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Further Spread of *Corythucha arcuata* (Hemiptera; Tingidae) in Croatia

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ABSTRACT

Corythucha arcuata (Hemiptera; Tingidae), i.e. oak bug is an invasive alien species from North America that has rapidly spread in Europe. It was first reported in Croatia in 2013, and in the following years it has spread rapidly toward the west of the continental part of the country, infesting 200,000 ha of *Quercus robur* L. forest stands. Oak lace bug causes losses in chlorophyll, which has a negative influence on photosynthesis and transpiration activity, as well as on the health status of oak trees. We conducted our study on two sites in the Mediterranean region in Istria, Croatia, where infestation with oak lace bug has not been recorded. Results showed new records of oak lace bug in Istria. *Q. pubescens* Willd. is the dominant tree species in Sub-Mediterranean forests in Istria, so it will be interesting to follow the spread and preferences of oak lace bug for *Q. robur* and *Q. pubescens* in Istria, as well as in other coastal *Q. pubescens* and *Q. ilex* L. forests in Croatia. We assume that the negative influence of oak lace bug coupled with other biotic and abiotic stressors in the Mediterranean region will probably have some influence on the health status of oak trees.

Keywords: oak lace bug; Istria; alien invasive species; spread; *Quercus*

INTRODUCTION

Invasive alien species have been recognized as one of the main threats to biodiversity worldwide (Vilà et al. 2011) and the number of their introductions is constantly increasing (Seebens et al. 2017). *Corythuca arcuata* (Say) (Hemiptera; Tingidae), commonly known as the oak lace bug (OLB), is one of the recent introductions of alien species that has spread over Europe. It is native to North America, feeding on leaves of various North American oak species, with main hosts from genus *Quercus*. Other host species are species from genera *Castanea*, *Acer*, *Pyrus*, *Malus* and *Rosa* (Csóka et al. 2020a).

OLB was first reported in Italy in 2000 (Bernardinelli and Zandigiacomo 2000). It has since spread to other areas of Europe (Csóka et al. 2020a). Sap feeding by nymphs and adults causes losses in chlorophyll, which has negative influence on photosynthesis and transpiration activity (Nikolić et al. 2019). This impact could, together with other harmful biotic and abiotic factors, negatively influence the health of oak trees that are under additional stress from consequences of climate change (Acácio et al. 2017)

OLB was first recorded in Croatia in the pedunculate oak stands (*Quercus robur* L.) of Spačva forests in eastern part of Croatia in 2013 (Hrašovec et al. 2013). In the following years, OLB quickly spread to other parts of continental Croatia causing premature color change and yellowing of the leaves (OIKON 2019). Using MODIS satellite imagery, Kern et al. (2021) concluded that the damage caused by OLB is significant and persistent after the infestation has started.

Early detection of invasive alien species is important to facilitate various responses in controlling and/or monitoring of the species. Early detection of the pathways of introduction and speed of spread may provide important insights into the behavioral traits of invasive alien species in new environments that can be used for predicting its distribution and damages (de Groot et al. 2020).

OLB has been recorded only in continental part of Croatia. Sub-Mediterranean and Mediterranean forests in the coastal part of Croatia are important forest ecosystems that provide irreplaceable ecosystem services (Vukelić et al. 2018), and arrival of new alien species could pose a threat to these forest ecosystems that are under additional

pressure caused by climate change (MedECC 2020). The aim of our research is to record the occurrence of *C. arcuata* in Istrian Peninsula.

MATERIALS AND METHODS

Study Area

Our study was performed on two sites in Istria, Croatia (Figure 1). The distance between Site 1 and Site 2 is 5 km of clearance distance.

Site 1 (no.1 in Figure 1b) is an avenue lined with *Q. robur* trees around Istrian Thermal Resort (HTRS96 Lat.295105.14, Lon.5029778.49). In the avenue, 15 oak trees were inspected. Leaves were collected from the ground, up to the height of 2 m using telescopic pruning shears.

Site 2 (no.2 in Figure 1b) is in management unit Mirna (HTRS 96 Lat. 295723.5, Lon. 5025592.3) in central Istria, Croatia. The area of the management unit Mirna consists entirely of stands of *Q. robur* in the famous Motovun forest, which represents the last remnant of the autochthonous lowland flood forests called "longozas" in the river valleys of the Mediterranean and Pontic coasts. The characteristic lowland terrain that rises slightly from west to east, together with the high level of underground water and occasional floods during spring and autumn and the influence of other synecological factors caused the appearance of lowland flood forests similar to those in Slavonia. The presence of many thermophilic elements (*Ruscus aculeatus* L., *Asparagus tenuifolius* Lam., *Arum italicum* Mill. and others) clearly distinguishes the Motovun forest from the related Slavonian flood forests *(Genisto elatae-Quercetum roboris, Leucojo aestivi-Fraxinetum angustifoliae*). A recent study (Vukelić et al. 2018) has classified mixed forests of hardwood broadleaved trees along the Mirna River in the association *Asparago-tenuifolii-Quercetum roboris*, which also includes Site. The second site covered the area of 13.30 ha. Oak trees were chosen using Python script for n number of plots in QGIS and for extracting its coordinates. In the field, using a hand-held GPS receiver, we have searched for the nearest oak tree to the plot extracted in QGIS. In total, 30 oak trees were chosen. The leaves were collected from the lower part of the tree and from the top of the canopy using big shots.

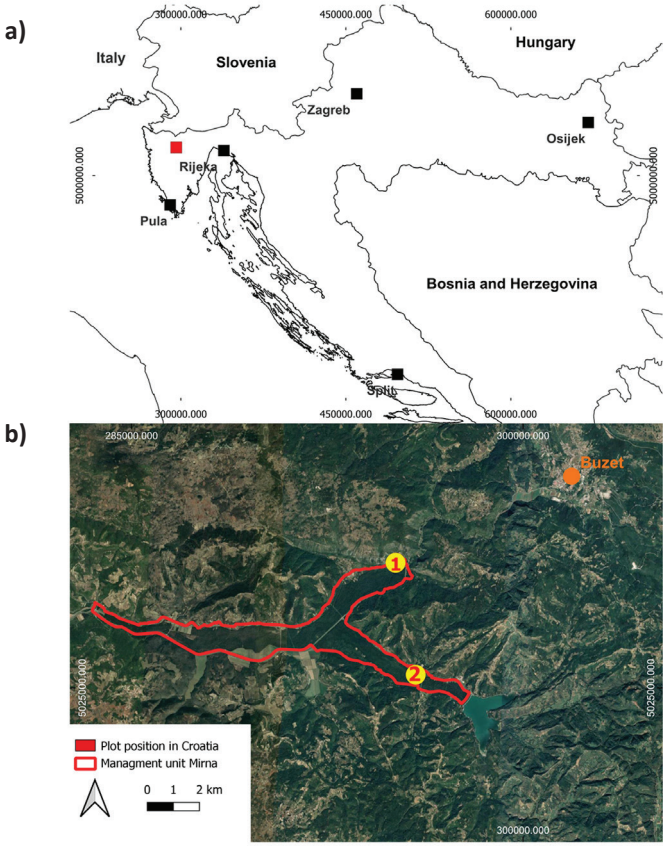

Figure 1. Location of plot sites in: **a)** Croatia (red mark); **b)** management unit Mirna.

Collecting Method

From each tree on both sites (15 trees on Site 1 and 30 trees on Site 2), 50 leaves from the north, south-east and south-west side were collected. Each collected leaf has been visually inspected for the presence of OLB. The leaves have been stored in sealed plastic bags and taken to entomological laboratory of the Croatian Forest Research Institute for closer inspection and morphological identification.

Identification

The collected egg masses and adults were identified in the Laboratory for Entomological Analysis of the Croatian Forest Research Institute according to Horn et al. (1979) using Olympus SZX7 stereomicroscope. The samples were stored in the freezer of the Laboratory for further analyses.

RESULTS

The sampling on Site 1 - Istria Thermal Resort resulted in the collection of leaves infested with OLB. On the leaves larvae and adults were present (Figure 2a, 2bb) and morphologically confirmed in the morphological laboratory analysis. All 15 sampled trees were infested with –*C. arcuata*. On Site 2, out of 30 sampled oak trees, only one tree was infested with *C. arcuata* (HTRS96 Lat. 295950.221, Lon. 5025515.762). Egg masses and adults have been found on three (3) leaves on the northern part of the canopy (Figure 2c, 2d). On all other inspected trees on Site 2 egg masses, larvae or adults of OLB have not been found.

DISCUSSION

OLB was first recorded in the continental region of Croatia in 2013 (Hrašovec et al. 2013). In the same year (2013) this pest has been recorded in neighbouring Hungary (Csóka et al. 2013) and Serbia (Pap et al. 2015), and in the following years in Slovenia (Jurc and Jurc 2017) and Bosnia and Herzegovina (Dautbašić et al. 2018). The most recent finding of this pest in Europe was in the Czech Republic in 2020 (Csóka et al. 2020b) Since its discovery in Croatia, OLB has spread quickly to all continental oak forests, infesting over 200,000 hectares. However, it has not been detected in the Sub-Mediterranean or Mediterranean forests of Croatia (IPP 2021).

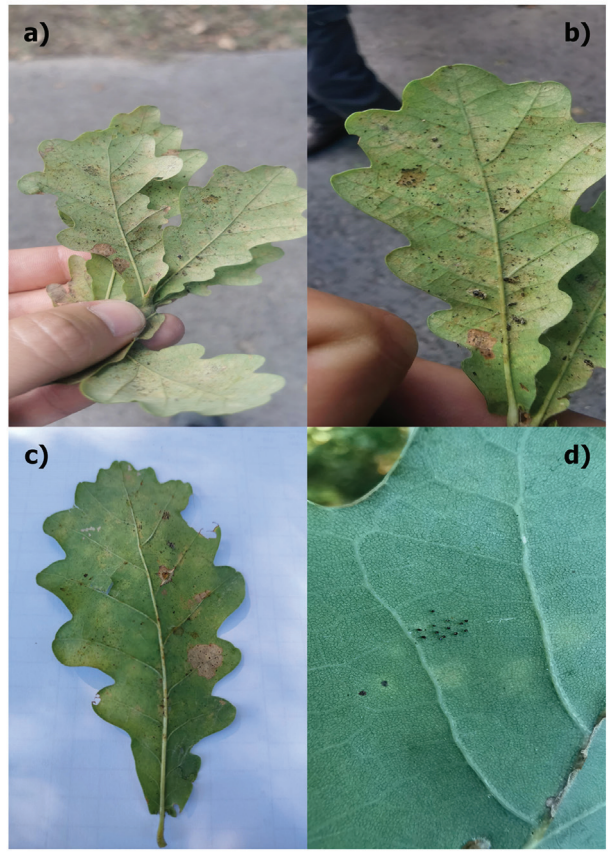

Figure 2. Infested leaves from: **(a, b)** Site 1; **(c, d)** Site 2.

This first record in Istrian Peninsula is important as the first record in Sub-Mediterranean oak forests, because other potential host species such as *Q. pubesens* (Willd.) and *Q. ilex* (L.), hosts described by Bernardinelli (2006), surround Motovun forest area (Vukelić et al. 2018). Motovun forest is the only known *Q. robur* forest in Croatia that has not been infected with oak lace bug. The first record on only one oak tree is valuable as we will be able to closely monitor and measure the speed of spread of this highly invasive species. The data on establishment and spread of newly introduced alien species are important for early detection and rapid response on newly introduced alien species (de Groot et al 2020).

Q. pubescens is one of the suitable host plants for OLB (Csoka et al. 2020) and this oak species is dominant in Sub Mediterranean forests in Istria (Vukelić 2018). There are no records of oak lace bug presence on *Q. pubescens* in Croatia so it will be interesting to follow the spread and preference of oak lace bug on *Q. robur* and *Q. pubescens* in Istria as well as in other coastal *Q. pubescens* and *Q. ilex* forests in Croatia. Most of European climate is suitable for OLB (Bernardinelli 2006), so there will be no obstacles for OLB to spread freely in newly invaded regions in coastal Croatia.

OLB has negative influence on photosynthesis, transpiration and stomatal conductance of oak plants (NIkolić et al. 2019). When coupled with other biotic and abiotic stressors, particularly those associated with climate change (Pureswaran et al. 2018), these physiological impacts can negatively affect the health status of oak trees (Nikolić et al. 2019, Pilipovic et al. 2021).

CONCLUSIONS

Detection of oak lace bug (OLB) in the continental region of Croatia, and its subsequent spread to over 200,000 hectares of oak forests, presents a significant concern for health of oak forests in the region. The first record of this alien invasive pest in the Sub-Mediterranean oak forests on the Istrian Peninsula allows us to track its spread and host preferences in this new environment. Notably, *Q. pubescens*, a dominant oak species in Sub-Mediterranean forests, is a potential host for OLB, which could lead to a further increase in its distribution. Given that the European climate is largely suitable for OLB, its proliferation in newly invaded regions of coastal region of Croatia on suitable host plants seems inevitable. The detrimental impacts of OLB on oak physiology, particularly in conjunction with climate change-related stressors, underscore the importance of early detection and rapid response to mitigate its potential harm to health and productivity of oak trees. Future research will be valuable for monitoring the spread and preference of OLB on different oak species in Istria and other coastal forests in Croatia.

Author Contributions

NZ and MF conceived and designed the research, NZ carried out the field measurements, DM performed laboratory analysis, DM secured the research funding, supervised the research and helped to draft the manuscript, NZ and DM wrote the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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