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Does spirea aphid (*Aphis spiraecola* Patch, Homoptera: Aphididae) overwinter on apple in Central Europe?

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Abstract The native green apple aphid (*Aphis pomi* DeGeer) and the invasive green spirea aphid (*Aphis spiraecola* Patch) share apple as a common host plant during the summer months in Central Europe. Various studies suggest that, under certain conditions, the originally host-alternating *A. spiraecola* is able to overwinter on apple as a winter host, following a similar life history to *A. pomi*. In this study, we collected stem mothers (fundatrices) and aphids of the second generation (fundatrigeniae) from ten localities throughout Hungary for nine consecutive springs to assess whether *A. spiraecola* can overwinter on apple as a winter host. All the collected aphid individuals (1126 aphids from 114 stem colonies during the nine years of the study) belonged to *A. pomi*, indicating that *A. spiraecola* does not, or very rarely can, overwinter on apple under Central European conditions.

Keywords *Aphis pomi* · *Aphis spiraecola* · Overwintering · Central Europe · Biological traits

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Introduction

The green apple aphid, *Aphis pomi* DeGeer, native to Europe, and the invasive green spirea aphid, *Aphis spiraecola* Patch, originated in Eastern Asia, showing great similarities in their morphology. Under continental climate conditions, they share apple (*Malus*) species as a common host plant during the summer (Blackman & Eastop, 2000; Rakauskas et al., 2015). Despite their similarities, the biological features of the two species differ to a great extent. *Aphis pomi* is a holocyclic but non-host-alternating (monoecious) species which completes its life cycle on apple and other Maloideae species (Baker & Turner, 1916; Blackman & Eastop, 1994; Holman, 2009), although its winged (alatae) females appearing in early summer colonise new apple trees (Baker & Turner, 1916). On the other hand, *A. spiraecola*, under temperate climatic conditions, is a holocyclic and host-alternating (heteroecious) aphid. It typically overwinters on *Spiraea* species, and the summer generations in early May migrate to a wide range of summer host plants, including members of the Maloideae subfamily (Blackman & Eastop, 2000; Satar & Uygun, 2008; Andreev et al., 2009; Holman, 2009). Komazaki (1990) proved that *A. spiraecola* is able to overwinter in the egg stage on apple and lemon trees in Japan. Populations using apple trees as a primary host were also found in Henan Province, China (Zhang et al., 1997). In contrast, under subtropical and Mediterranean climate conditions, both in its original distribution range and newly invaded areas, *A. spiraecola* has an anholocyclic life cycle, and colonies persist on citrus trees or other summer hosts throughout the year (Miller, 1928; Hodjat & Eastop, 1983; Satar et al., 2020).

Aphis spiraecola appeared in the United States at the beginning of the 20th century (Wolcott, 1954). In this new range, overwintering eggs were found on spiraea, apple, pear and Japanese quince in North Florida, USA (Miller, 1928). Pfeiffer et al. (1989) also found evidence for the overwintering of *A. spiraecola* on apple in Virginia, West Virginia and Maryland, USA. However, it was also suspected that the most common developmental form of the species might still be the classical host-alternating development (Brown, 2011). *Aphis spiraecola* invaded Southern Europe in the middle of the 20th century (Gómez-Menor, 1943; Barbagallo, 1966) and has been reported from Central and Northern European apple orchards since the 2000s (Thieme, 2002; Petrović-Obradović et al., 2009; Rakauskas et al., 2015; Borbély et al., 2020). Although the presence of the overwintering eggs of this species on apple was found in Hungary (Mezei & Kerekes, 2006), no comprehensive study was conducted to clarify the commonness and significance of this life cycle trait in Central Europe.

Aphis pomi and *A. spiraecola* differ in the manner of oviposition as well. As the gynoparae and the sexual forms of *A. pomi* are wingless, sexual reproduction can be more successful in the presence of abundant colonies in the autumn, and eggs are laid in great clusters on the bark of the infested apple shoots, in other words, the eggs of several reproductive females are laid together (Baker & Turner, 1916). In contrast, in *A. spiraecola*, the presence of winged gynoparae and winged males makes it possible to reproduce and lay the eggs of each female in different locations, typically causing small egg clusters on the shoot ends (Komazaki, 1995; Blackman & Eastop, 2000).

Previous studies reported that the invasive *A. spiraecola* outcompeted the native *A. pomi* in some regions of the world: in the United States (Pfeiffer et al., 1989; Brown et al., 1995; Mayer & Lunden, 1996), in Israel (Zehavi & Rosen, 1987) and in South-Bulgaria (Andreev et al., 2009). Since the overwintering of *A. spiraecola* on apple as a primary host may contribute to its competitive advantage over *A. pomi* (Brown et al., 1995), the aim of our study was to assess the overwintering ability of *A. spiraecola* on apple as a winter host under Central European conditions.

Materials and methods

Aphis spp. individuals were collected in the spring over nine consecutive years (2015–2023) from ten apple orchards, park or house garden trees across various regions of Hungary. These locations include Mihályi (lat. 47.523007; long. 17.099191), Adyváros, Győr (lat. 47.672412; long. 17.658372) and Győrszentiván (lat. 47.699844; long. 17.748005) in West Hungary. In Central Hungary, samples were obtained from Elvira-major, Érd (lat. 47.346246; long. 18.860841), the Botanical Garden of the Hungarian University of Agriculture and Life Sciences (MATE), Budapest (lat. 47.481335; long. 19.038214), Óbudai-Island, Budapest (lat. 47.554747; long. 19.054914) and Soroksár (lat. 47.396091; long. 19.144748). Additionally, three orchards from the surrounding area of Újfehértó were sampled, including an orchard under integrated pest management (lat. 47.825602; long. 21.671144), an organic orchard (lat. 47.819778; long. 21.665274) and an apple gene bank (lat. 47.819187; long. 21.668583). The assessment covered between 15 apple trees (home gardens) and 200 apple trees (orchards) per site (Table 1). Sampling took place during the second half of April, between the growth stages BBCH 19 ('first leaves fully expanded') and BBCH 33 ('beginning of shoot growth: axes of developing shoots are visible') (Meier et al., 1994). This period coincides with the development of the stem mothers (fundatrices) and the second generation (fundatrigeniae) of *A. pomi* and *A. spiraecola* (hereinafter referred to as stem colonies) to the adult stage. The trees at each location were carefully inspected one by one for young aphid colonies or colony clusters. From each colony, 20 adult individuals (stem mothers or adults from the second generation), or as many as possible, were collected and placed in 1.5 ml Eppendorf tubes filled with a 70 V/V% ethanol solution, using a fine paintbrush. In cases where more than one aphid colony was present on a sampled tree, only one colony was randomly selected to ensure the independence of the collected samples. Identification of the aphid individuals was performed using a stereomicroscope (Zeiss Stemi

Table 1 Number of identified *Aphis* spp. stem colonies (and individuals) from different locations in Hungary between 2015 and 2023

	Mihályi	Adyváros, Győr	Győrszentiván	Elvira-major, Érd	MATE Bot. Garden[1]	Óbudai-Island	Soroksár	Újfehértó	Újfehértó	Újfehértó gene bank
Site type	orchard	park	gardens	orchard	park	park	orchard	orchard	orchard	orchard
Pest management	organic[2]	–	–	conventional[3]	–	–	conventional	IPM[4]	organic	conventional
Assessed trees	200	24	15	200	20	65	200	200	200	200
2015										10(76)
2016										9(78)
2017								10(30)		
2019					2(6)	1(11)	2(11)	8(147)		
2020	11(81)	4(18)	3(15)					5(60)	5(61)	5(62)
2021		1(15)	2(21)	1(3)	1(4)			5(75)		5(67)
2023	2(40)	5(39)	3(60)	1(20)	1(12)	12(114)				
Total	13(121)	10(72)	8(96)	2(23)	4(22)	13(125)	2(11)	28(312)	5(61)	29(283)

All identified individuals belonged to the species *Aphis pomi*. No stem aphid colonies were found in the surveyed orchards in 2018 and 2022

[1]MATE Bot. Garden: MATE Botanical Garden, Budapest; [2]Organic pest management; [3]Conventional pest management based on broad spectrum insecticides; [4]Integrated pest management based on selective insecticides

200 C, Carl Zeiss, Germany) based on the morphological key of Halbert and Voegtlin (1992) revised by Foottit et al. (2009) and Rakauskas et al. (2015). As morphological characters, number of lateral tubercules on abdominal segments 2–5, the number of caudal setae and the shape of the cauda were used. In the cases of any uncertainty the rostrum of the aphid was cut and mounted on microscope slides, and the length of the ultimate rostral segment was measured by a formally calibrated Zeiss Axio Imager A2 microscope. As no keys for the separation of the stem mothers are available, *A. spiraecola* stem mother adults also had been collected from *Spirea x vanhouttei* bushes (MATE Botanical Garden, Budapest and Adyváros, Győr locations) for morphological comparison of *A. pomi* and *A. spiraecola*. The morphological keys, especially the presence or absence of the lateral tubercules on the abdominal segments IV. and V., also provided reliable separation of the stem mothers of the two species.

Results and discussion

Table 1 presents the number of identified aphid stem colonies from the nine years of the study. As green apple aphids need special environmental conditions (still-growing shoot ends in September and October) for laying overwintering eggs, the number of stem colonies was generally low, and they did not appear in all sites and years (Table 1). Regardless of whether they were collected from a small stem colony or a large cluster, all the collected individuals (1126 aphids from 114 stem colonies) belonged to *A. pomi.* This indicates that contrary to our expectations, *A. spiraecola* does not, or only rarely, overwinters on apple trees in Central Europe.

One possible explanation for the differences between our findings and those reported in Eastern Asia and the United States may be that *A. spiraecola* has different host-specific biotypes, which are more or less adapted to one of the potential winter hosts and also show some differences in life history (Komazaki, 1983, 1990, 1991, 1998). Komazaki (1990) observed that the biological traits of *A. spiraecola* populations overwintering on apple in Japan differed significantly from those of the populations overwintering on citrus, and slightly from the traits of the populations overwintering on spirea. However, he could not prove whether they belonged to a separate (apple-specific) biotype, or if the differences could be explained by other ecological factors. The presence of an apple-specific biotype among others in East Asia and the United States, and its absence in Europe, could easily explain the lack of *A. spiraecola* populations overwintering on apple in Central Europe.

However, it is also possible that following the classical host-alternating life cycle is simply more beneficial for *A. spiraecola* than following a non-host-alternating strategy under the climate conditions in Central Europe. The stem colonies of *A. spiraecola* frequently appeared around the study locations and produced winged forms in great numbers from late April on spirea bushes (personal observation). Moreover, this species often forms colonies in the apple orchards of Hungary later in the season (from mid-May until autumn) (Mezei & Kerekes, 2006; Borbély, 2018; Borbély & Nagy, 2022), which also indicates the classical host-alternating life cycle of *A. spiraecola*, where the apple serves as a secondary (summer) host. Overall, the results of this study indicate that although the overwintering of *A. spiraecola* on apple may be possible, it is an exception rather than the rule in Central Europe.

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Author contributions Csaba Borbély and Csaba Nagy collected the aphid samples, Csaba Borbély identified the experimental material at species level. Viktor Markó planned and coordinated the study, and he also contributed to the evaluation of the data. All authors took part in the writing process of the manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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