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The novel host associations for the aphid parasitoid, *Pauesia hazratbalensis* (Hymenoptera, Braconidae, Aphidiinae)

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ABSTRACT
Here, we report a species of pine aphid, *Cinara pinihabitans* (Mordvilko, 1895) (Hemiptera, Lachnidae) as a new host record for *Pauesia hazratbalensis* Bhagat, 1981 (Hymenoptera, Braconidae, Aphidiinae), associated with *Pinus mugo* Turra (Pinaceae). The novel host, *C. pinihabitans*, was recently reported as an important pest of Iranian conifers in Razavi Khorasan Province. Thus, the present paper provides the first new host associations of *P. hazratbalensis* in a world background.

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Biological agent; *Pinus mugo*; *Cinara pinihabitans*; *Pauesia hazratbalensis*; new associations

Introduction

Aphids are important herbivores in different agroecosystems worldwide, of which the species of the genus *Cinara* Curtis, 1835 evolved in association with conifers (Mendel et al. 2016). This genus includes many species, distributed worldwide. Of 47 species in Palaearctic region (Nafría et al. 2012), 13 species recorded from Iran (Mehrparvar 2014) including *C.* (*Cupressobium*) *tujafilina* on *Platycladus orientalis* (Linnaeus) (Starý et al. 2005), and *C. pinihabitans* on *Pinus mugo* Turra has recently been recorded from northeast Iran (Heidari Latibari et al. 2016a, 2016b). It is a common species in the Mediterranean region on oriental thuja (Halperin et al. 1988), of which probably spread from the Far East (Mendel et al. 2016).

Among natural enemies of the aphids, members of the subfamily Aphidiinae (Hymenoptera, Braconidae) are solitary endoparasitoids of aphids (Starý 1970), and species of the genus *Pauesia* Quilis, 1931 almost exclusively attack Cinarinae aphids (Starý et al. 2005). Until now, two species have been recorded in the genus *Pauesia* from Iran, including *P. antennata* (Mukerji, 1950) and *P. hazratbalensis* (Bhagat, 1981) (Barahoei et al. 2014). These both

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are considered as rare species, strictly associated with their specific host aphids, *Pterochloroides persicae* (Cholodkovsky) and *C.* (*C.*) *tujafilina* (Del Guercio, 1909), respectively (Barahoei et al. 2013; Rakhshani et al. 2017).

The occurrence of several *Cinara* spp. on oriental thuja in Iran (Hodjat 1993; Heidari Latibari et al. 2016a, 2016b) and the presence of their parasitoid, e.g. *Pauesia hazratbalensis* Bhagat (Starý et al. 2005; current study), suggest that Iran may be a source of the aphid in the Mediterranean. The present account is an attempt to present new associations, at least structurally the role of *P. hazratbalensis* as one of the biological agents, which centers the ornamental plant protection related to a broader urban landscape.

Material and methods

A field survey was carried out during 2015–2016 in urban green space of Mashhad city (36°15′N, 59°37′E, 985 m a.s.l.), Khorasan Razavi Province, Iran (Fig. 2). The terminals of infested branches, *P. mugo*, by aphid were sampled and cut approximately 20 cm in length (Fig. 1A). The cut branches were immersed in water vials at the basal ends and caged individually, using the mesh-covered cylindrical cages (35 × 20 cm; height × diameter), before being transported to the laboratory (Fig. 1B).

The aphid-infested branches were then maintained in a growth chamber at 25°C, relative humidity of 56% (RH) and a 16:8 (L:D) h photoperiod, in order to inspect the presence of mummified aphid (Fig. 1B). The rearing cages were inspected daily to prevent the activity of emerging hyperparasitoids. The emerged parasitoids were also carefully collected using an aspirator on a daily basis and associated aphid species preserved into 75% ethanol for further examination.

The parasitoids were identified according to morphological characteristics of adults using the available taxonomic keys (Starý 1979; Rakhshani et al. 2017). A few specimens, both parasitoid and aphids, from each sample were carefully mounted in slides using a Hoyer medium. External morphology was illustrated using an Olympus™ BH-2 phase contrast microscope (Japan). All studied species deposited in the insect collection at the Department of Entomology at the Ferdowsi University of Mashhad, Iran.

Results

C. pinihabitans is considered closely associated with pine trees, especially trees in the genus *Pinus*. Parasitoids can be highly effective natural enemies of some insect pests, but their presence may not be visible until the emergence of adults (M. Heidari Latibari, pers. obs.). Because of this, it is often necessary to rear parasitised insects to determine the presence of

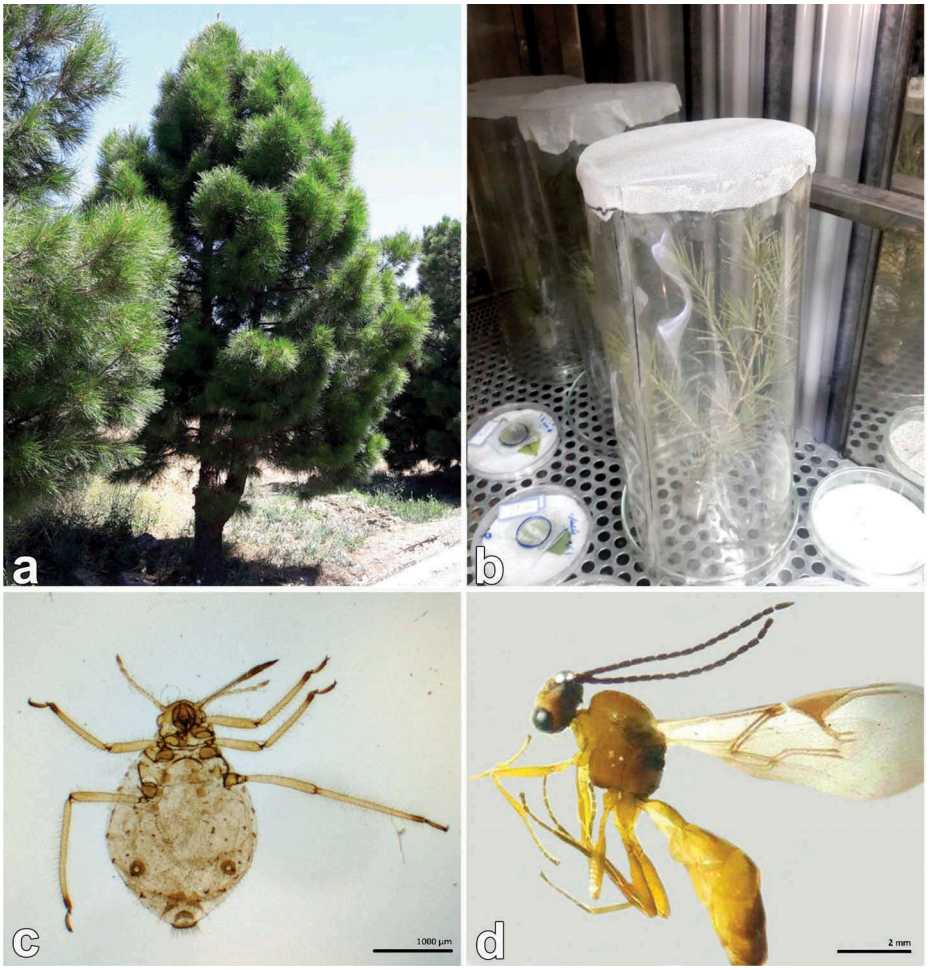

Figure 1. Sampling area, materials and findings. A, *Pinus mugo* Turra, the host of species *Cinara pinihabitans* (Mordvilko); B, Mesh-covered cylindrical cages for rearing parasitoid wasp; C, *C. pinihabitans*, apterae; D, Habitus of *Pauesia hazratbalensis* Bhagat.

parasitoid species. Utilising this method, two females and three males of *P. hazratbalensis* emerged from *C. pinihabitans* on infested branches (Fig. 1C).

The summary history association of *P. hazratbalensis* provided in Table 1. In this table, the host plant, *P. orientalis*, is valid name and *Biota orientalis* and *Thuja orientalis* are senior and junior synonyms, respectively. In addition, likely unidentified host aphid, *Lachnus* sp., from India be the same *C.* (*C.*) *tujafilina*. The following are all previous records along with geographic distribution. This allows the conclusion that the aphid species, *C. pinihabitans*, and host plant, *Pinus mugo* Turra, are new records for *P. hazratbalensis*.

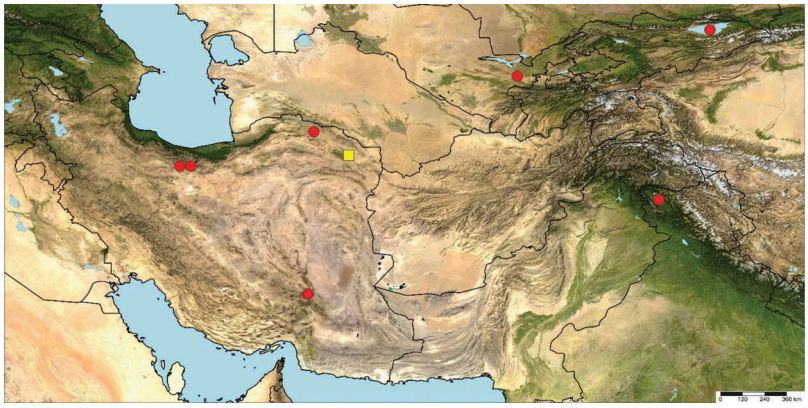

Figure 2. Distribution map of *Pauesia hazratbalensis* Bhagat in a world background (red) and study locality (yellow).

Table 1. The general summary host associations of *Pauesia hazratbalensis* Bhagat, 1981 throughout worldwide.

Host aphid species	Host plant	Country	Reference
Lachnus sp.	*Platycladus orientalis*	India	Bhagat (1981)
Cinara tujafilina (Del Guercio)	*P. orientalis*	Kyrgyzstan	Davidian (2004)
C. tujafilina	*P. orientalis*	Iran	Starý et al. (2005)
–	–	Uzbekistan	Rakhshani et al. (2017)
C. pinihabitans (Mordvilko)	*Pinus mugo*	Iran	Current study

Lachnidae

Cinarinae Börner, 1930
Cinara Curtis, 1835
Cinara pinihabitans (Mordvilko, 1894)
(Fig. 1C)

Material examined

Iran, Razavi Khorasan Province, Mashhad County, 36°15′N, 59°37′E, 985 m a.s.l., 09.v.2015, 30 m# and 6 f#, reared on *Pinus mugo* tree, leg. M. Heidari Latibari.

Distribution in Iran

Razavi Khorasan Province (Heidari Latibari et al. 2016a, 2016b).

Global distribution

Western Palaearctic (Czech Republic, Finland, Germany, Georgia, Italy, Iran, Lithuania, the Netherlands, Russia, Serbia and Turkey).

Braconidae

Aphidiinae Haliday, 1833
Pauesia Quilis, 1931
Pauesia hazratbalensis (Bhagat, 1981)

Pauesia (*Kashmirpauesia*) *hazratbalensis* Bhagat, 1981: 196 (description). Holotype f# – Hazratbal, Srinagar, Kashmir, India [Entomological Collection of the Museum of P. G., Department of Zoology, Kashmir University, Srinagar]

(Fig. 1D)

Material examined

Iran, Razavi Khorasan, Mashhad, 985 m a.s.l., 36°15′N, 59°37′E, 09.v.2015, 3 m# and 2 f#, ex. *C. pinihabitans* reared on *P. mugo* tree, leg. M. Heidari Latibari.

Distribution in Iran

Tehran (Starý et al. 2005), North Khorasan (Rakhshani et al. 2012), Kerman (Rakhshani et al. 2017) and Razavi Khorasan provinces (**new record**).

Global distribution (Fig. 2)

Eastern Palaearctic, Oriental (India, Iran, Kyrgyzstan and Uzbekistan) (Barahoei et al. 2014; Rakhshani et al. 2017).

Hosts

Cinara (*C.*) *tujafilina* (Starý et al. 2005; Rakhshani et al. 2012) and *C. pinihabitans* (**new record**).

Discussion

In general, changes in host acceptance, host switching, by parasitoid depending on plant type are recorded for other aphid parasitoids (Albittar et al. 2016). Starý (2006) attempted to determine changes in the species composition of parasitoid complexes within the complexes that affected by obligatory host plant alternation by aphids. Thereupon, these changes probably due to the adaptation aphids with their host plant.

Cinara pinihabitans was newly recorded from Iran and was collected from *P. mugo* during an investigation on the insect's conifer fauna in urban green space of Mashhad, Iran, from June 2014 to July 2015 (Fig. 1A) and distributed only in Mashhad district (Heidari Latibari et al. 2016a, 2016b). *Cinara* (*C.*) *tujafilina* become cosmopolitan (Eastop and Lambers 1976) and is widely

distributed in the Mediterranean region (Nafría et al. 2012). Many ornamental coniferous species have been distributed by humans to other areas over the world, thereby the areas of origin of the aphids, *C. pinihabitans* and *C.* (*C.*) *tujafilina*, are not clear. On the other hand, Oriental thuja, *P. orientalis*, is originated from China, and thus, *C.* (*C.*) *tujafilina* is probably naturalised in Iran. Hence, we may suggest that associated *C.* (*C.*) *tujafilana*, like other *Cinara* spp., often followed its host plant species more or less successively.

Starý et al. (2005) stated that *P. hazratbalensis* can be considered as an important aphid biocontrol agent in the Mediterranean and other parts of the world (e.g. India, Iran, Kyrgyzstan and Uzbekistan). It was detected in Iran from Tehran, North Khorasan and Kerman provinces (Starý et al. 2005; Rakhshani et al. 2017) and was only found in associations with its known host, *C.* (*C.*) *tujafilina*. Several reports confirmed that parasitoids of *Cinara* spp. are limited to the genus *Pauesia* spp., with most species native to Asia (Starý 1979; Kfir et al. 1985; Starý et al. 2005), central Asia and India (Akhtar et al. 2011). Some species have also been reported from Africa (Kfir et al. 2003), Europe (Davidian et al. 2015), Japan (Yamaguchi and Takai 1977) and the USA (Cock 1985).

The few other Iranian species have less well-understood habitat and host associations, but this species, *P. hazratbalensis*, clearly contains an interesting array that showing forms of specialisation (Starý et al. 2005; Rakhshani et al. 2017). It may, therefore, be worthwhile considering *P. hazratbalensis* as a candidate for the biological control agent of *C. pinihabitans* in the urban green landscape of Iran.

Our outputs tentatively show that the rearing of parasitoids on genus *Cinara* depends not only on the species of aphid but also on the host plant and previous rearing history. Accordingly, this research proved valuable in determination of aphids and their parasitoids on coniferous plants in the Mashhad landscape and highlighted the importance of continuous monitoring and rearing programs of the aphids biological control agents throughout the Iran.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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