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Citizen science reveals the current distribution of the new plant pest *Aphis nerii* in Slovakia

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Abstract: This paper presents the first record of the oleander aphid (*Aphis nerii* Boyer de Fonscolombe, 1841; Hemiptera: Aphididae) in Slovakia, and also one of the most northern record of this natural pest on the invasive common milkweed (*Asclepias syriaca* Linnaeus.; Apocynaceae) in Central Europe. Modern social media crowdsourcing has achieved comprehensive distribution data in the horticultural community, and a total of 35 new distribution sites were discovered in 28 Slovak settlements, one new site in Austria, and one in the Czech Republic. It was further established that the oleander aphid could survive in anthropogenic refuges during the winter months.

Keywords: oleander aphid; common milkweed; social crowdsourcing

Aphis nerii Boyer de Fonscolombe, 1841 (Hemiptera: Aphididae) is commonly known as the oleander or milkweed aphid. It is globally distributed, especially in tropical and subtropical regions (Blackman & Eastop 2019) and it is reported to infest over 50 plants species (Holman 2009). The Apocynaceae family, and especially the Asclepiadoideae subfamily, are the major plant hosts of this polyphagous species; with *Nerium oleander* Linnaeus and various *Asclepias* spp. and *Vinca* spp. milkweeds being the most reported hosts (Martel & Malcolm 2004; McAuslane 2014; Blackman & Eastop 2019). The aphid feeding causes bud-blighting, tender leaf deformation, discoloured spots on the foliage and loss of mature leaves (Rani & Sridhar 2005).

Most viruses transmitted by *A. nerii* which inflict plant damage are potyviruses or cucumoviruses (Hobbs 2000; Elliott et al. 2009). The European and Mediterranean Plant Protection Organization (EPPO) (2015) adds that *A. nerii* would most likely have less of an impact on non-preferred hosts if it only had a warm seasonal existence. The European distribution of *A. nerii* correlates with its primary host plant *Nerium oleander* Linnaeus in Greece (John et al. 2007), Italy (Starý 1966), Malta (Misfud et al. 2013), Mediterranean France (Starý 1976), Portugal (Costa & Starý 1988) and Spain (Cambra et al. 2000). While *A. nerii* has also been detected in northern Europe where its *N. oleander* host does not naturally occur, its effect there also concentrates

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on the invasive *Asclepias syriaca* Linnaeus known as the common milkweed.

A. syriaca was introduced to Europe from eastern North America as a nectariferous and ornamental plant over 300 years ago (Gaertner 1979). This invasive plant produces the cardenolides toxin and latex which deter large herbivores from consuming it, and it also escapes most of the specialist communities of chewing and phloem sucking insects which attack it in its native landscape (Agrawal & Konno 2009). In Central Europe, *A. syriaca* infested by *A. nerii* was reported in Hungary (Haltrich & Vas 1996), Serbia (Vucurović et al. 2018) and the Ukraine (Chumak et al. 2016). Although Haltrich and Vas (1996) studied this species widely, they could not confirm its overwintering. They did however suggest that winter survival could be possible in a mild winter and the summer when the aphid arrives from southern Europe. The *Asclepias*, however, are not evergreen, and *A. nerii* which is predominately anholocyclic – reproducing parthenogenetically, with only a local bisexual mode of reproduction, most likely cannot overwinter in the wild because of frost (Kagezi et al. 1999). Furthermore, Austrian research revealed that *A. nerii* was observed in controlled temperature sites as an *N. oleander* pest (Hartbauer 2010) and Polish authors kept it in experimental glasshouses, thus providing indoor protection against the colder more northern parts of Poland (Osiadacz & Hałaj 2012).

Herein, we report the first record of *A. nerii* in Slovakia, and this is currently one of the northernmost Central European wild locations recognised for the *A. syriaca* infestation. By employing the unique methodology of the popular modern social media known as the crowdsourcing, the knowledge of the *A. nerii* distribution and also its current horticultural impact has improved.

MATERIAL AND METHODS

Two sites (Borša and Radvaň nad Dunajom) with wild populations of *A. syriaca* in Slovakia were inspected for the occurrence of *A. nerii*.

For the *A. nerii* distribution research in Slovakia, citizen science – crowdsourcing on the social networking platforms – designed by Dickinson et al. (2010) and Chamberlain (2018) was also utilised. We adapted this method for the *A. nerii* Slovak distribution survey. In January 2019, we co-opted the five largest Facebook social media gardening groups moderating in the Slovak language. These groups were diverse, with 5 000 to 75 000 members, and they were kindly requested to supply *A. nerii* observations from a representative species' photograph (Figure 1). Private conversations began with the group members conversant with the photograph, and these respondents were requested to supply their locality, date of the first observation, the infested plant species and culture longevity and their observations of the aphids during the winter months. The chosen gardeners were also requested to provide a photograph from their observation or to collect the samples in our pre-sent tubes for further determination. The five largest Slovak public botany gardens and five arboreta were also e-mailed with a similar scientific request.

Figure 1. *Aphis nerii* parthenogenetic females hosting on *Asclepias syriaca* in south-western Slovakia

All the assembled aphid specimens were photo documented, sampled by hand collection, preserved in 70% ethanol, mounted according to the standard preparatory techniques (Wojciechowski et al. 2015) and determined according to the key provided by Blackman and Eastop (2019). The material was deposited in the collection of the Department of Zoology, the Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic and in the collection of the Department of Zoology, the University of Silesia in Katowice, Poland.

RESULTS

The *Aphis nerii* wild distribution in Slovakia. In 2010, the first *A. nerii* record, and one of the northernmost in Central Europe, was registered on *A. syriaca* in ruderal vegetation near the Borša village in South-Eastern Slovakia. In 2018, during

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the complex botanical research, the next record of *A. nerii* apterous viviparous females and larvae infesting the same plant species in the wild was revealed in a mosaic of non-forest psammophilous vegetation of the *Koelerion arenariae* R. Tx. alliance near the Pannonian sand dunes in the South-Western Slovak village of Radvaň nad Dunajom. This locality is a part of the Dolné Pohronie Special Protected Area which is included in the NATURA 2000 protected areas.

The *A. nerii* indoor distribution in Slovakia. A total of 35 Facebook social media respondents (Users) answered positively to our crowdsourcing posted request for observations of *A. nerii* on *N. oleander* (Table 1). Of these, 31 (83.78%) answered by private message and provided greater detail on their observation. The initial gardeners' observations of *A. nerii* were recorded 'all-year-round', including five in spring (16.12%), 22 in summer (70.96%), two in autumn (6.45%) and two in winter (6.45%). A further nine participants, recorded *A. nerii* on overwintering plants, six participants (66.66%) sent photo documentation, and six participants (66.66%) collected the samples in our pre-sent tubes filled with 70% ethanol (Table 1, Figure 2). One of most interesting samples was made by a gardener who returned a sample from Koštany nad Turcom – a record of *A. nerii* hosted by *Mandevilla sanderi* Woodson (Apocynaceae). In three Slovak botany gardens and one arboretum, *A. nerii* was confirmed on three plant species: *N. oleander* and *Gomphocarpus fruticosus* (Linnaeus) W. T. Aiton (Apocynaceae) and *M. sanderi* (Table 1). Overwintering was confirmed in 13 (35.14%) of the 37 recorded sightings; including three sampling sites at the highest altitude (Table 1, Figure 2). The northern-most Slovak horticultural *A. nerii* sampling site was recorded near Trstené, and the

Table 1. The distribution data of the 35 records of *Aphis nerii* gained by the crowdsourcing methods

Sampler	Locality	Country	Coordinates		Altitude (m a.s.l.)	Host plant	Season
			(N)	(E)			
Botanical gardens and arboreta							
Botanical garden 1	Bratislava	SVK	48.1463	17.0735	152	*N. oleander, A. syriaca*	su^{OW}
Botanical garden 2	Nitra	SVK	48.3056	18.0967	167	*N. oleander*	su^{OW}
Botanical garden 3	Košice	SVK	48.7353	21.2378	208	*N. oleander, A. syriaca, G. fruticosus*	su^{OW}
Arboretum Mlyňany	Vieska nad Žitavou	SVK	48.3197	18.3689	205	*N. oleander*	su^{OW}
Social networking users							
User 1	Budkovce	SVK	48.6325	21.9291	103	*N. oleander*	wi^{OW}
User 2	Čierna Voda	SVK	48.2225	17.2313	117	*N. oleander*	sp
User 3**	Nové Zámky	SVK	47.9876	18.1625	119	*N. oleander*	au
User 4	Senec	SVK	48.2206	17.3983	125	*N. oleander*	su
User 5	Most pri Bratislave	SVK	48.1422	17.2719	128	*N. oleander*	su
User 6	Komjatice	SVK	48.1500	18.1833	128	*N. oleander*	su
User 7	Malinovo	SVK	48.1577	17.2990	128	*N. oleander*	su
User 8*	Sereď	SVK	48.2864	17.7375	129	*N. oleander*	su^{OW}
User 9	Cífer	SVK	48.3167	17.5000	135	*N. oleander*	su
User 10	Chorvátsky Grob	SVK	48.2275	17.2908	141	*N. oleander*	sp
User 11*	Zeleneč	SVK	48.3333	17.6000	146	*N. oleander*	au^{OW}
User 12**	Golianovo	SVK	48.2682	18.1868	149	*N. oleander*	sp
User 13	Lužianky	SVK	48.3420	18.0290	150	*N. oleander*	su
User 14**	Bratislava	SVK	48.1439	17.1097	152	*N. oleander*	su
User 15**	Bratislava	SVK	48.1439	17.1097	152	*N. oleander*	su

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Table 1. to be continued

Sampler	Locality	Country	Coordinates		Altitude (m a.s.l.)	Host plant	Season
			(N)	(E)			
User 16	Bratislava	SVK	48.1439	17.1097	152	*N. oleander*	su
User 17	Bratislava	SVK	48.1439	17.1097	152	*N. oleander*	su
User 18	Bratislava	SVK	48.1439	17.1097	152	*N. oleander*	su^{OW}
User 19*, **	Kostolište	SVK	48.4514	16.9865	164	*N. oleander*	su^{OW}
User 20	Veľké Leváre	SVK	48.5031	17.0012	170	*N. oleander*	su^{OW}
User 21	Nižná Olšava	SVK	49.1437	21.6326	191	*N. oleander*	su
User 22	Stropkov	SVK	49.2050	21.6514	202	*N. oleander*	su
User 23	Lemešany	SVK	48.8513	21.2717	229	*N. oleander*	sp
User 24	Zvolen	SVK	48.5783	19.1233	293	*N. oleander*	su
User 25	Šarišské Michaľany	SVK	49.0500	21.1333	313	*N. oleander*	su
User 26	Mojš	SVK	49.1994	18.8208	345	*N. oleander*	su
User 27*	Kosťany nad Turcom	SVK	49.0281	18.9050	415	*M. sanderi*	su^{OW}
User 28*	Kremnica	SVK	48.6997	18.9158	550	*N. oleander*	wi^{OW}
User 29*	Trstené	SVK	49.1122	19.6191	640	*N. oleander*	su^{OW}
User 30**	Prusinky	CZE	49.1548	17.5289	200	*N. oleander*	sp
User 31	Hinterbruhl	AU	48.0789	16.2383	280	*N. oleander*	su

*sampled individuals deposited in the authors' collections; **photo documentation in the authors' archives; Season – season of the first observation in this locality: sp – spring, su – summer, au – autumn, wi – winter; ^{OW}successful overwintering

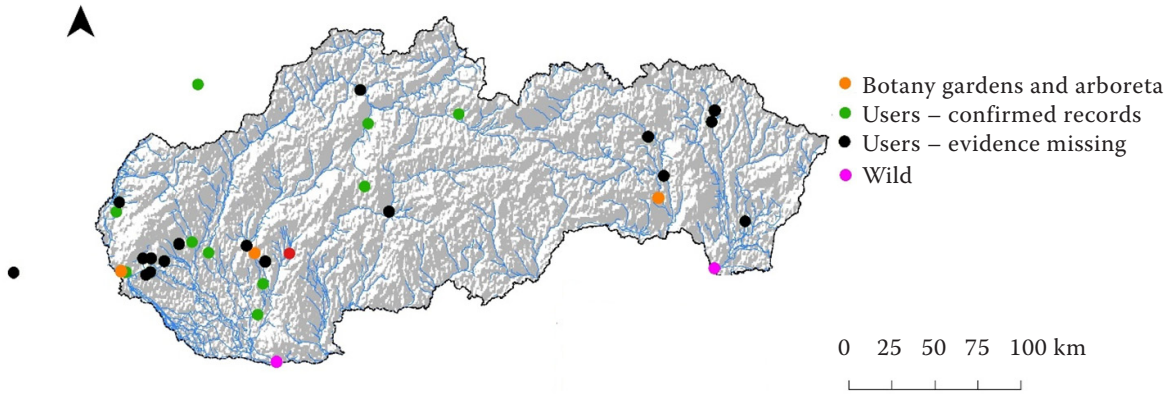

Figure 2. The distribution map of *Aphis nerii* in Slovakia based on the crowdsourcing data and our research

crowdsourcing method also produced sightings at Prusinky in the Czech Republic and Hinterbruhl in Austria (Table 1).

Material examined (our research). South-Eastern Slovakia, Borša, the alluvium between the rivers Roňava and Bodrog, 48.3817°N, 21.7017°E, 101 m a.s.l.; 12.9.2010; host plant: *A. syriaca*; leg. M. Suvák; det. M. Suvák (only photo documentation in author's archive).

South-Western Slovakia, Radvaň nad Dunajom, near a sand dune, 47.7500°N, 18.3403°E, 133 m a.s.l.; 30.8.2018; host plant: *A. syriaca*; leg. A. Purkart; det. Ł. Depa.

Material examined. (crowdsourcing research; coordinates, altitude and host plant are defined in Table 1).

(*i*) South-Western Slovakia, indoor; 18.1.2019; Sereď; leg. User 8; det. Ł. Depa. (*ii*) South-Western Slovakia, indoor; 18.1.2019; Zeleneč; leg. User 11; det. Ł. Depa. (*iii*) Western Slovakia, indoor; 16.1.2019; Kostolište; leg. User 19; det. Ł. Depa. (*iv*) Central Slovakia, indoor; 25.2.2019; Koštany nad Turcom; leg. User 27; det. Ł. Depa. (*v*) Central Slovakia, indoor; 24.1.2019; Kremnica; leg. User 28; det. Ł. Depa. (*vi*) Northern Slovakia, indoor; 28.1.2019; Trstené; leg. User 29; det. Ł. Depa.

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DISCUSSION

A. nerii aposematic colouring is an important trait, and this can be linked with the sequestration of the cardiac glycosides from its host plants (Malcolm 1986). Even amateur horticulturists can visually determine the *A. nerii* presence on commonly grown *N. oleander*. While private plant collections can hide findings from basic research, citizen science can fortunately supply the only opportunity for monitoring the biodiversity and ecological research when a single researcher or a small team cannot collect sufficient data over an extensive geographic range (Dickinson et al. 2010). Herein, Facebook social media gathered 31 *A. nerii* positive records throughout Slovakia. Many of these were impossible to confirm by sampling and proper determination because some gardeners had already eradicated the aphids by chemical and mechanical means. This was also accomplished throughout the year, and there were no resultant infestations in January 2019 when our crowdsourcing was approaching. Despite this, six horticultural sample records were determined as the northernmost and the highest placed locations, and the new Slovak *M. sanderi* host plant was identified.

In summary, *A. nerii* is a common pest of the *N. oleander* milkweed growers' community in Slovakia. It survives the winter on indoor host plants and gardeners' greenhouses and can then spread widely in outdoor areas in the warmer months. *A. syriaca* eradication is difficult because it has just a few natural enemies, large herbivores are unable to pasture it (Agrawal & Konno 2009), and mechanical excision is ineffective. Without regulation, *A. syriaca* could also impair the rare psammophilous association diversity in the wild and also incur financial losses for farmers. While *A. nerii* may be a natural pest of *A. syriaca* and useful in the biological control in Europe (Horváth & Szalay-Marzsó 1984), in North America, it is considered an invasive pest species of the same plant (Harrison & Mondor 2011).

The Central European spread of *A. nerii* is interesting. In 1983, it was first recorded near Bacsalmas in southern Hungary (Horváth & Szalay-Marzsó 1984), later near Kecskemét in central Hungary (Haltrich & Vas 1996) and then in Vinogradov and Chop in south-western Ukraine (Chumak et al. 2016). This was followed by the successful extension of *A. nerii* on wild plants in northern Central Europe, and now its extension includes southern Slovakia. However, *A. nerii* has limited options for overwintering in the wild because its preferred host plant *N. oleander* does not occur naturally in this region and the secondary host plant *A. syriaca* is not evergreen.

Haltrich and Vas (1996) outlined two hypotheses for this species' Hungarian colonisation, and our crowdsourcing approach suggests a third alternative. The *A. nerii* colonisation of the northern parts of the Holarctic is mediated by the oleander growers, and the climate change could possibly induce the outdoor *A. nerii* spread synergistically with the invasive *A. syriaca*. This hypothesis is supported by five spring season observations where the aphids most likely sprang from an overwintering specimen of the same indoor host plants. However, a similar infestation by outdoor specimens from distant southern regions is highly unlikely. The three additional Koštany nad Turcom, Kremnica and Trstené sampling sites are near mountain basins, and these are also highly improbable *A. nerii* habitats.

In conclusion, all our results confirm the strength of this innovative citizen scientific research method. Without social networking and crowdsourcing, none of these discoveries could have been made. In addition to our major interest in *A. nerii* infestations and its spread in Slovakia, two crowdsourcing respondents reported the *A. nerii* presence in Austria and the Czech Republic. This has inspired us to use and to propose the use of this methodology for similar researchers, in the surrounding countries to complete the *A. nerii* distribution in Central Europe. Finally, our crowdsourcing methodology could prove very successful in obtaining otherwise elusive information on the distribution of many taxa which are currently considered "indoor species living in controlled conditions".

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