



Occurrence of the alien zigzag elm sawfly, *Aproceros leucopoda* (Hymenoptera: Argidae), in arboretums and botanical gardens of Hungary

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Abstract

Background and purpose: The invasive alien zigzag elm sawfly, *Aproceros leucopoda* (Hymenoptera: Argidae), native to East Asia, was identified as a new pest of elms (*Ulmus* spp.) in Europe in 2003. Following the first records in Poland and Hungary, it has been found in many other European countries. Plant taxa on which damage by larval feeding has been observed under natural conditions either in Asia or in Europe all belong to the genus *Ulmus*. *Ulmus pumila* (including var. *arborea*) seems to be a preferred host, but other species have also been reported as having suffered severe defoliation by the pest. One objective of our study was to complete information on the distribution of the sawfly species in Hungary. Moreover, we searched for *Ulmus* taxa which might be affected under natural conditions.

Materials and methods: To provide data on distribution and susceptible elms, we carefully checked *Ulmus* taxa for the presence of any juvenile developmental stages of *A. leucopoda* and the characteristic feeding traces on leaves in 17 arboretums and botanical gardens throughout Hungary in 2011 and 2016.

Results and conclusions: We have recorded *A. leucopoda* or only the clear symptoms of damage by it at all the locations visited and totally on 20 *Ulmus* taxa. We have identified 14 of these for the first time as being susceptible to the pest. We suggest that the suitability for egg laying and sensitivity to at least partial damage by *A. leucopoda* of the damaged taxa should be considered before planting them for any purposes.

INTRODUCTION

The invasive alien zigzag elm sawfly, *Aproceros leucopoda* Takeuchi, 1939 (Hymenoptera: Argidae), is of East Asian origin, and was first recorded in Poland and Hungary in Europe in 2003 (1). Since the first report of the pest from many Eastern and Central European countries by Blank et al. (1), it has been found to have extended its range to both the southern and western parts of the continent, as it has been summarized briefly by Véték et al. (2). The limited number of data known from literature and indicating the countrywide distribution of the pest in Hungary are shown as a part of Figure 1 in the Results.

Aproceros leucopoda seems to be oligophagous on elms, *Ulmus* spp. (Ulmaceae) (1), although it cannot be excluded that the pest may also attack plant genera other than *Ulmus* (3). Parthenogenetically reproducing females of *A. leucopoda* insert their eggs into the edge of the leaf,

and, after hatching, feeding traces of young larvae appear as characteristic zigzag patterns on the leaf blade (1, 4). Based on the work of Eiseman (5) and according to S. Blank (pers. comm.) the 'zigzag' feeding habit has hitherto been recorded only in *A. leucopoda* and some *Sterictiphora* species in Sterictiphorinae, but larvae of the studied *S. prunivora* and *S. serotina* were found feeding on *Prunus* spp. (Rosaceae) (5). Later, as *A. leucopoda* larvae grow, the affected leaf might be almost completely consumed. During the vegetation period, pupation takes place in a loosely spun cocoon attached to the lower surface of the leaf (remnant) or woody parts of the plant, but the cocoon might also be found on the ground (1, 4).

Damaged trees may belong to either non-native or native taxa of the genus *Ulmus* (1). So far, *U. davidiana*, *U. pumila* (including var. *arborea*), *U. glabra*, *U. laevis* and *U. minor* have been reported as significantly infested elms (1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18). Some 'Resista' hybrid elms have also been found as having been damaged considerably by the pest (19). In Table 1 we tried to review the reports on *Ulmus* taxa specimens of which have been identified as having suffered damage by the pest. In order to avoid speculations and confusions which may be unintended consequences of interpreting plant names written only in national languages, only those

Table 1. *Ulmus* taxa reported in literature as damaged by *Aproceros leucopoda*.

Damaged <i>Ulmus</i> taxon ¹	References
<i>U. davidiana</i>	17, 20
<i>U. davidiana</i> var. <i>japonica</i> (syn.: <i>U. japonica</i>)	1, 19
<i>U. glabra</i>	1, 7, 18, 19, 21, 22, 23
<i>Ulmus</i> × <i>hollandica</i> (syn.: <i>U. glabra</i> × <i>U. minor</i>)	24
<i>Ulmus</i> × <i>hollandica</i> 'Belgica'	25
<i>U. laevis</i>	1, 7, 8, 26
<i>U. minor</i> (syn.: <i>U. campestris</i>)	1, 7, 12, 15, 18, 19, 21, 22, 23, 24, 25, 27, 28, 29
<i>U. minor</i> var. <i>suberosa</i>	19
<i>U. minor</i> 'Sarniensis'	21
<i>U. minor</i> 'Webbiana'	19
<i>U. pumila</i>	1, 2, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 20, 22, 23, 30, 31, 32
<i>U. pumila</i> var. <i>arborea</i>	1, 4, 16, 19, 28
<i>Ulmus</i> 'New Horizon'	19
<i>Ulmus</i> 'Rebona'	19
<i>Ulmus</i> 'Regal'	19
<i>Ulmus</i> 'Resista'	19

¹The synonym, based on the work of Mackenthun (33), is indicated in brackets if that name was used in any of the cited references. We did not check if the taxa named in the different publications have been identified correctly by the authors.

sources are shown here in which the scientific name of the taxon was (also) given by the author(s).

Classification of elms remains problematic even today. Both the extensive natural hybridization and the artificial crossings in breeding programs have led to a high and often confusing diversity of forms which lack clear features for a convincing taxonomic differentiation. As a result, there is no uniform and generally accepted system of elms actually (33). Nevertheless, recently published works by several authors (e.g. 33) may contribute to the transparency of the classification of elms and help us use the currently most acceptable taxon names.

One objective of our study was to complete information on the distribution of *A. leucopoda* in Hungary. Furthermore, by focusing our studies on arboretums and botanical gardens, not only additional records of the sawfly species but also data on various *Ulmus* taxa affected could be collected. Although besides Blank et al. (1) Vétek et al. (4, 16) have already published many presence records of the pest in Hungary, indicating also preliminary results of studies started in 2011 and carried out in arboretums and botanical gardens to get information on the occurrence of and taxa damaged by the pest (16), detailed data have not yet been published, and are presented in this paper.

MATERIALS AND METHODS

In 2011 and 2016, we visited totally 17 arboretums and botanical gardens located at various parts of Hungary (details are given in the Results) to collect data on the occurrence of *A. leucopoda* there. Based on the biology of the pest (see 1), we started the field survey in the middle of July so as to increase the chance of finding damaged elms. In each case, we carefully checked the *Ulmus* taxa found at a given site for the presence of any juvenile developmental stages of *A. leucopoda* and the characteristic feeding traces on leaves. We considered a record positive if a live stage of the species could be observed (e.g. an *A. leucopoda* larva feeding on the leaf or its pupa present in a cocoon attached to the leaf), but also if we could find only the characteristic feeding trace on an elm leaf, which latter in itself is considered to be a clear symptom of damage by this pest (24, 31). If we caught site of a zigzag feeding trace, we checked the symptoms thoroughly usually searching also for the remnants of the egg laid by the species (into the edge of the leaf). We did not regard any external injuries on leaves other than those showing the typical zigzag pattern as a proof of presence of *A. leucopoda*. Nevertheless, besides the feeding traces of the larvae (but without any live specimens), empty cocoons typical of the species, if also found, could serve as a confirmation of the record.

If we deemed the record positive, we collected a shoot sample of the damaged *Ulmus* taxon and we also made

photos of the individual plant concerned in several cases to help the process of identification and for further documentation. Voucher specimens have been deposited in the Herbarium Institutum Botanicum Universitatis Sopronensis, Hungary. The label, if present, of an individual elm tree could be informative when we tried to confirm the identity of a taxon. We identified the *Ulmus* taxa by following the keys of Roloff et Bärtels (34) and Fu et al. (35). The scientific name of a given taxon we use in the Results is based on the combination of information from relevant handbooks and databases, especially Mackenthun (33), but also Bärtels et Schmidt (36), Roloff et Bärtels (34), Bannon et Hipp (37), Fu et al. (35), Schütt et al. (38), The International Plant Names Index (39), and The Plant List (40).

RESULTS

Based on the already known presence records of *A. leucopoda* in Hungary completed with the results of our survey, the pest may be confirmed to be widely distributed throughout the country. We have managed to record *A. leucopoda* or only the clear symptoms of damage by it in all the 17 arboretums and botanical gardens we visited and totally on 20 different *Ulmus* taxa (Figure 1 and Table 2). (Note: The total number of *Ulmus* taxa as being 19 is an error in Véték et al. (41).) We have found a comparatively wide range of botanical taxa belonging to Ulmaceae in the following collections: Diószegi Sámuel Botanikus Kert, Kecskeméti Arborétum, and Nemzeti Botanikus Kert, Vácrátót.

We have identified 14 *Ulmus* taxa which have not hitherto been reported as damaged by *A. leucopoda*. These are

as follows: *U. castaneifolia*, *U. glabra* ‘Camperdownii’, *U. glabra* ‘Exoniensis’, *U. glabra* ‘Horizontalis’, *U. glaucescens*, *U. lamellosa*, *U. minor* var. *vulgaris*, *U. minor* ‘Dampieri’, *U. minor* ‘Jacqueline Hillier’, *U. minor* ‘Umbraculifera’, *U. minor* ‘Variegata’, *U. minor* ‘Wredei’, *U. rubra* ‘Mauro’ and *Ulmus* ‘Lobel’. The affected *Ulmus castaneifolia*, *U. glaucescens*, *U. lamellosa* and *U. rubra* seem to be new records also at the species level. (*Ulmus glaucescens* was labelled on the spot as *U. glaucescens* var. *lasiocarpa*, however, in the lack of fruits, we could not confirm the identity of the variety). We have identified the Dutch complex hybrid cultivar *Ulmus* ‘Lobel’ [*U. wallichiana* × *U. glabra* ‘Exoniensis’) × *Ulmus* × *hollandica* ‘Bea Schwarz’] also as susceptible to the pest. We could observe significant damage (partial defoliation) only at the following locations (the taxon concerned is in brackets): Kecskeméti Arborétum (*U. minor* ‘Variegata’), Növényi Diverzitás Központ (*U. pumila* var. *arborea*) and Tiszakürti Arborétum (*U. pumila* var. *arborea*). In all the other cases the damage was only moderate or rather insignificant.

DISCUSSION

Arboretums and botanical gardens proved to be appropriate sites for monitoring the occurrence of *A. leucopoda* as well as for studying the range of *Ulmus* taxa potentially affected by the pest. However, we have to note that even though the taxon name on the label of a plant is often informative it might also be misleading, therefore the recording of data from the labels should be completed with further identification based on collected plant samples and by using relevant keys.

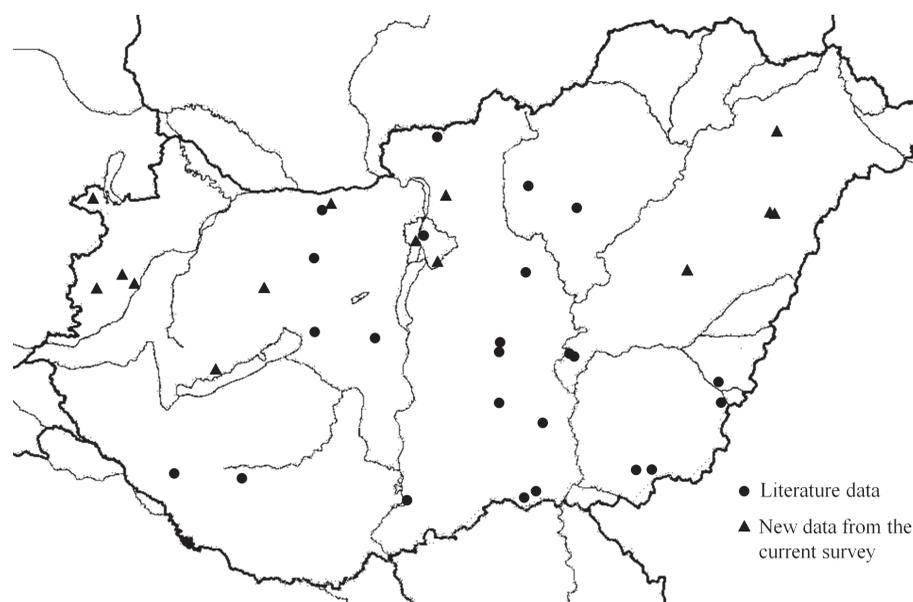


Figure 1. Distribution of *A. leucopoda* in Hungary. The map shows the presence records known from papers published until 2017 (1, 2, 4, 16, 42, 43, 44, 45) (black dots) and the new records from the current survey (black triangles).

Table 2. Detailed data on the occurrence of *A. leucopoda* in arboretums and botanical gardens of Hungary and the *Ulmus* taxa found damaged during the survey.

Name of the arboretum or botanical garden	Coordinates	Damaged <i>Ulmus</i> taxon/taxa identified	Developmental stage and/or symptom(s) found ¹	Date of record
Agostyáni Arborétum	47.6554°N, 18.4189°E	<i>U. glabra</i>	feeding trace, empty cocoon	31 July 2011
Budai Arborétum	47.4825°N, 19.0399°E	<i>U. pumila</i> var. <i>arborea</i> ²	feeding trace	08 Sept. 2011
Debreceni Egyetem Botanikus Kert	47.5584°N, 21.6205°E	<i>U. pumila</i> var. <i>arborea</i>	feeding trace, empty cocoon	15 Aug. 2011
Diószegi Sámuel Botanikus Kert	47.5593°N, 21.6063°E	<i>U. lamellosa</i> , <i>U. minor</i> 'Jacqueline Hillier'	feeding trace	15 Aug. 2011
Folly Arborétum és Borászati	46.8107°N, 17.5473°E	<i>U. minor</i> var. <i>vulgaris</i>	feeding trace	30 July 2011
Kámoni Arborétum	47.2564°N, 16.6078°E	<i>Ulmus</i> × <i>hollandica</i>	feeding trace	29 July 2011
Kecskeméti Arborétum	46.9129°N, 19.6515°E	<i>U. glabra</i> 'Camperdownii', <i>U. glabra</i> 'Horizontalis', <i>U. minor</i> 'Umbraculifera', <i>U. minor</i> 'Variegata', <i>U. minor</i> 'Wredei', <i>U. pumila</i> var. <i>arborea</i>	feeding trace, also larva on the second taxon	14 July 2011
Nemzeti Botanikus Kert, Vácrátót	47.7099°N, 19.2319°E	<i>U. castaneifolia</i> , <i>U. davidiana</i> var. <i>japonica</i> , <i>U. glabra</i> 'Exoniensis', <i>U. glabra</i> 'Horizontalis', <i>Ulmus</i> 'Lobel', <i>U. minor</i> 'Dampieri', <i>U. minor</i> 'Umbraculifera', <i>U. rubra</i> 'Mauro'	feeding trace, also larva on the second, fourth, fifth and sixth taxon, feeding trace and empty cocoon on the first and seventh taxon	09 Aug. 2016
Növényi Diverzitás Központ	47.3565°N, 19.8921°E	<i>U. pumila</i> var. <i>arborea</i>	feeding trace, empty cocoon	17 Aug. 2011
Nyugat-magyarországi Egyetem, Egyetemi Élő Növénygyűjtemény	47.6799°N, 16.5733°E	<i>U. glaucescens</i> , <i>U. minor</i> var. <i>vulgaris</i>	feeding trace ³	19 July 2016 (first taxon), 28 July 2011 (second taxon)
Püspökladány-Farkasszigeti Arborétum	47.3356°N, 21.0919°E	<i>Ulmus</i> × <i>hollandica</i> , <i>U. pumila</i> var. <i>arborea</i>	feeding trace, also empty cocoon on the second taxon	17 Aug. 2011
Sárvári Arborétum	47.2531°N, 16.9388°E	<i>U. minor</i> var. <i>vulgaris</i>	feeding trace, pupa in cocoon	28 July 2011
Soroksári Botanikus Kert ⁴	47.4003°N, 19.1543°E	<i>U. pumila</i> var. <i>arborea</i>	larva, feeding trace	04 July 2011
Szelestei Arborétum	47.3071°N, 16.8274°E	<i>U. minor</i> var. <i>minor</i>	feeding trace, empty cocoon	29 July 2011
Tiszakürti Arborétum	46.8920°N, 20.1239°E	<i>U. laevis</i> , <i>U. pumila</i> var. <i>arborea</i>	feeding trace, also empty cocoon on the second taxon	19 Aug. 2011
Tuzson János Botanikus Kert	47.9739°N, 21.7110°E	<i>U. pumila</i> var. <i>arborea</i>	feeding trace, empty cocoon	16 Aug. 2011
Zirci Ciszterci Arborétum	47.2617°N, 17.8795°E	<i>U. glabra</i> , <i>U. minor</i> 'Jacqueline Hillier'	feeding trace, also empty cocoon on the first taxon	27 July 2011

¹ Simply the live stage of and/or the typical symptom(s) by *A. leucopoda* we found are named without indicating exact numbers of them, therefore no plural forms are used here² The solitary tree has been cut since our survey³ We could also observe a larva and an empty cocoon of the pest on two unidentified *Ulmus* trees in the botanical garden⁴ Information with photos were sent by G. Botlik

Our results confirm earlier findings that *A. leucopoda* is associated with both exotic and native *Ulmus* taxa. The new damaged cultivar or variety records we collected are less surprising in the cases of *U. glabra* and *U. minor* (i.e. these taxa belong to the already known host plant species of *A. leucopoda* – see Table 1). Nevertheless, the revealed susceptibility of the very popular cultivars, such as *U. glabra* ‘Camperdownii’ or *U. minor* ‘Wredei’ (33), may be a major matter of concern in horticulture. The suitability for egg laying of any of the taxa we identified during this study and their sensitivity to at least partial damage by the sawfly species may be suggested being taken into consideration when their use is planned for ornamental purposes, landscape design or in breeding programs. For example, *U. pumila* (var. *arborea*), an already known preferred host of *A. leucopoda* (Table 1), which is extremely adaptable to unfavorable climate and soil conditions (33), and hence is widely planted in Hungary, and which is amongst the best known and most used species in breeding for resistance to Dutch elm disease (46), has been found also in our survey as having suffered significant damage in several cases. However, the actual vulnerability and host status of all the studied taxa still needs to be investigated. It remains unknown why the larvae of *A. leucopoda* were not found on damaged leaves in spite of the presence of a short feeding trace. We found no evidence of the disappearance of larvae. We do not know if it was the result of the *Ulmus* taxa concerned having proved unsuitable for larval development after a while for any reasons, or just because of a heavy rain having knocked off the larvae (as it was observed by us in one case in a group of container *U. pumila* var. *arborea* plants infested previously by larvae of the pest), or due to predation etc. In the cases of the absence of live stages of *A. leucopoda*, the “identification” based only on the characteristic feeding pattern (and empty cocoons) might involve some uncertainty regarding the causal agent. However, we did not find any information on any other insect species which might be responsible for the same type of symptoms on elm leaves (cf. 31, 32). We think that until no insect species is reported to occur and cause the same symptoms on leaves of elms in Hungary, our records may be accepted as confirmations of the occurrence of and feeding damage by the zigzag elm sawfly. Our data collection method was, nevertheless, similar to that described by Blank et al. (19) for the same species.

Finally, we may suggest that any elm taxa, including the newly reported damaged ones, should be studied in more details under adequately controlled conditions to determine their actual vulnerability to *A. leucopoda*, especially if the taxon was intended to plant on a large scale in environments of a risk of known or facing presumably or potentially high pest pressure.

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