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First observations on phoresy hosts of *Imparipes* (*Sporichneuthes*) *dispar* Rack, 1964 (Acari: Heterostigmatina: Scutacaridae)

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Abstract

Imparipes (*Sporichneuthes*) *dispar* Rack, 1964 is a species belonging to the mite family Scutacaridae which displays appetence behavior and a unique jumping ability. Both features indicate that *I. dispar* might disperse via phoresy, but possible hosts were not known until now. A field experiment was conducted to determine whether *I. dispar* performs phoresy and to identify potential host taxa. *Imparipes dispar* turned out to be a host generalist, accepting Diptera, Coleoptera and Hymenoptera as hosts. Several of the detected phoresy host taxa are potentially new for scutacarids.

Keywords host range | Mites | Diptera | Coleoptera | Hymenoptera

1. Introduction

The family Scutacaridae is a cosmopolitan taxon of mycophagous soil mites. While most scutacarid species live the inconspicuous life of a typical soil mite, spending their entire lifespan in their habitat where they move around, feed and reproduce, some have evolved remarkable behavioral traits. One of these exceptional scutacarids is *Imparipes* (*Sporichneuthes*) *dispar* Rack, 1964. The species has first been discovered in samples of a waste deposit in Hamburg-Langenhorn (Germany) and was described by Rack (1964) as a subspecies of *I. histricinus* Berlese, 1903. More than 20 years after its first discovery in Germany it was found in high abundance in a garden composter of the first author in Austria. The respective mites were thriving on the fungus *Aspergillus insuetus*, and due to the knowledge of the natural food source successful laboratory cultures could be established and kept alive for almost 15 years (Ebermann 1995). Additionally, *I. dispar* was also reared successfully on *Penicillium* sp. (Ebermann unpublished). Based on specimens gained from laboratory cultures, thorough morphological studies allowed a revision of the species, which on one hand supported its status as distinctive species and on the other hand resulted in its assignation to the newly created subgenus *Sporichneuthes*. This subgenus is based on the unusual morphology of the gnathosoma and the connected exceptional feeding mode, namely the sucking of fungal spores (Ebermann 1998).

Observation on the behavior of *I. dispar* in laboratory cultures also were done, revealing other remarkable traits in addition to the unusual feeding mode: jumping ability, which is unique in Scutacaridae (Ebermann 1995), and appetence behavior, which has also been reported for other scutacarid species (e.g. Ebermann 1991, 1995). Both behavioral traits strongly indicate that *I. dispar* performs phoresy, which is a common phenomenon in scutacarids. Nevertheless, no phoretic specimens of *I. dispar* have been reported so far, and the potential hosts accordingly are also unknown.

Aim of the present study was to investigate the range of possible hosts through field experiments. The study was performed within the framework of an unpublished master thesis conducted by the second author (Messner 2001).

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2. Material and methods

For detecting potential hosts of *I. dispar*, a composter modified for collecting arthropods (mostly inscects) had been installed at Haselsdorf-Tobelbad in Austria (46°59'19.16"N, 15°20'44.38"O) between 23.07. and 01.09.1998. The respective composter had been filled with ordinary compost and topped with coffee ground, inoculated with spores of *A. insuetus* and, after successful sporulation, supplied with *I. dispar* from the laboratory cultures mentioned in the introduction. Shortly after addition of the mites, the composter was covered with a cage (Figure 1). The front of the cage, which was orientated to the south, was made of acrylic glass and provided with two round openings through which arthropods leaving the composter could be collected. All sides and the top of the cage were covered with fly screens and an additional black plastic sheet. Entrance to the composter was possible through an opening left between the composter and the back side of the cage, which was directed to a forest. As sunlight could only enter through the round openings on the front side of the cage, arthropods practically always tried to leave the composter through this exit and not through the gap between composter and cage. Leaving arthropods were collected in plastic bags attached to the frontal openings and afterwards put in a deep freezer for several minutes. That way, possible phoretic mites stayed attached to their hosts and did not dismount. After freezing, arthropods were stored in 70% ethanol and later determined to family or superfamily level and investigated for mites using a stereo microscope (Leica Wild 8). Because of the experimental set-up, mostly flying arthropods were collected. In addition, non-flying arthropods were extracted from the surface of the substrate using a leaf vacuum.

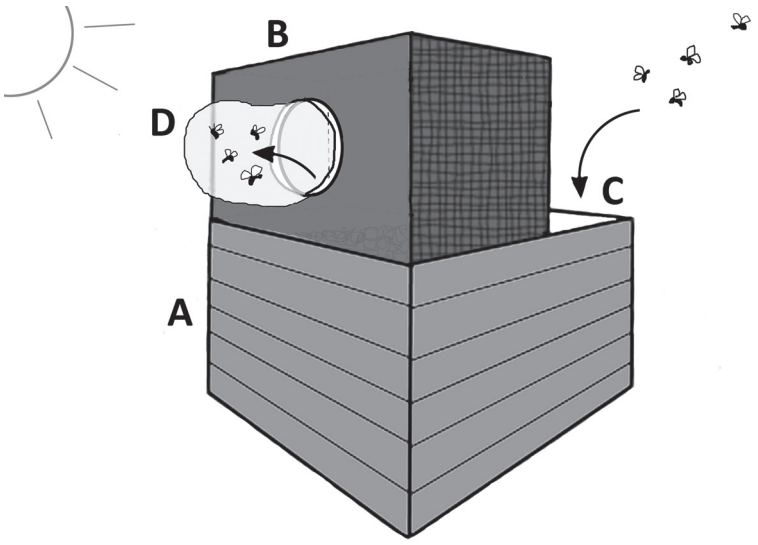

Figure 1. Setup used collecting arthropods leaving a composter. (**A**) Composter, (**B**) Acrylic glass cage, all sides covered with fly screens and black plastic sheets. The cage used in the experiments had two openings for collecting arthropods, but for clarification only one opening is illustrated, (**C**) Opening between the composter and the cage through which arthropods could enter the composter, (**D**) plastic bag for collecting arthropods.

Table 1. Arthropods captured leaving the composter (or on composter's surface), including the number of specimens per taxon and their percentage of the total number of collected specimens.

	number of collected specimens	% of total number
Diptera	3,672	88.80
various insect larvae	201	4.86
Coleoptera	106	2.56
Hymenoptera	88	2.13
Arachnida	49	1.19
Isopoda	17	0.41
Dermaptera	2	0.05
total sum	**4,135**	

3. Results

A total sum of 4,135 specimens belonging to Diptera, Coleoptera, Hymenoptera, Dermaptera, Arachnida and Isopoda were caught when leaving the composter or were vacuumed from the substrate's surface. The collected fauna was clearly dominated by Diptera: 88.8% of all specimens belonged to this taxon, whereas the percentages of specimens belonging to other taxa did not account to more than 5.0% (Tab. 1, Fig. 2A).

Out of the 4,135 captured arthropods, phoretic specimens of *I. dispar* were found on only 139 individuals (equal 3.4% of all collected animals) belonging to Diptera, Coleoptera and Hymenoptera. The infestation rates on these three orders were low: 4.0% of Diptera, 3.0% of Coleoptera and 23.0% of Hymenoptera were infested with *I. dispar* (Tab. 2, Fig. 2B).

In Diptera, the highest number of phoretic *I. dispar* was found on the family Scatopsidae, where 82 specimens were found to have mites attached. However, members of this family were clearly dominating the collection and the calculation of the infestation rate reveals that only 4.0% of all collected Scatopsidae bore *I. dispar*. Higher infestation rates were detected for Psychodidae (25.0%) and Mycetophilidae (17.0%), but members of these two families were present only in low numbers (Tab. 2).

The number of phoretic *I. dispar* on Coleoptera was also low: only two mites could be detected, one on *Cercyon nigriceps* (Hydrophilidae), and one on *Lithocharis nigriceps* (Staphylinidae) (Tab. 2).

The highest infestation rates were present in Hymenoptera. All infested hymenopterans belonged to families and superfamilies assigned to the group Parasitica. Most phoretic *I. dispar* were present on members of the superfamily Proctotrupoidea: 33.0% of the specimens belonging to this taxon had mites attached.

A certain trend towards differing favored attachment sites on different hosts was recognizable: on Diptera, half of all scutacarids were found on the thorax, the rest on the legs and the abdomen and only exceptionally on caput and wings. The mites found on Coleoptera were attached to thorax and abdomen, and those on Hymenoptera could be encountered on a variety of attachment sites (thorax, petiolus, abdomen, caput, legs and wings).

4. Discussion

The results of the present study confirmed that *I. dispar* indeed is a scutacarid species dispersing via phoresy. The mites were found attached to insects belonging to

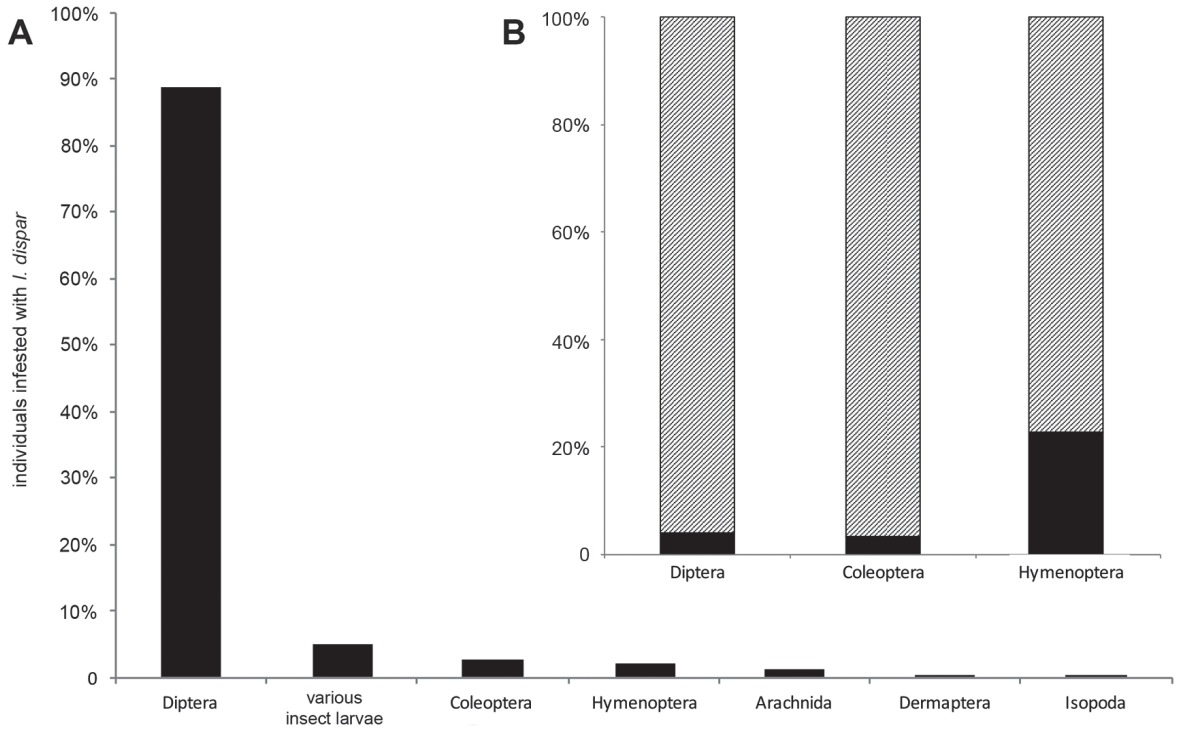

Figure 2. (**A**) Charts of arthropod taxa percentages collected while leaving a composter. (**B**) Charts showing the three taxa infested with *I. dispar* in the present study (Diptera, Coleoptera and Hymenoptera), giving the percentage of infested specimens in black blocks.

the three orders Diptera, Coleoptera and Hymenoptera, which indicates that *I. dispar* is rather generalistic in its host choice. In most cases, phoretic scutacarid species only use hosts belonging to one family or even one genus (Jagersbacher-Baumann unpublished).

The infestation rates of the insects caught in field experiments were low, which can probably be explained by the condition of the compost used in the field experiment: the substrate was obviously in a good state with a strong growth of fungi and thus offered a favorable environment for the mites, resulting in a low pressure towards phoretic behavior.

Several of the detected host taxa (Tab. 2) are new for scutacarids: within Diptera, only members of the families Phoridae and Sphaeroceridae were known to be used by scutacarid mites until now (e.g. Binns 1979, Khaustov 2008). Some of the attachment sites on Diptera detected in the present study, namely thorax, caput and wings, are also new for this host taxon. So far, only different parts of the abdomen and the metacoxae had been reported as preferred locations on Diptera (Norton & Ide 1974, Binns 1979, Zaki et al. 1987). Hymenoptera belonging to the group Parasitica are another taxon which is new as phoresy host for Scutacaridae. Until now, scutacarids had exclusively been reported from members of Aculeata (e.g. Khaustov 2008, Ebermann et al. 2013). The experimental set-up applied in the present study is expected to reflect the natural conditions very well. Because of this, it remains puzzling why *I. dispar* has never been reported as phoretic mite before.

In the scutacarid genus *Imparipes*, phoresy is widely spread, and the hosts range from arachnids (Ebermann & Palacios-Vargas 1988) to a variety of insect taxa (e.g. termites (Mahunka 1964), ants (e.g. Ebermann & Krisper 2014), wild bees (e.g. Delfinado & Baker 1976, Ebermann et al. 2013) and finally to mammals (e.g. Sevastyanov & Uzhevskaya 2003). Within the subgenus *Sporichneuthes*, which currently contains five species including *I. dispar*, no phoretic species have been reported to date. However, the wide distribution of *I.* (*S.*) *schusteri*, reaching from Brazil to Galapagos, El Salvador and Mexico, suggests that it might disperse via phoresy, too (Ebermann 1998). Most *Imparipes* species are rather specialized to their hosts, for example *I. robustus* always being associated with Formicidae (e.g. Khaustov 2008) or *I. vulgaris* with halictid bees belonging to the genus *Lasioglossum* (Delfinado & Baker 1976). In contrast, seven *Imparipes* species show broader host ranges: these are *I. dispar* (this paper), *I. cupes* associated with Coleoptera and Rodentia (Delfinado & Baker 1978, Estébanes-González & Cervantes 2005), *I. degenerans* with Rodentia and Hymenoptera (Karafiat 1959, Sevastyanov & Uzhevskaya 2003), *I. histricinus* with Hymenoptera, Dermaptera and Coleoptera (Paoli 1911, Khaustov 2008), *I. obsoletus* with Rodentia, Aves and Hymenoptera (Delfinado et al. 1976, Sevastyanov & Uzhevskaya 2003, Khaustov 2008), *I. penicillatus* with Rodentia and Diptera (Mahunka 1973, Sevastyanov & Uzhevskaya 2003), and *I. rectangulatus* with Hymenoptera and Orthoptera (Mahunka 1977). These

Table 2. (Super)families of Diptera, Hymenoptera and Coleoptera infested with *I. dispar* in the present study. Absolute number of infested specimens, total number of collected specimens and percentages of infested specimens are given.

		specimens infested with phoretic *I.* (*S.*) dispar	total number of collected specimens	% of infested specimens
Diptera	Scatopsidae	82	1,965	0.04
	Sciaridae	24	335	0.07
	Ceratopogonidae	6	674	0.01
	Dolichopodidae	5	59	0.08
	Chironomidae	1	9	0.11
	Psychodidae	1	4	0.25
	Anisopodidae	1	9	0.11
	Mycetophilidae	1	6	0.17
	Conopidae	1	1	1.00
		122	**3,062**	**0.04**
Hymenoptera	Proctotrupoidea	12	36	0.33
	Pteromalidae	2	16	0.13
	Eucoilidae	1	14	0.07
		15	**66**	**0.23**
Coleoptera	Hydrophilidae	1	14	0.07
	Staphylinidae	1	46	0.02
		2	**60**	**0.03**

associations do, however, not automatically imply that the mites are also phoretic on their hosts. In the nests of birds and mammals, they are to date only known as inquilines. The wide host ranges of some species, for example of *I. histricinus*, could also be explained by incorrect identifications.

Imparipes dispar thrives on layers of fungi like *A. insuetus* in compost, which are a rather ephemeral, quickly changing habitat. When the mites' food source is about to be exhausted, they need hosts in order to disperse to new suitable places, and as long as their host will visit habitats with favorable conditions, any host species will do. As *I. dispar* most probably is no inquiline of any of its hosts, it is not expected to depend on any special environmental conditions (e.g., occurrence of a special fungus species which serves as food) which can only be found in association with its host, and thus it can afford a broad host spectrum. On the other hand, mite species living as inquilines most probably profit from habitat conditions which are only present in their host's nests, and accordingly they are expected to display host specificity to some degree. However, a closer look on the other *Imparipes* species with broad phoresy host spectrums (see above) unexpectedly revealed that all of them can be found as inquilines of their hosts. While the generalist behavior of *I. dispar* can convincingly be explained, it is more difficult to do so for these other *Imparipes* species. What seems plausible is that some of them might in fact be complexes of (cryptic) species associated with different host taxa, and it would be necessary to conduct morphological and molecular genetic studies on the intraspecific variability of these mites to clarify their status.

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