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ORIGINAL PAPER

Fast spread of *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae) in Slovakia during the period 2020–2022

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Abstract

This research examines the rapid spread of the oak lace bug, *Corythucha arcuata* (Say, 1832), in Slovakia from 2020 to 2022. A native of the Nearctic region, this pest was first detected in Europe back in 2000 and has since extended across considerable part of the continent. Monitoring efforts revealed its presence in Slovakia in 2018, with subsequent surveys showing its distribution through the southern region and a northward expansion. The pest mainly infests oak trees, and in 2022, it was seen there on as many as 87% of the plots. Out of a total of 233 locations visited in the period 2020–2022, the bug was found on 169 sites, which represents 72.5%. The study identified the pedunculate and Turkey oak as primary host-plants. The results provided a clear trend from the bugs moving further north with each passing year, covering an estimated total distance of 84.5 km over the three-year timeframe. Factors influencing its spread included passive transport via vehicles and possible wind-assisted dispersal on a local scale. The study also highlights the need for continuous monitoring and management strategies to mitigate its impact on oak ecosystems.

Key words: oak lace bug; dispersal; invasive species in Europe; forest pests on oaks

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1. Introduction

The oak lace bug, *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae), is a small, sap-sucking insect originally from Eastern North America. Until 2000, it was only known in the Nearctic region, with a particular distribution in the United States and southern Canada (Drake & Ruhoff 1965). This species was introduced in Europe, where it was detected for the first time in 2000, in the Lombardy and Piedmont regions of northern Italy (Bernardinelli 2000). It quickly spread to neighboring Switzerland as well (Forster et al. 2005). In the years ahead, *C. arcuata* has occurred over a broad area of southeastern Europe, and several countries (Bulgaria, Hungary, Serbia, Russia, Albania, Romania, Slovenia, Bosnia and Herzegovina, France, Ukraine, Greece, Slovakia, Croatia, Bulgaria, Turkey) already reported its presence on their territories (Csóka et al. 2019). In 2019, this species was also found in countries neighboring Slovakia – in Austria (Sallmannshofer et al. 2019) and the Czech Republic (Mertelík & Liška 2020). In 2021, the oak lace bug has already been recorded in Poland, which is likely the northernmost point of its European invasion (Gierlasiński & Orzechowski 2023). Larger areas of oak forests heavily infested by OLB were first reported in Europe, specifically from Croatia, in 2016. From the eastern part of the country, where the pest population was the highest as the damage to forest stands, it has rapidly spread across the center to the western side (Franjević et al. 2016). Even summer vacationers traveling to reach the sea, along the highway from Zagreb to Split, had a chance since the 2016–2017 to see a heavy infestation of the oak forest around, mainly between Zagreb and Karlovac (personal experiences). Later on, strong pest outbreaks were reported as well from other countries, for example from Hungary in 2017 (Csepelényi et al. 2017), Bulgaria and Romania in 2016–2017 (Simov et al. 2018; Tomescu et al. 2018) or Austria in 2022 (Hoch et al. 2022).

The oak lace bug has wide spectrum of host-plants; however, the main host-plants are oak trees (*Quercus* spp.). Besides several oak species, it was also brought

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to the attention to develop on sweet chestnut (*Castanea* sativa Mill.), *Acer* spp., and European wild apple (*Malus sylvestris* [L.] Mill.), *Ulmus* spp., and many others (Jurc & Jurc 2017; Simov et al. 2018; Csóka et al. 2019). Not all authors of publications may took into account the fact that there are plants on which a psyllid species completes its immature to adult life cycle (host-plants) and there are also plants on which adult psyllids feed, but do not breed and do not spend an extended period of time (food-plants) (Burckhardt et al. 2014). It is therefore likely that many of the "host-plants" listed in the cited literature are actually just "food-plants" and in reality there are fewer actual "host-plants".

Since 2017, we started searching for *C. arcuata* on oaks and other trees, in Slovakia's territory. In June 2018, the presence of this species was first confirmed when an adult specimen and a few eggs were found near the village of Mužla in southwestern Slovakia, close to the Danube River. The place of occurrence is located not far from the border with Hungary. It was discovered on leaves of *Quercus cerris* L. growing in a mixed floodplain, a broad-leaved forest (Zúbrik et al. 2019). No monitoring was realized in 2019, however, a detailed follow-up on this pest in the country was done during the period 2020–2022 in order to detect its spatial distribution. This paper presents the results obtained as part of this project.

2. Material and methods

Between 2020 and 2022, we conducted visits to identify potentially suitable zones for the presence of *C. arcuata*. We have searched for the species in both, urban environments (such as municipal parks, recreational areas, and trees along city roads) as well as in forests. We chose plots where oaks are present. The size of the plots depended on their location in the landscape. When situated in the forested areas, the inspected area typically covered approximately 1 hectare. However, in urban environments or along roadsides, the plots often consisted of only a few trees, usually 5 or more. We carried out these visits from July to September each year.

Two people randomly examined the tree leaves in the plot up to a height of about 2 m, for a time interval of approximately 10 min and intensely looked for pest presence – characteristic symptoms of leaf damage, the occurrence of eggs, nymphs, or adults. If no signs were observed, the plot was marked as clear – none was present. If some were detected during the 10-minute interval searching, we selected 100 leaves randomly from different trees in the plot and scored the attack rate on the scale shown in Table 1. The geographic coordinates and altitude data were collected for each plot, alongside information on the tree species on-site, including the identification of the hosts. For identifying pests, we used the key by Forster et al. (2005).

Table 1. The scale used to express the degree of infestation by *Corythucha arcuata* in a plot (100 leaves examined).

Infestation level	Number of leaves with evidence of *C. arcuata* occurrence*
5	91–100
4	61–90
3	41–60
2	11–40
1	1–10
0	no presence

Notes: *Leaf damage – characteristic symptoms, occurrence of eggs, nymphs, or adults.

We used R version 4.2.3 (2023–03–15 ucrt) and RStudio (2023.03.0+386) to estimate in kilometers the northward movement of the oak lace bug between successive years. Data analysis was performed with the dplyr package (Wickham et al. 2023).

The dataset was filtered to include only instances where the bug occurrence was observed (≥ 1). The primary measurement of its spread was the maximum latitude reached by the oak lace bug annually, as it represented the northernmost boundary of its range. For any year in which it was found, we extracted the latitudinal values from the data, resulting in the highest latitude measure per year. For estimating the bug's northward movement in kilometers, we converted these max latitude points to radians and calculated the difference in the latter between the current and the previous year.

We employed a one-way ANOVA test (Analysis of variance), followed by ad hoc *t*-tests, to identify a statistically significant increase in the infestation of sites by *C. arcuata*. To achieve this, we utilized data about intensity of infestation on individual sites over the years.

3. Results

3.1. Occurrence of *C. arcuata* in Slovakia

In 2020, a survey was conducted primarily in the eastern part of Slovakia, and it yielded an unexpected result – *C. arcuata* was already established in a relatively large zone (Fig. 1). Based on findings from 2020, the monitoring for the presence of pests was carried out in 2021 and 2022, during which the area of interest was expanded to cover the whole southern region of the country. In 2021, severe infestations (level ≥3) of the bug were identified in several locations, especially around Šahy (Kosihovce, Dolné Semerovce, Príbelce). The surveillance in 2022 confirmed that this zone was the most heavily infested and a strong one was spreading eastward into the Rožňava region. Additionally, it was noted that this pest was gradually occurring in more northern areas. It was found completely unexpectedly in such places as Partizánske, Bánovce, or in Central Slovakia, surrounding Banská Štiavnica, Harmanec, etc. The northernmost presence was in the village of Cingelov Laz near Považská Bystrica

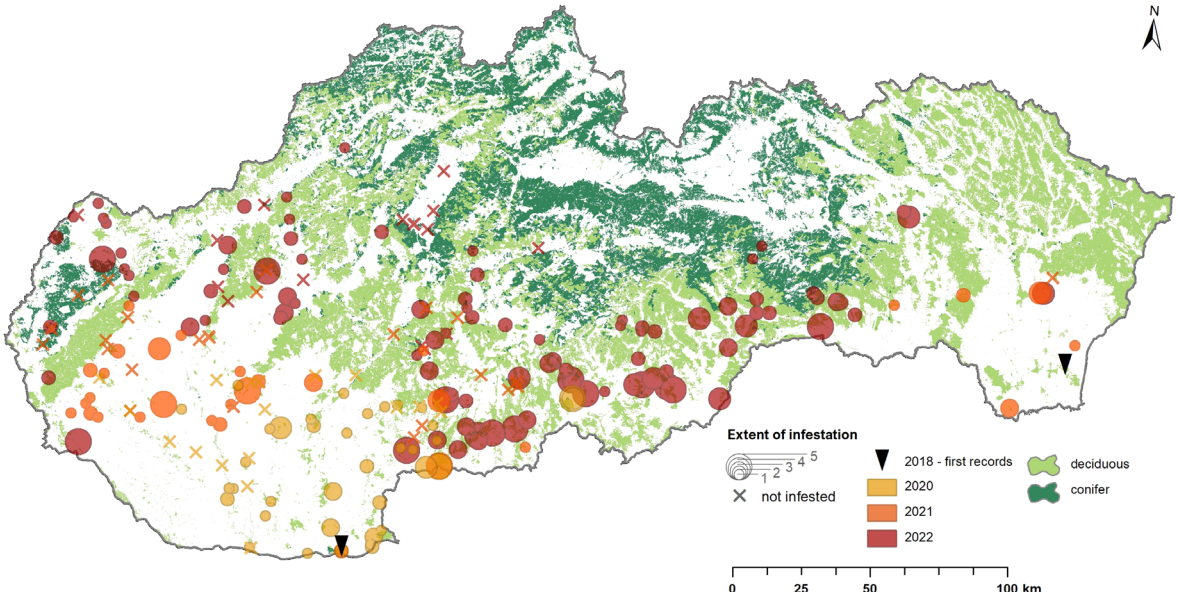

Fig. 1. Presence of *Corythucha arcuata* in Slovakia based on surveys realized in the period of 2020–2022. Black triangles show the plots where *C. arcuata* was found for the first time in 2018. The dot size represents the level of infestation and the localities marked with an "×" constitute the study sites without *C. arcuata*.

(Fig. 1). From Fig. 1, it is obvious that *C. arcuata* was broadly distributed in Slovakia, in 2022. It occurs along the entire border with Hungary, scattering in almost all oak forests, up to the central part of Slovakia.

As early as 2020, over 60% of the plots visited were invaded by *C. arcuata* (refer to Fig. 2). This was entirely surprising, considering that it had only been two years since the pest being first discovered in the country, in just a couple of places (Zúbrik et al. 2019). In 2022, it was present in as many as 87% of the plots. Out of a total of 233 locations visited during the period from 2020 to 2022, the bug was on 169 sites, accounting for 72.5% (Fig. 2).

The oak lace bug presence was confirmed not only in lowlands, but also in locations at higher elevations, or in mountainous regions, respectively. The majority of plots with its occurrence were found at altitudes ranging from approximately 170 m to 300 m (average was 246.8 m a.s.l.). Additionally, the species was recorded in highly elevated areas, with occurrences even at an altitude of 953 m a.s.l. (Fig. 4).

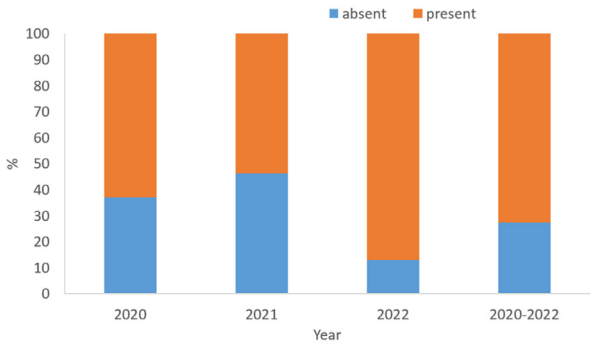

Fig. 2. Ratio of plots with and without the presence of this pest according to years. "absent" – the number of locations without its occurrence, "present" – the number of locations with its occurrence.

3.2. Intensity of infestation

In infested plots, host trees were typically showing leaf discoloration in 2020 and 2021, but the change was not as pronounced as it was in 2022. In 2022, infected oak trees were visible from a distance in the regions around Šahy. By examining Fig. 3, it is visually apparent that the number of sites with a low degree of infestation (level 1) has decreased from 2020 to 2022. Conversely, the number of locations with a higher degree (levels 2–5) has increased. The sites with the strongest level, the fifth one, increased from 13.2% in 2020 to 16.0% in 2022 (Fig. 3).

Table 2 displays the intensity of infestation by *C. arcuata* on visited locations, measured on a scale of 0 to 5. The data includes the average intensity, variance, and the results of *t*-tests for the years 2020, 2021, and 2022. While there are no significant differences between the years 2020 (average intensity 1.11) and 2021 (average intensity 1.11), the year 2022 shows a notable increase in the average intensity to 2.21. The *t*-test result being significant confirm a statistically significant difference in the intensity of *C. arcuata* attacks in 2022, which differ from both 2020 and 2021. These data confirm a rapid and significant increase in pest activity in 2022.

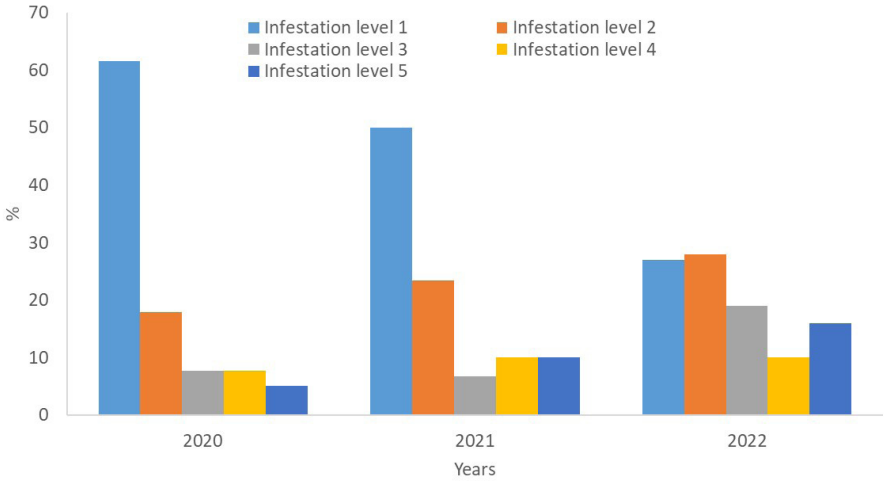

Fig. 3. The proportion of individual infestation levels recorded in visited plots for a given year.

Table 2. The annual intensity of *C. arcuata* infestation of visited locations, measured on a scale of 0 to 5. Different letters indicate statistical differences between variables.

Year (variable)	Average	Variance	*t*-test
2020	1.111111	1.616487	a
2021	1.107143	2.097403	a
2022	2.210526	2.48626	b

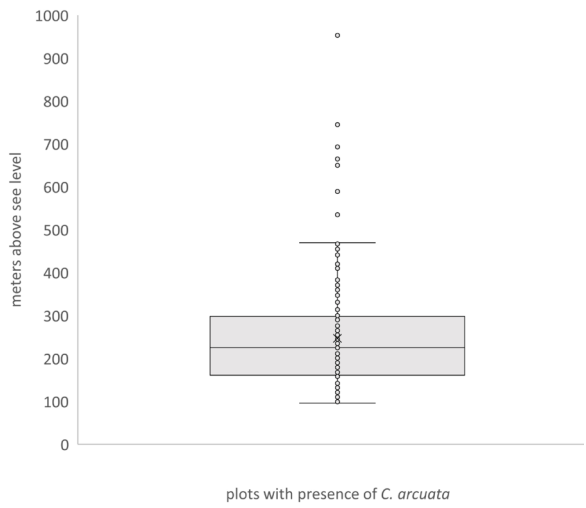

Fig. 4. Distribution of plots with presence of *C. arcuata* (169 plots) along altitude (meters above sea level). Circles representing original values of particular study plots are accompanied with box-and-whisker plot illustrating non-outlier range (whiskers), lower and higher quartiles (box) and median of altitudes.

3.3. Host-plants of *C. arcuata*

At 169 locations where *C. arcuata* was identified, we examined a total of 16,900 leaves originating from ten distinct host tree species during our monitoring. From this substantial sample, we detected various pest stages or characteristic symptoms on 5,704 leaves. The distribution among individual tree species is as follows: *Quercus cerris* L. 28.8%, *Quercus robur* L. 67.6%, *Quercus petraea* [Matt.] Liebl. 2.4%, *Quercus polycarpa* Schur 0.6%, and *Crataegus* spp. 0.6%.The pedunculate oak *Q. robur* L. and the Turkey oak (*Q. cerris*) were the most common host-trees within Slovakia during the study. We can confirm that all the five aforementioned species can be considered host-plants as all stages of the pest were found on the leaves.

3.4. Northward movement

The oak lace bug has been progressively moving north over the years in Slovakia. In 2020, the most northern point of its spread was recorded at the latitude of 48.3°N (Table 3). In the following year, it had traveled further north, reaching a peak of 48.8°N, indicating a northward spread of approximately 47.1 km. By 2022, the pest went to 49.1°N, marking a movement of about 37.4 km from the previous year. The data clearly show a consistent trend of a bug migrating from the south over a three-year span. During this period, their migration covered an approximate distance of 84.5 km northward.

Table 3. Annual northward movement of *Corythucha arcuata*.

Year	Max latitude (°N)	Difference in latitude (radians)	Northward movement (km)
2018*	47.6	—	—
2020	48.3	—	—
2021	48.8	0.00739	47.1
2022	49.1	0.00587	37.4

Note:*For comparison, we present latitude of locality Mužla – the place of the first discovery of OLB in Slovakia (Zúbrik et al. 2019).

4. Discussion

A survey conducted in 2020 revealed that *C. arcuata*, the oak lace bug, was already in a relatively large area in Slovakia's east. Subsequent monitoring in 2021 and 2022 confirmed its spread across the southern region, with heavy infestations found in the first place around Šahy. Pest populations gradually expanded to more northern zones, reaching locations such as Partizánske or Bánovce, and Central Slovakia. This pest was widely distributed in Slovakia by 2022, scattering in oak forests along the border with Hungary and extending into the central part of the country. The oak lace bug is spreading rapidly since 2018 and occupied most of broad-leaved forest stands with oaks in Slovakia until 2022 (for four years). We can speak about the very quick spread of the pest during the period between 2018 and 2022. Throughout Europe, 2015–2016 range expansion seems to be faster than the process it was from 2000 to 2015, and as "rapid" was reported from several European countries (Franjević et al. 2016; Csepelényi et al. 2017; Simov et al. 2018; Hoch et al. 2022).

The incidence of *C. arcuata* increased significantly from 2020 to 2022. In 2020, over 50% of the plots visited were with the oak lace bug, while it was present in 2022 in as many as 87% of them. The infestation level also heightened as time goes by, with a greater proportion of sites exhibiting a higher degree to which they were infested in 2022 compared to 2020. Several authors reported the same results – damage gradually increasing after the settlement of the pest in new territories (Franjević et al. 2016; Hoch et al. 2022).

It can be assumed that the oak lace bug reached Slovakia from Hungary, where it has been present since 2013 (Csóka et al. 2013; Zúbrik et al. 2019), and particularly in the years 2016 and 2017, it had already spread quite extensively (Csepelényi et al. 2017).

Direct mortality of oak trees caused by *C. arcuata* has not yet been recorded, but a negative impact on their health is highly probable (Paulin et al. 2020). An increase in the activity of secondary pests and fungal pathogens can be expected (Pap et al. 2018; Stojanović et al. 2021). In Slovakia, the main secondary pests of oak forests are *Scolytus intricatus* (Ratzeburg, 1837) (Coleoptera: Curculionidae), species of the genus *Agrilus* (Coleoptera: Buprestidae), *Armillaria* (Basidiomycota: Physalacriaceae), or *Microsphaera* (Erysiphaceae: Ascomycota).

There is a noted connection between oak defoliation and acorn crop reduction, with even minor foliage loss, causing significant declines in acorn yield. While observations in Croatia and Hungary have shown early acorn fallout and reduced acorn size in heavily infested oak stands, attempts to establish a direct link between oak lace bug infestation and acorn crop reduction have not yielded significant results (Franjević et al. 2018). The long-term cumulative effects of oak lace bug infestations on acorn crops could have practical implications for forestry, potentially leading to significant difficulties in natural oak stand regeneration and reproductive material production (Paulin 2020).

Presence of *C. arcuata* can affect the biodiversity of oak forests due to exploitative competition (exhausting the food source before other herbivores can finish their development) (Paulin et al. 2020).

The pedunculate oak (*Q. robur* L.) and the Turkey oak (*Q. cerris* L.) were identified as main host-plants for this pest in Slovakia. As in Europe, some other trees were also recognized as such (Jurc & Jurc 2017; Simov et al. 2018; Csóka et al. 2019), we expect this spectrum could be larger in the country too, if more attention is being paid to this issue in our study.

Adults of oak lace bugs are not strong fliers; however, we observed them quite frequently in the air. Especially in heavily infested areas, it is common to see adult individuals flying around the host-trees during windless days. We assume that wind may also have an important role as a pathway for their dispersal mainly at a local level (from crown to crown).

In general, many species, including some plant-eating insects like the gypsy moth for example, can be dispersed over large distances by wind (Doane & McManus 1981). The maximum transport distance for insects can vary widely depending on factors such as wind speed, weather conditions, and their size, weight, and wing structure. While some may only travel a few meters or less, others can be carried over several kilometers. There is no information that might verify if the oak lace bug can go over long distances assisted by the wind. In its spread in Slovakia, anthropogenic factors, such as passive transport by vehicles, likely played a greater role. Although there were some occurrences away from the main roads, the majority of locations with pest presence were near them. The significance of passive transport through traffic for the long-distance spread of *C. arcuata* has also been observed and confirmed in other countries (Bernardinelli 2006; Mutun et al. 2009; Jurc & Jurc 2017; Hoch et al. 2022). Regarding further spread, in addition to passive transport, climatic factors appear to be highly significant. Some recent study shows, that the increasingly warmer winters may not limit the expansion into more northern areas (Paulin et al. 2021, 2023).

The results of this study should be understood within the context of our methodology for data collection. In particular, our analysis was based on localities that were monitored for the presence of *Corythucha arcuata*. The geographic scope of our observations was limited and did not cover the total area of Slovakia.

While we are cautious not to generalize our findings to zones beyond our study sites, we argue that our results still provide valuable insights into the northward spread of the oak lace bug. Our approach based on analyzing the point's maximum latitude of pest occurrence each year is geared toward tracking the edge of the species range expansion. This facilitates our understanding of the

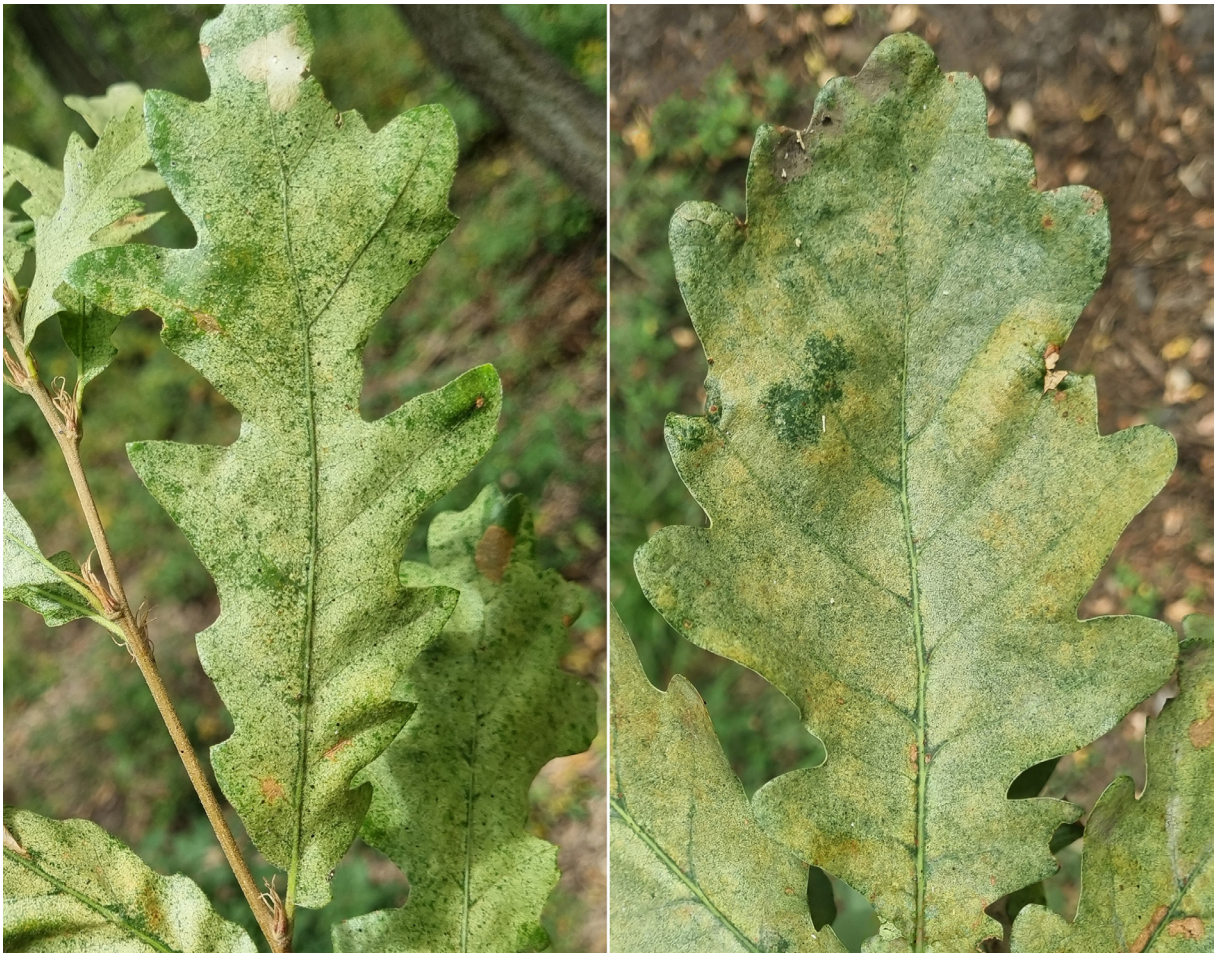

Fig. 5. Symptoms of *Corythucha arcuata* presence on Turkey oak (*Q. cerris* L.) – left and the pedunculate oak (*Q. robur* L.) – right.

broad northward movement for the bugs, even though not every location within this range has been thoroughly investigated. The further northward spread of the species in our region is expected. The recent discovery of the species in Poland in 2021 (Gierlasiński & Orzechowski 2023) underscores these concerns. Defining the precise boundaries of this expansion is challenging, as comparing it with the species' original North American range – USA and South Canada (Barber 2010) – may not provide an ideal reference due to differing climatic conditions. Nevertheless, Europe, encompassing the territory from the Baltic Sea to Spain (excluding mountainous regions), appears to offer a conducive environment for this species.

The results show a clear trend from the bugs traveling further to the north with each year that goes, spanning an estimated total length of 84.5 km over two seasons – the average annual movement was 42.25 km. We believe that despite the localized nature of our observations, this finding provides a reasonable approximation of their northward spread in Slovakia during the study period.

However, it is important to stress that broader geographical coverage will be necessary to deliver a more comprehensive picture of the oak lace bug distribution across Slovakia.

5. Conclusions

The paper examines the rapid spread of the oak lace bug, *C. arcuata*, in Slovakia between 2020 and 2022. This invasive species, originally native to North America, was first detected in Europe in 2000 and has since spread to various countries. In Slovakia, the study's findings reveal a significant expansion of *C. arcuata* within a short timeframe, with the pest now occupying a large portion of the country.

The study documented a remarkable increase in the presence of *C. arcuata* in Slovakia over the years, with over 87% of the surveyed plots exhibiting varying degrees of infestation by 2022. The level of infestation intensified, as higher degrees of pest presence were observed in 2022 compared to 2020. The authors suggest that the spread of *C. arcuata* in Slovakia has been rapid between 2018 and 2022.

The paper underscores the potential negative impact of the oak lace bug on oak forests, as increasing infestations may affect tree health and lead to secondary pest outbreaks and fungal pathogen activity. Additionally, the study identified the pedunculate oak (*Q. robur* L.) and the Turkey oak (*Q. cerris* L.) as the primary host-plants of the pest in Slovakia.

Anthropogenic factors, such as passive transport via vehicles, are believed to have played a significant role in the spread of *C. arcuata* in Slovakia. The authors note that passive transport through traffic likely facilitated the pest's introduction to the country, primarily from Hungary.

This research provides valuable insights into the spread of an invasive species and its potential impact on local ecosystems. The paper highlights the need for continued monitoring and management efforts to mitigate the effects of *C. arcuata* on oak forests in Slovakia and beyond.

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References

Barber, N. A., 2010: Light environment and leaf characteristics affect distribution of *Corythuca arcuata* (Hemiptera: Tingidae). Environmental Entomology, 39:492–497.

Bernardinelli, I., 2000: Distribution of the oak lace bug *Corythucha arcuata* (Say) in northern Italy (Heteroptera Tingidae). Redia, 83:157–162.

Bernardinelli, I., 2006: Potential host plants of *Corythucha arcuata* (Het., Tingidae) in Europe: A laboratory study. Journal of Applied Entomology, 130:480–484.

Burckhardt, D., Ouvrard, D., Queiroz, D., Percy, D., 2014: Psyllid host-plants (Hemiptera: Psylloidea): resolving a semantic problem. Florida Entomologist, 97:242–246.

Csepelényi, M., Hirka, A., Szénási, Á., Mikó, Á., Szőcs, L., Csóka, G., 2017: Az inváziós Tölgy csipkéspoloska [*Corythucha arcuata* (Say, 1832)] gyors terjeszkedése és tömeges fellépése Magyarországon [Rapid area expansion and mass occurrences of the invasive oak lace bug [*Corythucha arcuata* (Say, 1932)] in Hungary]. Erdészettudományi Közlemények, 2:127–134. (In Hungarian).

Csóka, G., Hirka, A., Somlyai, M., 2013: A tölgy csipkéspoloska (*Corythuca arcuata* Say, 1832 – Hemiptera, Tingidae) elsô észlelése Magyarországon. Növényvédelem, 7:293–296. (In Hungarian).

Csóka, G., Hirka, A., Mutun, S., Glavendekić, M., Mikó, A., Szőcs, L. et al., 2019: Spread and potential host range of the invasive oak lace bug [*Corythucha arcuata* (Say, 1832) – Heteroptera: Tingidae] in Eurasia. Agricultural and Forest Entomology, 22:61–74.

Doane, C. C., McManus, M. L., 1981: The gypsy moth: Research toward integrated pest management. Technical Bulletin (United States. Department of Agriculture) no. 1584. Washington, D. C., Forest Service. Science and Education Agency, 757 p.

Drake, C. J., Ruhoff, F. A., 1965: Lacebugs of the world: A catalog (Hemiptera: Tingidae). Bulletin of the United States National Museum 243. Washington D.C., Smithsonian Institution Press, 634 p.

Forster, B., Giacalone, I., Moretti, M., Dioli, P., Wermelinger, B., 2005: Die amerikanische Eichennetzwanze *Corythucha arcuata* (Say) (Heteroptera, Tingidae) hat die Süsschweiz erreicht. Mitteilungen der Schweizerischen Entomologischen Gesellschaft, 3–4:317–323. (In German).

Franjević, M., Pernek, M., Posarić, D., Banović, D., Hrašovec, B., 2016: Rapid spread and first data on damage levels and life cycle of *Corythucha arcuata* (Heteroptera, Tingidae) in Croatia. Book of Abstracts. 2nd Croatian Symposium on invasive species – with international participation, 21–22 November 2016. Zagreb, Croatia, 48 p.

Franjević, M., Drvodelić, D., Kolar, A., Gradečki-Poštenjak, M., Hrašovec, B., 2018: Impact of oak lace bug *Corythucha arcuata* (Heteroptera: Tingidae) on pedunculate oak (*Quercus robur*) seed quality. In: Radojčić Radovniković, I., Jakovljević, T., Petravić Tominac, V., Panić, M., Stojaković, R., Erdec, D. et al., (eds): Natural resources, green technology & sustainable development – GREEN/3. Zagreb, Croatia, University of Zagreb, Faculty of Food Technology and Biotechnology, p. 161–165.

Gierlasiński, G., Orzechowski, R., 2023: *Corythucha arcuata* (Say, 1832) (Hemiptera, Heteroptera: Tingidae) w Polsce. Acta entomologica silesiana, 31:1–6. (In Polish).

Hoch, G., Sallmannshofer, M., Connell, J., Hinterstoisser, W., Schafellner, C., 2022: Rasche Ausbreitung der invasiven Eichennetzwanze (*Corythucha arcuata*) in Österreich. Forstschutz Aktuell, 68:1–7. (In German).

Jurc, M., Jurc, D., 2017: The first record and the beginning the spread of oak lace bug, *Corythucha arcuata* (Say, 1832) (Heteroptera: Tingidae), in Slovenia. Šumarski list, 141:485–488.

Mertelík, J., Liška, J., 2020: Faunistic records from the Czech Republic – 495, Hemiptera: Heteroptera: Tingidae. Klapalekiana, 56:295–296.

Mutun, S., Ceyhan, Z., Sözen, C., 2009: Invasion by the oak lace bug, *Corythucha arcuata* (Say) (Heteroptera: Tingidae), in Turkey. Turkish Journal of Zoology, 33:263–268.

Pap, P., Drekić, M., Poljaković-Pajnik, L., Vasić, V., Marković, M., Zlatković, M. et al., 2018: Monitoring and forecasting of harmful organisms in forests and plantations of Vojvodina, Serbia in 2018. Topola, 201–202:251–274.

Paulin, M. J., Hirka, A., Eötvös, C. B., Gáspár, C., Fürjes-Mikó, Á., Csóka, G., 2020: Known and predicted impacts of the invasive oak lace bug (*Corythucha arcuata*) in European oak ecosystems – A review. Folia Oecologica, 47:131–139.

Paulin, M., Hirka, A., Csepelényi, M., Fürjes-Mikó, Á., Tenorio-Baigorria, I., Eötvös, Cs. et al., 2021: Overwintering mortality of the oak lace bug (*Corythucha arcuata*) in Hungary – a field survey. Central European Forestry Journal, 67:108–112.

Paulin, M. J., Eötvös, C. B., Zabransky, P., Csóka, G., Schebeck, M., 2023: Cold tolerance of the invasive oak lace bug, *Corythucha arcuata*. Agricultural and Forest Entomology, 1:1–10.

Sallmannshofer, M., Ette, S., Hinterstoisser, W., Cech, T. L., Hoch, G., 2019: Erstnachweis der Eichennetzwanze, *Corythucha arcuata*, in Österreich. Forstschutz Aktuell, 66:1–6. (In German).

Simov, N., Grozeva, S., Langourov, M., Georgieva, M., Mirchev, P. Georgiev, G., 2018: Rapid expansion of the oak lace bug *Corythucha arcuata* (Say, 1832) (Hemiptera: Tingidae) in Bulgaria. Historia Naturalis Bulgarica, 27:51–55.

Stojanović, D. B., Orlović, S., Zlatković, M., Kostić, S., Vasić, V., Miletić, B. et al., 2021: Climate change within Serbian forests: Current state and future perspectives. Topola, 208:39–56.

Tomescu, R., Olenici, N., Nețoiu, C., Bălăcenoiu, F., Buzatu, A., 2018: Invasion of the oak lace bug *Corythucha arcuata* (Say.) in Romania: A first extended reporting. Annals of Forest Research, 61:161–170.

Zúbrik, M., Gubka, A., Rell, S., Kunca, A., Vakula, J., Galko, J. et al., 2019: First record of *Corythucha arcuata* in Slovakia – Short Communication. Plant Protection Science, 55:129–133.

Other sources

R Core Team, 2023: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.R-project.org/.

Wickham, H., François, R., Henry, L., Müller, K., Vaughan, D., 2023: dplyr: A grammar of data manipulation. R package version 1.1.1. Available at: https://CRAN.R-project.org/package=dplyr.