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New data on ant-attendance in leafhoppers (Hemiptera: Cicadellidae)

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Abstract. Reports on ant-attendance in the leafhopper family Cicadellidae (Hemiptera: Cicadomorpha) are rare and mainly concern species from the tropics and subtropics. We documented trophobiotic relationships between leafhoppers *Hephathus freyi* (Fieber, 1868), *H. nanus* (Herrich-Schäffer, 1835) (Macropsinae), *Balcanocerus balcanicus* (Horváth, 1903) (Idiocerinae) and *Selenocephalus obsoletus* (Germar, 1817) (Deltocephalinae) and different ant species (Hymenoptera: Formicidae) in Bulgaria on their host plants. This is the first time ant-attendance in *Hephatus freyi* and *Selenocephalus obsoletus* has been recorded whereas trophobiosis between *H. nanus* and ants was last observed a hundred years ago. Behavioural characteristics and the different degrees of relationships between both partners are discussed.

Key words: *Hephathus*, *Selenocephalus*, *Balcanocerus*, trophobiosis, Cicadellidae, ants, Bulgaria.

Trophobiosis, or ant-attendance, is well-known within aphids and scale insects (Hemiptera: Sternorrhyncha: Aphidoidea and Coccoidea), and certain lycaenid and riodinid caterpillars (Lepidoptera); but is less known in leafhoppers and planthoppers (Cicadomorpha and Fulgoromorpha) (Hölldobler & Wilson 1990, Devries 1991, Delabie 2001, Attié et al. 2008, Fletcher 2009, Lőrinczi 2012). Relationships between ants and species from the Cicadomorpha have been mostly studied in the tropics and subtropics, predominantly in the family Membracidae and, less frequently, in the Eurymelidae, Aethalionidae and even some Cicadellidae (Delabie 2001, Barônio et al. 2012). Unlike common Cicadellidae species, membracid nymphs exhibit sessile (non-jumping) behaviour and aggregations, and in this way may ensure easy honeydew collecting by ants (Dietrich & McKamey 1990).

Ant-associated Cicadellidae are known from Africa (Bergevin 1910, Lamborn 1914, Linavuori 1978, Quartau 1990, Stiller 2012); India (Viraktamath 1980, Chatterjee 1934, Knight 1973 according to Dietrich & McKamey 1990); Australia (Shcherbakov et al. 2000) and the New World (Kirkaldy 1906, Wheeler 1921, Beamer & Michener 1950, Lavigne 1966, Leech 1966, Dietrich & McKamey 1990, Larsen et al. 1992, Moya-Raygoza & Nault 2000, Rakitov 2000, Maravalhas & Morais 2009, Souza & Francini 2010).

The first anecdotal report of interactions between ants and representatives of the family Cicadellidae concern *Hephathus nanus* (Herrich-Schäffer, 1835) (as *Bythoscopus nanus*) and *Anacertagallia venosa* (Fourcroy, 1785) (as *Bythoscopus venosus*) (Dür 1870). These reports were considered by André (1874) to be only incidental interactions.

However, a single leafhopper species has recently been observed being tended by ants in Europe — *Balcanocerus balcanicus* (Horváth 1903) (Gjonov 2002). It was established that this species forms dense groups of both nymphs and adults, which enter into trophobiotic relationships with five ant species from two subfamilies — *Lasius alienus* (Förster, 1850), *L. niger* (Linnaeus, 1758), *L. fuliginosus* (Latreille, 1798), *Formica pratensis* Retzius, 1783 (Formicinae) and *Crematogaster schmidti* (Mayr, 1853) (Myrmicinae), exclusively on the host plant *Crataegus monogyna* Jacq. (Rosaceae). Özgen et al. (2012) confirmed the ant-related life style of *B. balcanicus* with three hitherto unknown ant species (*Camponotus gestroi* Emery, 1878, *C. xerxes* Forel, 1904 and *Formica clara* Forel, 1886) from the Anatolian part of Turkey.

In Belgium, one other species *Balclutha punctata* (Fabricius, 1775) (Steiner et al. 2004) was reported to have facultative relationships with ten ant species of three subfamilies, which require the honeydew excreted by leafhopper nymphs on *Calamagrostis epigejos* (L.) Roth (Poaceae). In this case, no direct contact has been recorded between the ants and the leafhoppers.

Here we present field observations on trophobiotic interactions between four cicadellid species: *Hephathus freyi*, *H. nanus*, *Balcanocerus balcanicus* and *Selenocephalus obsoletus* and different ant species (Hymenoptera: Formicidae) (Table 1).

Table 1. List of ant-attended cicadellids recorded in Bulgaria.

Leafhopper species	Locations	Date	Host plants	Ant species
Hephathus freyi (Fieber, 1868)	Southwest Bulgaria, Petrich district, General Todorov village, N41° 26′ 33″ E23° 17′ 02″	31 August 2011	*Cirsium* cf. *arvense* (Asteraceae)	*Formica cunicularia* Laterille, 1798 *Camponotus piceus* (Leach, 1825)
Hephathus nanus (Herrich-Schäffer, 1835)	Southeast Bulgaria, Malko Tarnovo district, Slivarovo village, N41° 59′ 05″ E27° 38′ 10″	28 June 2011	*Cirsium* sp. (Asteraceae)	*Lasius paralienus* Seifert, 1992
Balcanocerus balcanicus (Horváth, 1903)	Southeast Bulgaria, Tsarevo district, Kosti village, N42° 01′ 39″ E27° 48′ 25″	03 August 2006	*Crataegus monogyna* Jacq. (Rosaceae)	*Camponotus vagus* (Scopoli, 1763)
Selenocephalus obsoletus (Germar, 1817)	South Bulgaria, Western Rhodope Mts, near Satovcha village, N41° 36′ 39″ E23° 59′ 21″ Southwest Bulgaria, near city of Boboshevo, N42° 09′ 50″ E22° 58′ 44″ Southeast Bulgaria, Tsarevo district, near Fazanovo village, Popovi skali locality, N42° 09′ 53″ E27° 44′ 03″ South Black Sea coast, near Sinemoretz village, Silistar locality, N42° 01′ 23″ E28° 00′ 28″ South Black Sea coast, near city of Tsarevo, N42° 08′ 56″ E27° 51′ 14″	20 June 2009 09 June 2010 27 June 2011 27 June 2011 28 June 2011	*Cytisus* sp. (Fabaceae) *Cynara* sp. (Asteraceae) *Onopordum acanthum* L. (Asteraceae)	*Camponotus aethiops* Latreille, 1798 *Camponotus piceus* (Leach, 1825) *Formica cunicularia* Laterille, 1798

The present study provides the first data on ant-attendance in *Hephathus freyi* and *Selenocephalus obsoletus*, although these species were described many years ago and have a wide distribution (Tishechkin 1999).

Trophobiosis in *H. nanus* had not been recorded since Bergevin (1910) reported ant-attendance on *Carlina involucrata* Poiret (Asteraceae) in North Africa (Algeria) but without information of the associated ant species. The author established close relationships between the partners, where ants first antennated the immobilized nymphs, then directly imbibed the excreted honeydew droplets.

Here, we report again the finding of *Balcanocerus balcanicus* in association with ants, this time with an additional ant species, *Camponotus vagus*, which was not observed in the previous study (Gjonov 2002). So far, without exception we have invariably observed *B. balcanicus* tended by ants suggesting the obligatory character of their trophobiotic relationships.

Various degrees of association between ants and leafhoppers influence different behaviour patterns between the partners.

Physical contact. Close physical contact between all Cicadellidae species observed by us — *Hephathus freyi* (Fig. 1), *H. nanus* (Fig. 2), *Balcanocerus balcanicus* (Fig. 3) and *Selenocephalus obsoletus* (Fig. 4) and the tending ant species on the plant hosts were observed in the present study. This includes both the ants touching the leafhopper bodies with their antennae to initiate honeydew release and direct imbibing of honeydew from the leafhoppers. Such behaviour also has been described in the American obligate myrmecophilous cicadellid *Dalbulus quinquenotatus* DeLong & Nault, 1983 (Moya-Raygoza & Nault 2000). This is in opposition to *Balclutha punctata* in Belgium (Steiner et al. 2004) where no direct contact was observed between the ants and the leafhoppers.

Aggregations. The grouping of honeydew-producing insects during ant-attendance ensures much more efficient food collecting, as well as better protection from predators and parasitoids.

The largest groups of nymphs and adults we observed were those of *Hephathus freyi* (Fig. 1) and *Balcanocerus balcanicus*. Ant-attendance in *Selenocephalus obsoletus* took place between single specimens or in small groups located in the leaf axils of the host plants. From other leafhopper species known to be associated with ants, the aggregations of *Dalbulus quinquenotatus* are most similar to those of *Hephathus freyi* and *Balcanocerus balcanicus*, while *Balclutha punctata* forms larger groups of nymphs on the plants in the presence of ants, as opposed to the plants not attended by ants.

Sessile (non-jumping) behaviour. A sessile behaviour and reduced jumping activity were observed in the presence of ants for all four leafhopper species. Although all ants attending these cicadellids are predators, the latter did not demon-

Figure 1. *Hephathus freyi* nymphs and adults with *Formica cunicularia* workers on *Cirsium* cf. *arvense*.

Figure 2. Interaction of workers of *Lasius paralienus* with a *Hephathus nanus* adult on the plant host *Cirsium* sp.

Figure 3. An adult of *Balcanocerus balcanicus* tended by *Crematogaster schmidti* ants on the host plant *Crataegus monogyna*.

Figure 4. A group of three *Selenocephalus obsoletus* nymphs actively tended by *Camponotus aethiops* ants.

strate any escape reactions.

Conclusion. Because we observed *Hephatus nanus* and *Selenocephalus obsoletus* that were not always attended by ants, or the groups formed on the host plants were small or non-existent, we deem their trophobiotic behaviour to be facultative. The specialization of both species in their relationship with ants is thus intermediate, between that of *Balclutha punctata* and the more specialized *Balcanocerus balcanicus* and *Dalbulus quinquenotatus*. Although this is the first report of *Hephathus freyi* observed in trophobiotic relationships with ants, the noted characteristics — the presence of close physical contact, size and compactness of the attended groups, as well as the established sessile behaviour and lack of escape reaction, are those of a typical myrmecophile leafhopper species.

The present study highlights new data on the partner specificity and observations *in situ* for poorly known associations between ants and leafhoppers, though more ecological details remain to be studied.

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