species have been found in Kent, Great Britain. A species, new for the British Isles *Zyginella pulchra* have been detected.

2. Quantitative relations of cicada assemblages in herb layer of apple and pear orchards have been characterised. We determined that the species *Empoasca decipiens*, *Eupteryx atropunctata*, *Edwardsiana rosae*, *Zyginidia pullula*, *Eupteryx calcarata* and *Ribautiana tenerrima* occur in the canopy of Hungarian apple orchards in more than 5% of relative abundance values.
Empoasca solani, Eupteryx atropunctata, *Empoasca decipiens* and *Laodelphax striatellus* occur inthe herb layer of apple and pear orchards in more than 5% of relative abundance values.
The most frequently occurring cicada species in apple orchards of Kent, Great-Britain were identified. These were, in decreasing order of relative abundance *Empoasca decipiens*, *Ribautiana debilis*, *Edwardsiana rosae*, *Empoasca vitis*, *Edwardsiana crataegi*, *Alnetoidia alneti*, *Zygina flammigera*, *Eupteryx atropunctata*, *Zygina flammigera* in the canopy and *Javesella pellucida*, *Euscelis incisus, Arthaldeus pascuellu, Deltocephalus pulicaris* in the herb layer.

3. Cicada species feeding most likely on apple trees were determined. Occurrence of the apple pest *Edwardsiana crataegi* was first recorded in Hungarian apple orchards. Additionally connection of four other cicada species to apple was detected. These were *Empoasca decipiens, Ribautiana tenerrima, Edwardsiana lamellaris, Cicadella viridis.* Connection of *Empoasca vitis* and *Ribautiana debilis* to apple in Great Britain was confirmed.
Connection of *Philaenus spumarius* and *Empoasca solani* (Hegab, 1981; Balás & Sáringer, 1984) to apple in Hungarian apple orchards was not reinforced according to our studies. These species occurred characteristically in herb layer.
Intensive migration of *Kybos populi* and *Kybos virgator* into the apple orchards from the surrounding vegetation was observed. Occasional feeding on apple can be supposed in the case of these two species.

4. Three generations of *Edwardsiana rosae, Edwardsiana lamellaris* and *Empoasca decipiens* was detected in Hungary, while only two generations in Great Britain. Two generations of *Edwardsiana crataegi* and *Ribautiana tenerrima* was observed.
Adults of *Kybos populi* és *Kybos virgator,* mentioned in literature from June and occurring in two generations, can be detectable already in May in Hungary and with three generations.

5. The investigations demonstrated that cicada assemblages of less intensely cultivated orchards with lower insecticide load are more diverse and more abundant. However, only the application of integrated pest management does not cause significant increase in number of species and individuals. Thus besides insecticide load other factors can also play important role.

6. As a result of investigations in Hungarian apple orchards and their surroundings was shown that the cicada assemblages of the orchards are primarily determined by the surrounding habitats. The differences between the orchards, edges and forests are secondary. It was observed that neither in orchards with low pesticide load develop characteristic cicada assemblages, distinctly different from the surrounding habitats. Although in orchards without insecticide treatments number of cicada species related to apple increased, species related to edges or forests were still present in high relative abundance.

7. The investigations demonstrated that the 'zero pesticide residues' programme, similarly to the conventional treatment reduced significantly the number of cicadas regarded as potential apple pests in the canopy.
Cicada species which are related to apple according to literature data -males of *Edwardsiana rosae, Edwardsiana crataegi, Ribautiana debilis, Zygina flammigera, Empoasca vitis*, and *Alnetoidia alneti* and females belonging to the genus *Empoasca*- the zero pesticide residue programme have similar decreasing effect on the number of individuals like the conventional treatment.
Effect of plant protection treatments on cicadas in herb layer was less perceptible.

8. New observations were made on the activity of *Edwardsiana rosae, Empoasca decipiens* and *Ribautiana debilis* in the apple orchards. The females of *E. rosae* and *R. debilis* showed greater activity in the first half, while the males in the second half of the vegetation period. Our results may confirm the supposition that mainly the females of these species immigrate into the orchards in spring and mainly the fertilized females leave the orchard to their winter host plants in the end of the vegetation period. The males of *Empoasca decipiens* also occurred in higher numbers in the second half of the vegetation period.

9. The investigations showed that cicadas generally occur in significantly higher abundance in lower parts of the canopy than in upper parts. Relation of seven cicada species to different canopy layers was allocated. It was determined that the males of *Edwardsiana rosae,* on the contrary to *Edwardsiana* females and other species occur in remarkably high numbers in the upper part of the canopy, compared to the lower parts. The reason can be better solar conditions in the upper part of the canopy.
It was established that the connection of cicada assemblages between the lower part of the canopy and the herb layer is not notable. Thus, the herb layer does not determine cicada assemblages of the lower part of the canopy.

10. Insecticide treatments significantly reduced the parasitization level of *Edwardsiana rosae.* However the parasitization was not considerable. In the case of the genus *Empoasca*, on the contrary to the genus *Edwardsiana*, the proportion of parasitized individuals was higher in the first half of the vegetation period. The parasitization level of the females decreased parallelly with the lower insecticide load. There was not considerable difference in parasitization level of the males according to plant protection treatments.
Vertical distribution of the parasitized specimens did not differed essentially from the characteristics observed at non parasitized individuals.

11. Observing the apple varieties it was found that cicadas occurred in lowest abundance in the canopy of Saturn, while in highest abundance in the canopy of Queen Cox. Varieties Ahra, Fiesta and Discovery did not differ from each other notably. Relationship was found between susceptibility of apple varieties against diseases and cicadas.

12. We confirmed that the male specimens of cicadas can be collected in higher proportion by methods based on migrating activity (Malaise traps, yellow sticky traps), and yellow sticky traps are more suitable for collecting cicadas in the canopy than beating method, although some species can be overrepresented. The proportion of males in sweep net samples can increase as a result of certain disturbing factors like regular intensive mowing.

4. Summary

4.1. Survey of cicada assemblages of Hungarian apple and pear orchards and their surroundings

Faunistical and quantitative survey of cicada assemblages in apple and pear orchards was first conducted in Hungary. In apple and pear orchards and their surroundings in seven localities altogether 145 cicada species were found, representing approximately 25% of the Hungarian cicada fauna. Compared to previous investigations in other habitats (Dér et al., 2003). Hegab (1981) Orosz (1981, 1983, 1996, 1997, 1999, 2002) Györffy (1920, 1982, 1987) our results are remarkable from faunistical respect.

It was found that besides *Edwardsiana rosae*, *Edwardsiana crataegi* can also play important role in cicada assemblages of Hungarian apple orchards. *Edwardsiana crataegi* can reach high density with decrease, or lack of plant protection treatments. *Edwardsiana rosae* can occur more frequently in Hungarian apple orchards, but the damage ascribed to this species can cause often *E. crataegi.*

We demonstrated relation of four additional cicada species to apple. These were *Empoasca decipiens, Ribautiana tenerrima, Edwardsiana lamellaris, Cicadella viridis.* Intensive migration of *Kybos populi* and *K. virgator* into the apple orchards was observed from the surrounding vegetation. Feeding of these species on apple can be possible.

We detected that *Empoasca decipiens* has three generations a year in Hungary, which often do not distinct clearly. The majority of the third generation individuals can leave the orchards. Two generations of *Edwardsiana crataegi* and three generations of *Edwardsiana rosae* was observed in Hungarian orchards. The adults of *Kybos populi* and *K. virgator* contrary to other literature data (Schiemenz, 1990; Nickel, 2003) can appear already in mid May and have three generations in Hungary.

We detected that despite that food resources available in apple orchards are of great volume, homogeneous and distinct from the surrounding vegetation, there did not developed cicada assemblages characteristic in apple orchards.

Contrary to observations of Altieri and Schmidt (1986) and Markó and Kádár (2005) there did not form cicada assemblages characteristic in apple orchards, distinct from the surrounding even in those orchards, where insecticide treatments were finished (Nyírtura and Újfehértó). However, when the localities were investigated separately, some differences between cicada assemblages of the investigated habitats were observed.

The lower intensity of cultivation caused development of greater cicada assemblages. However, only the application of integrated pest management -the lower insecticide load- did not cause significant increase in number of species and individuals. Supposedly the role of the diverse and dense herb layer can be more remarkable in developing of diverse cicada assemblages.

4.2. Investigations in apple orchards in Great-Britain

All of the frequent species mentioned in apple orchards in Great-Britain turned up during our investigations. Even though *E. decipiens* and *R. debilis* were among the most frequent species during our investigations, they were not been found by Chiswell (1964) in his previous observations in apple orchards at East Malling. In addition, Bennett (1959) did not mentioned *E. decipiens* in his samplings in British apple orchards. Massee (1941), however recorded these two species in apple orchards of Great Britain, and Alford (1992) reported, that *E. decipiens* can occur as an apple pest in some occasions. Chiswell (1964) found *Alnetoidia alneti* and *E. crataegi* as the most common species at East Malling, and *E. rosae* and *Z. flammigera* less frequent. Bennett (1959) also found *A.*

alneti in very high densities on apple in Britain. Jay and Cross (1999) recorded *E. crataegi* as the most common species, which was followed by *E. rosae* in less numbers in a Kent orchard. Lehmann (1973) found *E. rosae* as the dominant species on apple and cherry in Germany. Chiswell (1964) also recorded *E. vitis* and *Typhlocyba quercus* (Fabricius, 1777) in apple orchards but in lower number.

Collecting by yellow sticky traps, Malaise traps and sweep nets were effective methods for sampling cicada assemblages. The beat sampling technique was not satisfactory enough for collecting cicadas in sufficient quantities. Furthermore, the beating samples were dominated by females, which were very difficult or impossible to identify, while the sticky traps collected mainly males. The males can be overrepresented in samples collected by methods based on migrating activity, and underrepresented in sweep net samples. However some disturbing factors, as for example intensive mowing can cause increase of the males in sweep net samples too.

The investigations demonstrated that the 'zero pesticide residues' programme, similarly to the conventional treatment reduced significantly the number of leafhoppers regarded as apple pests in the canopy. The insecticide treatments increased the proportion of the males in the cicada assemblages.

The conventional treatments reduced the abundance of the species feeding only on woody plants. These were the males and the females of *Edwardsiana rosae, Edwardsiana crataegi, Ribautiana debilis, Zygina flammigera, Empoasca vitis* and *Alnetoidia alneti.* The most significant decrease in abundance could be detected at *E. rosae.* However, opposite tendency could be observed in the case of the males of the dominant species, *Empoasca decipiens* which was detectable in conventional plots in higher or equal numbers compared to untreated plots. While the females of *Empoasca* genus (supposedly mainly *E. decipiens*) were more abundant in untreated plots. On the whole, it can be assessed that the males of *E. decipiens* could tolerate, or even compensate heavier insecticide load successfully, by migration into the orchard.

The effect of pesticide treatments on the density of cicadas was less perceptible in herb layer. However, the diversity relations indicated that the insecticide treatments, although in smaller degree, have influence onto the cicada assemblages of the herb layer.

Two generations of *Edwardsiana rosae* and *Empoasca decipiens* were observed in Great-Britain. New observations were detected on activity of *E.rosae, E. decipiens* and *R. debilis* in apple orchards. The activity of males and females can differ remarkably during the vegetation period. The females of *E. rosae* and *R. debilis* showed greater activity in the first half, while the males in the second half of the vegetation period. Supposedly there were mainly the females of these species, which immigrated into the orchards in spring, and mainly the fertilized females left the orchard to their winter host plants in the end of the vegetation period. The males of *Empoasca decipiens* also occurred in higher numbers in the second half of the vegetation period. It would be worthy to investigate the sex ratio of these species on their winter host plants in spring and in autumn. In the case of *E.rosae* on wild rose, at *R. debilis* on blackberry and at *E. decipiens* on ivy.

Relation to different vertical levels of the canopy was observed in the case of seven cicada species. According to the previous studies (Jay & Cross, 1999; Verestsagina, 1962; Teulon & Penman, 1987) cicadas occur in significantly higher densities in lower parts of the canopy. This tendency was observable in case of the majority of the frequent species. However, *E. rosae* occurred in distinctly higher numbers in upper part of the canopy. Verestsagina (1962) and Claridge és Wilson (1978) recorded, that *E. rosae* prefers older leaves in the inward parts of the canopy for feeding. Thus, supposedly the reason of higher densities on upper parts would be better solar conditions rather than feeding. *E. crataegi* was related to the lower part of the canopy, according to Noble (1929), on the contrary to observations of Teulon and Penman (1987), who detected increase in numbers towards upper parts.

Majority of parasitised cicadas collected by us were infected by ectoparasitoids. Although they were not identified on species level, supposedly belonged to families Dryinidae (Hymenoptera) and

Pipunculidae (Diptera), similarly to previous findings of Chiswell (1964) and Jay and Cross (1999). The maximum parasitisation level was about 14% at the genus *Edwardsiana* and about 7% at the genus *Empoasca*. Parasitisation level of *Edwardsiana* genus increased significantly in the second half, while the parasitisation level of *Empoasca* genus in the first half of the vegetation period. The higher insecticide load reduced remarkably the parasitisation level of the genus *Edwardsiana*. Thus, the insecticide treatments had greater reducing effect on the activity and density of the parasitoids, than to the density of *Edwardsiana rosae*. This could be the possible explanation of rapid and heavy infestation caused by cicadas in apple orchards in Kent in 1994 and 1995 (Jay & Cross, 1999), when the cicadas became resistant against chlorpyriphos, while their parasitoids supposedly died. Thus, the resistance of cicadas and lack of parasitoids simultaneously caused serious plant protection problems. However, the parasitisation level observed in untreated control plots in our studies may not have important role in regulating of *E. rosae*. This coincides with findings of Verestsagina (1962) in the case of the family Drynidae. The question is, which other factors can influence the density of *E. rosae* and *E. crataegi*.

Five apple varieties were compared. The variety Saturn, resistant against venturia and powdery-mildew proved to be resistant against cicadas too, on the contrary to the susceptible Queen Cox, which was most sensitive against cicadas. Supposedly there can be a connection between disease resistance of apple varieties and resistance against cicadas.

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