# *Corythucha arcuata* SAY, 1832 (HETEROPTERA: TINGIDAE) IN THE CITY AND COUNTY OF SIBIU, ROMANIA, IN 2023

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**Abstract.** This paper presents a continuation of previous research published in 2023, which aimed to study the biology, ecology and ethology of the oak lace bug (OLB) *Corythucha arcuata* (Say, 1832) in the climatic conditions of the city of Sibiu, Romania. The objective of this paper is to continue the research carried out in previous years (2021-2023), the study being based on field observations carried out in the 18 monitoring points of the attacked trees and on the data provided by the Sibiu Forestry Department on the status of the spread of the invasive species *C. arcuta* in Sibiu county (Romania) in 2023. The insect was reported for the first time in the city of Sibiu in 2021, and in the period 2021-2023 it spread in all urban forest ecosystems, including public parks, green spaces in city districts and the Dumbrava Sibiului Forest (Romania). From 2023 onwards, it was also reported in forest ecosystems in Sibiu County, in the following forestry offices: Tarnava, Seica Mare, Medias, Saliste, Sibiu, Agnita, Darlos, Miercurea Sibiului, Poplaca. Through these surveys, it was possible to identify the rate of spread of the species in the city and county of Sibiu, in the context of climatic conditions in 2023. The detection and spread of the attack of this species in all urban ecosystems where oaks tree (*Quercus robur* L.) and sessile oak (*Quercus petraea* L.) are found in the city of Sibiu, but also in all 8 forestry offices in Sibiu County, demonstrates the danger of infestation in the future of an increasing area of oak and sessile oak.

**Key words:** invasive species; oak lace bug; distribution; damages; Sibiu; Romania.

## INTRODUCTION

Invasive insects are a major problem for global biodiversity, negatively impacting ecosystems and causing significant economic damage. These species, often originating from their natural habitat, migrate to new regions, becoming serious threats to plants, animals and even humans [8-12, 15, 25-29, 40-45, 49-51].

Due to climate change, more and more invasive insect species are appearing and affecting urban and forest ecosystems in Sibiu county (Romania). In recent years, three bug species (Heteroptera)- sycamore lace bug *Corythucha ciliata* Say, 1832 (Tingidae), oak lace bug *Corythuca arcuata* Say, 1832 (Tingidae) and the newest species lime seed bug *Oxycarenus lavaterae* (Lygaeidae) have been reported.

A relevant example in this context is *C. arcuata*, also as the oak bug (OLB). This insect originates from North America [1]. Nowadays, the OLB has spread to various regions of the world, Italy [3, 13, 18], Switzerland [19, 49], Turkey [2, 17, 28, 32, 44], Iran [41], Poland [50], Bulgaria [14, 43], Hungary [8, 9, 25-27, 37], Croatia [4, 23], Serbia [29, 34, 37], Russia [5, 22, 30, 31, 33], Albania, Greece and Ukraine [8, 11, 16, 21, 24], Slovenia [12], France [47], Slovakia [10, 51], Bosnia and Herzegovina [11], Austria [40], North Macedonia [45], Spain [38] and Portugal [20]. The first report of OLB in Europe occurred in northern Italy (in the regions of Lombardia and Piemonte) in May 2000 [3] and was observed on species such as *Quercus robur* L.*, Q. pubescens* Willd. and presumed hybrids between *Q. robur* L. and *Q. petraea* (Matt.) Liebl. Since then, this species has spread rapidly into over 20 European countries [13-15, 30-34, 36, 37, 47], mainly affecting Eurasian oak species but also other woody plants.

The first observation of the invasion of this species in Romania was recorded in July 2015 in the University Botanical Garden "Pavel Covaci" in Macea [16]. A second report occurred in October 2015 in Arad [38]. In the period 2016-2022, the attack of the invasive species *C. arcuata*, spread rapidly in various areas of the country: in the west, east and Bucharest area [6, 7].

In August 2016, OLB was identified around Bucharest [6], spreading to Giurgiu County, mixed forests in Calarasi County (with an attack rate between 60-100%), Băicoi (Prahova County), Baciu Forest (Cluj County) [46], Timișoara, Denta (Timiș County) (Rădac *et al*., 2017), Craiova, Balasan (Dolj County), Ciolănești (Teleorman County) [46].

Affected host species include oaks (*Quercus robur* L.*, Q. petraea* (Matt.) Liebl.*, Q. cerris, Q. frainetto, Q. pubescens* Willd.), elms (*Ulmus minor* L.), limes (*Tilia platyphyllos* L.*, T. tomentosa* L.) and plums (*Prunus cerasifera* L.) [48].

The defoliation of the attack ranged from 1% to 100% [7, 35, 46, 48]. In 2023, the attack was also confirmed in other counties of Romania, with the presence of the species reported in Bistrita, Suceava, Piatra-Neamț, Mures, Hunedoara and Alba.

Out of the 41 counties of Romania, OLB has been recorded in 34 counties, which represents 82.93 % of the Romanian territory [35].

Since 2021 OLB has been reported in Sibiu County. In the following years 2022-2023, it was monitored and its biology, ecology, and ethology were studied in the local climatic conditions. Also in 2022 the monitoring of the species started in the forest lands of the Sibiu Forestry Department by forestry offices of forest protection.

## MATERIAL AND METHODS

The research task included evaluation the parameters of OLB seasonal development based on weather data of 2023 and comparing with those of 2021-2022: assessment of OLB speread and infestation

level in Sibiu urban stands and in the forests of Sibiu County.

In February-December 2023, as in the previous two year [46], to assess the degree of infestation with *C. arcuata*, the 18 observation points (Table 1) were monitored in the city of Sibiu, all located in the urban area of Sibiu, not only in isolated stands but also in parks (Sub Arini Park-4 sites, Astra and Citadel Parks-2 sites), green areas (Museum of Natural History Sibiu, Turismului street, Cârlova street, Ștefan Cel Mare street, Ovidiu street-3 sites, the city cemetery, Sibiu Zoo) in the districts of Ștrand, Hipodrom, Gușterița and Turnișor and the trees on the edge of Dumbrava Sibiului forest [46].

To follow the diapause of OLB, we mounted a cardboard tree trunks in 30 November 2023 on the trunks of the trees and at a height of 1-1.5 metres above the ground, during the period when the adults of the third generation $G_3$ were preparing for hibernation.

The traps were installed when the air temperature dropped below 10°C. The traps, measuring 50 cm in length, were made of embossed cardboard and contained approximately 30-50 tubes, depending on the diameter of the trunk on which they were mounted.

The traps were removed from tree trunks in the spring of 2024, when air temperatures exceeded 8°C in 9 April 2024 (Fig. 2). At the time of trap removal, live adults were found between the trunk and the trap, confirming that, in the climatic conditions of Sibiu, the insect has successfully wintered in the adult stage of the last generation of 2023. At the time of dismantling the traps, the tree canopy was already leafy.

**Table 1.** Observation points located in urban areas of Sibiu

| Observation point-location | Latitude | Longitude |
|---|---|---|
| (P1)- Museum of Natural History | 45.794861 N | 24.154331 E |
| (P2)- Gușterița Hill | 45.8130271 N | 24.1929242 E |
| (P3)- Ovidiu Street | 45.8020408 N | 24.1679062 E |
| (P4)- Cetății Street | 45.7930233 N | 24.1511521 E |
| (P5)- Cetății Street | 45.7930287 N | 24.1511370 E |
| (P6)- Bâlea Street | 45.7901032 N | 24.1644136 E |
| (P7)- Turismului Street | 45.7942431 N | 24.1385803 E |
| (P8)- Vasile Cârlova Street | 45.7910946 N | 24.1377347 E |
| (P9)- Municipal Cemetery | 45.766123 N | 24.138881 E |
| (P10)- Municipal Cemetery | 45,767434 N | 24,139437 E |
| (P11)- Municipal Cemetery | 45.763336 N | 24.139674 E |
| (P12)- Forest border Dumbrava Sibiului | 45.774330 N | 24.135681 E |
| (P13)- Astra Park | 45.793181 N | 24.148019 E |
| (P14)- Sub Arini Park | 45.7835213 N | 24.1398915 E |
| (P15)- Sub Arini Park | 45.7782210 N | 24.1393353 E |
| (P16)- Sub Arini Park, Silva Restaurant | 45.784750 N | 24.142833 E |
| (P17)- Onisifor Ghibu High School | 45.789686 N | 24. 135182 E |
| (P18)- Sibiu Zoo | 45.7609454N | 24.1251612E |


**Figure 1.** Location of the 2023 study area in Sibiu with map (www.google.com/maps/)

**Figure 2.** Trap belt for adult retreat of *C. arcuata* in the 2023 hyenal diapause

In the year 2023, on 5 May to follow OLB development, 5 branches (Fig. 3) were marked at 5 of the 18 observation points at the time of oak inflorescence. Throughout 2023 all three developmental stages of OLB (eggs, nymphs and adults of different generations), were registred to calculate the number of days the insect passed from one developmental stage to another. The information obtained was necessary to calculate the insect developmental constants related to weather data.

During 2023, the insect passed through all developmental stages (Fig. 4) and three generations developed under the weather conditions of the year (Table 2). The development constants of the species were calculated for each generation, and the data obtained were reported on the number of days (Tab. 2).

To determine the severity of OLB attack in 2023 we monitored the lavel of defoliation of tree defoliation during the growing season at the observation points, studied the morphology of the insect and determined in November the extent of the attack. As early as 28 May, the first tip and presence of OLB on the underside of leaves were found and yellowish to brownish spots were reported during the evolution, with the presence of adults, nymphs or dark excrements recognized as additional signs (Fig. 5).


**Figure 3.** Marked branches for monitoring the species at different stages of development

**Figure 4.** Development stages of OLB under weather conditions of 2023 (eggs, larvae, nymphs), image enlarged by 10X

**Figure 5.** Leaves attacked by *C. arcuata* at different stages of development

The Sibiu Forestry Directorate manages a large area of forests in Sibiu County, totalling 119.370 hectares. Of this area, state owns 61.065 hectares, 45.699 hectares are owned by administrative-territorial units and 12.606 hectares are privately owned.

The forests managed by the Sibiu Forestry Directorate cover 117.516 hectares, of which 37.611 are coniferous and 79.905 hectares are deciduous. The afforestation rate of Sibiu County is 34%, above the national average.

The Sibiu Forestry Directorate manages forests through 8 Forest Park Offices (Agnita, Arpaș, Avrig, Miercurea Sibiului, Dumbrăveni, Mediaș, Sibiu, Valea Cibinului-Sălișteș), covering an area of 112.837 hectares of forest.

Regarding the species structure of state-owned forests, coniferous trees account for 40.6%, with spruce as the best- represented species in pure stands. Beech is also well represented, with 23.2% in pure or mixed stands, and quercus (oak) contributes 17.4%. The remaining 18.8% is occupied by hardwoods (18%) and miscellaneous softwoods (0.8%).

Temperature variations (Table 2-5) played a central role in metabolism and metamorphosis as OLB spread to different areas of the city in search of new host trees. This influenced the number of eggs laid on the leaves and the occurrence of the three generations under 2023 conditions.

Table 2 shows the average monthly minimum temperatures recorded in the period 2021-2023 at the Sibiu Weather Station. An increase of these minimum temperatures is observed, ranging between 4.55°C and 5.89°C, which represents an increase of 1.34°C of the minimum temperature in the city of Sibiu. This increase in the annual minimum temperature favours the development of the species *C. arcuata* and its wintering as an adult.

Table 3 shows the monthly average temperatures recorded in the period 2021-2023 at the Sibiu Weather Station. An increase in these average temperatures is observed, ranging between 9.9 °C and 11.37 °C, which represents an increase of 1.8 °C in the average temperature in the city of Sibiu. This increase in average annual temperature favours the extension of the attack of *C. arcuata* and the emergence of three generations per year in the climatic conditions of Sibiu.

Table 4 shows the average monthly maximum temperatures recorded in the period 2021-2023 at the Sibiu Weather Station. An increase of these maximum temperatures is observed, ranging between 15.86 °C and 16.94 °C, which represents an increase of 1.08 °C of the maximum temperature in the city of Sibiu. This increase in the annual maximum temperature led to an extension of the attack to the whole county and to an increase in the degree of attack at the end of September in all forest ecosystems where oak and cecile oak species are present.

The rainfall recorded in the period 2021-2023 in the city of Sibiu (Table 5) supported the growth of forest vegetation, which in turn provided habitat and food for *C. arcuata*. This invasive species has adapted its life cycle and reproduction to the humidity conditions of Sibiu.

**Table 2.** Average minimum temperatures for 2021-2023

| Month | Year 2021 | Year 2022 | Year 2023 |
|---|---|---|---|
| January | -3.7 | -4.52 | -0.1 |
| February | -2.53 | -3.13 | -5.13 |
| March | 1.79 | -3.36 | 0.9 |
| April | 2.42 | 1.98 | 4.63 |
| May | 8.63 | 8.23 | 9.45 |
| June | 12.55 | 12.19 | 13.52 |
| July | 15.39 | 13.97 | 15.2 |
| August | 13.34 | 14.91 | 15.68 |
| September | 8.35 | 9.86 | 11.09 |
| October | 2.59 | 5.48 | 6.14 |
| November | 0.31 | 5.3 | 0.87 |
| December | 0.84 | -1.08 | -1.63 |
| **Average** | **4.55** | **4.99** | **5.89** |

**Table 3.** Average mean temperatures in 2021-2023

| Month | Year 2021 | Year 2022 | Year 2023 |
|---|---|---|---|
| January | 0.36 | -0.62 | 3.76 |
| February | 2.48 | 1.87 | 0.3 |
| March | 2.86 | 2.25 | 6.86 |
| April | 7.68 | 8.39 | 8.69 |
| May | 14.36 | 16.01 | 15.02 |
| June | 18.85 | 19.79 | 18.34 |
| July | 22.45 | 21.59 | 21.48 |
| August | 19.9 | 21.33 | 21.8 |
| September | 14.31 | 13.77 | 18.2 |
| October | 7.88 | 11.02 | 13.4 |
| November | 4.99 | 5.7 | 5.9 |
| December | 2.12 | 3.3 | 2.73 |
| **Average** | **9.90** | **10.37** | **11.37** |

**Table 4.** Average maximum temperatures in 2021-2023

| Month | Year 2021 | Year 2022 | Year 2023 |
|---|---|---|---|
| January | 4.53 | 3.9 | 7.78 |
| February | 8.07 | 8.51 | 5.68 |
| March | 8.88 | 8.58 | 12.47 |
| April | 13.91 | 14.98 | 13.53 |
| May | 20.46 | 22.87 | 20.87 |
| June | 25.08 | 26.81 | 22.93 |
| July | 28.82 | 28.61 | 27.94 |
| August | 16.78 | 27.19 | 28.13 |
| September | 21.62 | 19.67 | 24.54 |
| October | 14.80 | 18.4 | 20.97 |
| November | 11.81 | 10.72 | 10.34 |
| December | 5.33 | 7.72 | 8.06 |
| **Average** | **15.86** | **16.5** | **16.94** |

**Table 5.** Average precipitation for the months of 2021- 2023

| Month | Year 2021 | Year 2022 | Year 2023 |
|---|---|---|---|
| January | 0.12 | 0.38 | 2.11 |
| February | 0.26 | 0.35 | 0.01 |
| March | 2.29 | 0.79 | 0.58 |
| April | 1.78 | 2.44 | 2.78 |
| May | 3.53 | 1.04 | 1.03 |
| June | 2.55 | 1.64 | 5.32 |
| July | 2.96 | 2.15 | 2.67 |
| August | 1.84 | 1.84 | 1.49 |
| September | 2.08 | 3.08 | 1.02 |
| October | 0.43 | 1.87 | 1.14 |
| November | 0.94 | 1.31 | 1.54 |
| December | 1.98 | 1.62 | 0.26 |
| **Average** | **1.87** | **1.54** | **1.66** |

Blunck's formulas were used to present the development equations of *C. arcuata* [42].

$$t_0 = \frac{x_2 \cdot t_2 - x_1 \cdot t_1}{x_2 - x_1} (1)$$

Thermal constant (K), representing the sums of daily temperatures ($t_1$-$t_o$) required to complete a life cycle from egg to adult stage of the species and is calculated from the growth equation:

$$K = \frac{x_n (t_1 - t_0)}{x_{n_1} - x_{n_2}} (2)$$

The thermal optimum ($t_n$) is the thermal value at which the maximum prolificacy and growth of *C. arcuata* is reached. This thermal limit is calculated with the formula:

$$t_n = t_0 + \frac{K}{\sqrt{x}} (3)$$

The upper thermal limit noted with (T) is the threshold at which the insect activity stops, because the species does not survive beyond this limit and the adults die. This thermal threshold T is calculated with the formula:

$$T = t_0 + \sqrt{K} (4)$$

## RESULTS

### 1. Parameters of OLB seasonal development

The growth constants of OLB in the weather conditions of Sibiu County in 2023 confirmed the relations between the rate of insect development and temperature. The constants calculated for the three generations ($G_1$, $G_2$, $G_3$) are the values at which the processes of change and development of the species from one stage to another occur with the change in meteorological values.

**Table 6.** Development constants of *C. arcuata* in the weathere conditions of Sibiu in 2023

| Generation | Period (Day/month) | Thermal constant K (°C) | Biological threshold ($t_0$) |
|---|---|---|---|
| $G_1$ | 6.II.-27. V. | 881.7 | |
| $G_2$ | 28.V-9.VII | 795.1 | |
| $G_3$ | 10.VII-22. VIII. | 953.4 | |
| **Generation** | **Prolificity threshold ($t_n$)** | **Number of days ($x_n$)** | 1.08 °C |
| $G_1$ | $t_1$= 7.93 | $X_1$=111 | |
| $G_2$ | $t_2$=18.07 | $X_2$= 44 | |
| $G_3$ | $t_3$=17.66 | $X_3$= 54 | |

G (number of generations1-3), II-VIII (months of the year, February-August), K (Thermal constant), $t_n$ (thermal optimum).

In the spring of 2023, adults were observed grouping on the main leaf vein and the first egg deposition was reported on 27 May. Egg deposition monitoring revealed an average between 12 and 120 eggs per observation point on marked branches (Fig. 3). The second egg deposition was observed on 2 July, when the lower leaves were covered with first generation adults, second generation eggs $G_2$ and nymphs in stages I, II and III.

On 16 July, on the branches marked at the observation points, the presence of first generation adults $G_1$, fourth stage nymphs and second generation eggs were confirmed around 22 July, when the first second generation adults $G_2$ appeared. At the end of July, between 29 and 31, the presence presence of G2 adults, stage V G1 nymphs and third generation eggs $G_3$ were reported at all 18 observation points.

On 13 August, the first nymphal stage of $G_2$ was observed, with all stages of the insect's development present on the leaves: G2 adults, nymphs and $G_3$ eggs. In mid-September, $G_3$ adults were also reported on the leaves, during this period the leaf attack rate was about 80-99%.

The minimum temperature at which the OLB reacted in the weather conditions of Sibiu in 2023, as well as the average temperatures specific to each generation are shown in Tables 2-5:

$$t_0 = \frac{x_2 \cdot t_2 - x_1 \cdot t_1}{x_2 - x_1} = \frac{111 \cdot 7.93 - 44 \cdot 18.07}{111 - 44} = 1.27 (5)$$

Generation-specific average temperatures during 2023 are shown below:

$$t_1 = \frac{K_1}{x_1} = \frac{881.7}{111} = 7.94 (6)$$

$$t_2 = \frac{K_2}{x_2} = \frac{795.1}{44} = 18.07 (7)$$

$$t_3 = \frac{K_3}{x_3} = \frac{953.4}{54} = 17.66 (8)$$

The growth constants of OLB under the weather conditions of 2023 in Sibiu were calculated using Blunck's growth equation [42] according to the relationships below:

$$K = \frac{x_n (t_1 - t_0)}{x_{n_1} - x_{n_2}} = \frac{111 \cdot (7.93 - 1.08)}{111 - 44} = 11.34 °C (9)$$

***Prolificity threshold (O)***

It was represented by the degree of temperature $t_n$ and above these values the two sexes of OLB become fertile. In 2023 the prolificacy threshold of the OLB was 11. 34°C.

$$t_n = t_0 + \frac{K}{\sqrt{x}} = \frac{876.73}{\sqrt{365}} = 26.98 °C (10)$$

***Thermal Optimum ($O_1$)***

In the weather conditions of Sibiu, the thermal optimum in 2023 was represented by the temperature degree $t_n$ at which the growth processes of the OLB occurred in the shortest time and the prolificacy reached the maximum value. The values obtained were calculated with the relation below:

$$t_n = \frac{t_0 + \sqrt{t_0^2 + 4K}}{2} = \frac{1.08 + \sqrt{1.08^2 + 4 \cdot 11.34}}{2} = 24.39 °C (11)$$

***Upper temperature threshold (T)***

In 2023 in Sibiu, the upper temperature threshold was represented by the maximum temperature above which the species ceased to grow. The maximum temperature withstaded by the OLB in the city of Sibiu in 2023 was 30.28° C.

$$T = t_0 + \sqrt{K} = 1.08 + \sqrt{876.73} = 30.28 °C (12)$$

## 2. OLB spread and infestation level in the forests of Sibiu County.

From the information provided by the Sibiu Forestry Department, the presence of OLB in 2022 in the Forest Park Offices (Medias, Arpas, Saliste and Sibiu) is confirmed. Out of a total area of 10.498,93 ha, the infested area in 2022 was 10.004,29 ha which represents 95.28% of the total forest area where the species was reported (Table 7).

**Table 7.** Area infested with OLB in 2022 in the Forest Park Offices of Sibiu county (source: Sibiu Forestry Directorate)

| Production unit (PU) | Forest body (name) | Area (ha) | Infested area |
|---|---|---|---|
| Medias Forest Park | Darlos | 44.5 | 18.4 |
| Medias Forest Park | Tarnava | 1.0 | 0.6 |
| Medias Forest Park | Seica Mare | 40.5 | 7.0 |
| Medias Forest Park | Axente Sever | 6.4 | 3.0 |
| Sibiu Forest Park | Pr. Sibiu, CJ Sibiu | 614.36 | 614.36 |
| Sibiu Forest Park | Poplaca | 515 | 515.0 |
| Sibiu Forest Park | Dumbrava | 63.36 | 63.36 |
| Sibiu Forest Park | Daia | 502.8 | 502.8 |
| Sibiu Forest Park | Fantana Rece | 539.1 | 539.1 |
| Sibiu Forest Park | Sibiu Forest Park | 6302.73 | 6064.7 |
| Sibiu Forest Park | Pr. Miercurea Sibiului | 98.67 | 52.7 |
| Sibiu Forest Park | Pr. Miercurea Sibiului | 214.61 | 136.49 |
| Arpas Forest Park | Arpas Forest Park | 134.24 | 225.0 |
| Medias Forest Park | Medias Forest Park | 456.59 | 151.3 |
| Saliste Forest Park | Saliste Forest Park | 1520.0 | 1000.0 |
| | | 10.498,93 | 10.004,29 |

**Table 8.** Area infested with OLB in 2023 in the forestry offices of Sibiu County (source: Sibiu Forestry Directorate)

| Production unit (PU) | Forest name | Administrative unit (a.u.) | Area (ha) | Stand composition | Age | Infested area (ha) | | Infestation intensity | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % | Current | % | Current |
| F.P. Mediaș | U.B.Pr. Dârlos | 48E | 1.6 | 8Go, 2Ca | 45 | 1.3 | 1.3 | P | P |
| F.P. Mediaș | U.B.Pr. Dârlos | 48F | 1.3 | 5Fa,4Go,1Ca | 85 | 0.5 | 0.5 | M | M |
| F.P. Mediaș | U.B.Pr. Dârlos | 49D | 1.39 | 6Go,1Fa,3Ca | 90 | 5.0 | 5.0 | W | W |
| F.P. Mediaș | U.B.Pr. Dârlos | 55B | 5.1 | 7Go,2Ca,1Fr | 15 | 2.0 | 2.0 | M | M |
| F.P. Mediaș | U.B.Pr. Dârlos | 55C | 14.9 | 7Go,2Ca,1Fa | 85 | 5.5 | 5.5 | M | M |
| F.P. Mediaș | U.B.Pr. Dârlos | 55D | 1 | 3St,5Go,2Ca | 65 | 0.8 | 0.8 | P | P |
| F.P. Mediaș | U.B.Pr. Dârlos | 64A | 2 | 6Go,1St,2Ca,1 Dt | 145 | 1.0 | 1.0 | M | M |
| F.P. Mediaș | U.B.Pr. Dârlos | 64B | 4.6 | 3St,1Fa,2Go,2 Ca,1Fr,1Pa | 125 | 2.3 | 2.3 | M | M |
| F.P. Mediaș | Pr. Târnava | 40C | 1 | 9Go,1Dt | 120 | - | 0.6 | - | M |
| F.P. Mediaș | Pr. Seica Mare | 13E | 3.1 | 7Go,3Fa | 75 | - | 1.5 | - | VP |
| F.P. Mediaș | Pr. Seica Mare | 13D | 0.5 | 10Go | 70 | - | 0.5 | - | W |
| F.P. Mediaș | Pr. Seica Mare | 86B | 36.9 | 4Go,6Ca | 75 | - | 5.0 | - | W |
| F.P. Mediaș | Pr.Axente Sever | 31A | 6.4 | 8Go,1Fa,1Ca | 130 | - | 3.0 | - | M |
| F.P. Sibiu | Pr.Sibiu, Cj Sibiu | C2,C3 | 614.36 | St,Go | 40-150 | 614.36 | 614.36 | W | W |
| F.P. Sibiu | C.3 Poplaca | C3 | 515 | St,Go | 40-151 | - | 515 | - | - |
| F.P. Sibiu | C.2 Dumbrava | C2 | 63.36 | St,Go | 40-152 | - | 63.36 | - | - |
| F.P. Sibiu | C.6 Daia | C6 | 502.8 | St,Go | 40-153 | - | 502.8 | - | - |
| F.P. Sibiu | C.7 Fântâna Rece | C7 | 539.1 | St,Go | 40-154 | - | 539.1 | - | - |
| F.P. Miercurea | Pr. Miercurea Sibiului | 13-15 | 98.64 | 9Go,1Dt | 80-130 | - | 52.7 | - | P |
| F.P. Miercurea | Pr. Miercurea | 40-61 | 214.61 | 8Go,1Dt | 60-125 | - | 136.49 | - | P |
| F.P. Arpaș | III,I | 39-41,4,5,52-70,87-92 | 225 | St,Go,Dt | 50-110 | - | 225 | | W |
| F.P. Dumbraveni | I,III,V,VI | 50B, 52B, 71ª, 28ª, 72D,C, 73B,C,D, 75C, 76B,C, 121B, 122B, 54G, 117B, 11A, 3B, 47A,C,D,F,G, 48,54A,B,D | 134.24 | St,Go,Dt | 5-130 | - | 78.48 | - | W-P |
| F.P. Mediaș | III,IV,V,VI,VIII | 51A,50A,61A,B,62A, B,63A,41B,29C,D,10E,4B, 5B,5D,64C,45,77C,87B,59 D,5A,6A,56B,52B,51C,32, 33A,12D,C,21C,23A,69B,8 1B, 12A,14D | 456.59 | St,Go,Dt | 50-110 | - | 151.3 | - | VW-P |
| F.P. VI.Ciban Săliște | I,III,IV | 68-99,100-139/2-8,35-47,83-94,146,998/1-8,13,18,19,30-49,70,79,88 | 1520 | 10Go | 65-75 | 1000 | 1000 | M | M |
| F.P. Sibiu | I,III | Canton1, Canton15 | 6302.5 11.265,99 | St,Go | 40-150 | 1055.4 | 6064.7 9.972,29 | W | W |

**Legenda:** Form of attack **VW**- very slight (1-10%); **W**- slight (11-25%); **M**-middle (26-50%); **P**- severe (51-75%); **VP**- very severe (>75%). F.P.-forest park; **a.u**. – administrative unit; **Go**-sessile oak; **O(St)**-*Quercus*, **Fa**-*Fagus*; **Ca**-*Carpinus*; **Fr**-*Fraxinus.*

In 2022, the OLB was reported in the Medias Forest Park (Dârlos, Târnava, Șeica Mare, Axente Sever), Sibiu Forest Park (Dumbrava, Poplaca, Daia, Fantana Rece), Miercurea Sibiului Forest Park, Arpaș Forest Park and Sălișteforest Park.

From the data analysis presented in Table 8 which represents the forest units managed by the Sibiu Forestry Department, it can be seen that the ecosystems with beech and sessile oak stands were attacked and the age of the trees varied between 15-145 years. From the centralization of the data presented in the table, it can be seen that out of the 11.265,99 ha of forest in which oak and fir species are present, 9.972,29 ha were infested in the year 2023, which represents 88.52% of the total monitored forest.

In 2023, OLB was reported in the Medias Forest Park, Sibiu Forest Park, Miercurea Sibiului Forest Park, Arpaș Forest Park, Dumbraveni Forest Park and Sălișteforest Park (Table 8).

In 2023, OLB affected all Sibiu urban forest ecosystems, as well as oak and sessile oak forests in the whole County of Sibiu. This was the result of favourable weather conditions in the previous years, 2021-2023, which allowed the development of three generations per year in 2023 (Table 2), thus creating a significant biological reserve for 2024. In the winter of 2023, the average minimum temperatures of October and November did not fall below negative values and the average minimum in December was -1.63°C, sustaining favourable thermal conditions for this species and allowing adults to emerge from the hibernation diapause in bark crevices or under leaves.

In September 2023, the degree of attack of the insect varied between 70 % and 100 % in all 18 observation points, the leaves showing significant discoloration, which led to aesthetic damage of trees in the parks of Sibiu. On the reverse side of the leaves, all stages of development of the insect were observed (Fig. 5). In Sibiu county, the degree of attack varied between 25 % and 75 %, with more pronounced damage to trees at the edge of forest ecosystems, as they are more exposed to light and high temperatures.

Currently, *C. arcuata* is not included in the EU Plant Health Directive and is not considered a quarantine pest [39, 49, 52].

## DISCUSSION

In 2023, observations were continued in the 18 monitoring points, where the same parameters were studied as in previous years: stages of insect development, number of generations, degree of attack and growth constants were calculated concerning the weather conditions of the year. After the centralization of field data, 3 generations of the insect were identified in all years. The first generation in 2023 was reported from 6 February to 27 May and required a total of 111 days of development, taking into account the period during which the insect was in its hibernation diapause. The second generation was observed between 28 May and 9 July, with a total of 44 days of development, a period reduced due to the increase in temperatures during the summer months. The third generation was identified between 10 July and 22 August, with a range of 54 days of development required, 10 days more than $G_2$ due to climate fluctuations in the months (May-July). The biological threshold for the year 2023 was 1.08°C, a much higher value compared to previous years (2021-2022) [46]. Increasing annual temperatures caused the biological threshold value to increase, thus providing favourable conditions for the development and expansion of the range in urban and forest ecosystems in Sibiu County. The tree species attacked in the city of Sibiu were all oak species: *Quercus robur, Q. petraea*. and *Q. polycarpa*. As in previous years, it was found that these trees in urban areas in the forest ecosystems of Sibiu County were preferred hosts, as in other countries where the presence of OLB has been reported [3-5]. Climate change seems to have a very strong correlation with the emergence and rapid growth of OLB in Sibiu and Europe.

The thermal constants as temperature values at which the species undergoes radical changes in biochemical processes are of particular importance in the development cycle of the insect which allowed us to know the favourable and unfavourable end conditions (biological threshold) as shown in Table 2.

In the current invasion in Sibiu, a crucial step was to identify and monitor this species, understand the pest's behavior and contribute to decision-making based on research to control and limit the attack in the forest ecosystems of Sibiu County. During the three-year study in Sibiu, information was collected on population abundance and weather conditions in the area, as well as identifying factors influencing the development and reproduction of invasive OLB populations [46].

In the year 2023 in Sibiu, the minimum temperature was 5.89°C, the average temperature was 11.37°C and the maximum temperature was 16.94°C, all values being much higher than in previous years, which confirms that the climatic conditions in Sibiu are similar to those in eastern North America, the area of origin of the OLB species [17-24].

The spreadof OLB in 2023 in the city and county of Sibiu was due to means of transport, wind and air currents [36, 39]. The degree of attack reported in 2023 was much stronger than in previous years (2021-2022), demonstrating a successful hibernation of the insect in the adult stage under the bark and leaves of trees. Weather conditions in 2023 were beneficial for both a rapid development cycle, with the insect passing through 5 instars to adult stages, and the development of multiple generations.

In the coming years the attack of *C. arcuata* in Sibiu County is a major problem for the development of oak and sessile oak, which will lead to leaf deterioration very early in the growing season. Our study carried out fover three years taking into account weather conditions, represented by thermal constancy,

confirmed a correlation between temperature and the development cycle of OLB and the number of generations per year.

The application of chemical treatments in urban ecosystems in the city of Sibiu and in forest ecosystems in the county is not an economically and ecologically efficient solution, as it requires multiple sprays in a single growing season and there is a risk of re-infestation. A major problem with the use of chemical insecticides is the negative secondary impact on beneficial insects in urban and forest ecosystems [36, 49]. Biological control is an advantageous alternative method, involving the use of antagonists in the form of predators (Chrysopidae, Coccinellidae, spiders), entomopathogenic fungi and parasitoids (Beauveria, Metarhizium, Cordyceps) [26, 31, 36].

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