[SHORT COMMUNICATION]

Acarinaria and mite associates of the large carpenter bee *Xylocopa* *(Koptortosoma)* *ruficeps* (Hymenoptera: Apidae) from Taiwan

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Bees and wasps are associated with a wide variety of mites (O'Connor and Klompen, 1999; Klimov et al., 2007). Some of them have evolved specialized acarinaria (mite chambers) on their body and harbor more or less specific groups of mites in them. Female carpenter bees of the genus *Xylocopa* are well known for having a metasomal acarinarium of various levels of specialization (Hurd and Moure, 1963; Eardley, 1983; Klimov and O'Connor, 2008). In particular, female carpenter bees of the subgenera *Koptortosoma* and *Mesotrichia* have a distinct acarinarium on the first metasomal tergite (T1), which is the “largest known” (Klimov et al., 2007) acarinarium in insects. The metasomal acarinarium is a spacious chamber occupying a large portion in the first metasomal segment and is connected to the bee’s exterior through a small aperture on its anterior surface, and it harbors species-specific mites of the genus *Dinogamasus* (Klimov et al., 2007).

Although the female metasomal acarinarium of *Koptortosoma* and *Mesotrichia* has long been known, its detailed structures have been described in only a few species including *Xylocopa* *(Mesotrichia)* *caffra* L. (Skaife, 1952) and *Xylocopa* *(Mesotrichia)* *flavorufa* (DeGeer) (Madel, 1975) from Africa. Detailed information regarding the morphology of the acarinaria in as many species as possible is indispensable to understand the evolution of the structure and the interrelationship between bees and mites.

The carpenter bee *Xylocopa* *(Koptortosoma)* *ruficeps* Friese, distributed in the Oriental region (Hurd and Moure, 1963), has also been reported to possess a distinct metasomal acarinarium (Okabe and Makino, 2005). However, its structure has not been examined in detail. In addition to...
the metasomal acarinarium, the bee also has a pair of acarinaria on the dorsolateral position on
the mesosoma (“axillar acarinaria” sensu Klimov and OConnor, 2008) as is usual in the genus
(OConnor, 1993; Okabe and Makino, 2002, 2005). In the present study, we describe the
morphology of acarinaria in the carpenter bee and their contents based on specimens collected in
Taiwan.

Five female adult bee specimens of *X. ruficeps* were collected from flowers on Orchid Island
(Lanyu) (22.03°N, 121.32°E), Taiwan, in May 2010. The collected specimens were preserved in
70% ethanol and were later examined using a dissecting microscope. Tips of the mandibles were
worn-out in two of the five specimens, whereas they were sharp and pointed in the remaining
three specimens, suggesting that the former were older than the latter. All mites in the bees were
recorded for their positions on the host. Parts of the insects and mites were measured using an
ocular micrometer.

The metasomal acarinarium was a deeply invaginated, fava-bean shaped chamber on T1, with
an opening situated slightly above the center of the vertical surface of the tergite (Figs. 1A, B, C
and 2). The measurements of the chamber in the specimens examined varied from 2.4 to 2.6 mm
in height, from 3.8 to 3.9 mm in width, and from 1.4 to 2 mm in depth, occupying a large space

\begin{figure}
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\caption{Metasomal acarinarium of *Xylocopa ruficeps*. (A) Frontal view of the 1st metasomal tergite, with the
opening of the acarinarium situated approximately at the center. (B) The opening is barely wide enough for
a single *Dinogamasus* sp. mite to enter or exit at a time. (C) Close-up of the opening that is connected with a
depression via a groove. (D) The wall of the acarinarium looks like a swelling viewed from the rear of the 1st
metasomal segment, which is detached from the other parts of the body. Scale bar = 1 mm.}
\end{figure}
in the first metasomal segment (Fig. 2). The inner surface of the acarinarium was smooth and shiny, without any noticeable structure, and its wall was much thinner (0.014–0.017 mm) than other parts of T1 (0.041–0.051 mm) as noted by Skaife (1952). The opening was nearly oval (0.65–0.70 mm in width and 0.90–1.00 mm in height), slightly pointed at the lower end (Fig. 1C), and accompanied with many long (approximately 1 mm) hairs above the upper margin (Hurd and Moure, 1963). The general structure of the metasomal acarinarium is similar to those described for *X. (Koptortosoma) caffra* (Skaife, 1952) and *X. (Mesotrichia) flavorafa* (Madel, 1974). *Xylocopa (Koptortosoma) nigrita* (Fabricius) is also shown to have a similar, distinct acarinarium that occupies much of the interior of T1 (Eardley, 1983; Michener, 2007). A groove (“vertical fold” sensu Hurd and Moure, 1963) originated from the lower end of the opening and ended at the antecostal suture (Fig. 1C) by forming a depression around the foramen of T1.

The mesosomal acarinarium (“axillar acarinaria” sensu Klimov and OConnor, 2008) were a pair of slit-like pockets situated behind each hind wing base and consist of indentations on the dorsolateral portions on the axillae of the mesosoma (Fig. 3). They were very similar to those described for *Xylocopa latipes* (Drury) (OConnor, 1993) or *Xylocopa appendiculata* Smith (Okabe and Makino, 2002, 2005). The opening of the mesosomal acarinarium was elongated, spindle-like, which was 1.0 mm in length, 0.12 mm in width, and 0.36 mm in depth.

Two species of mites were found in the specimens: adults of *Dinogamasus* sp. (Mesostigmata: Laelapidae) and deutonymphs of *Sennertia* sp. (Astigmata: Acaridae). *Dinogamasus* sp. occurred exclusively in the metasomal acarinarium as reported in other species of the subgenera *Koptortosoma* and *Mesotrichia* associated with the genus of mites (Michener, 2007; Klimov and OConnor, 2008). Two of the five female bees with worn-out mandibles (possibly older individuals)
harbored 2 and 6 *Dinogamasus* mites, whereas the remaining three with relatively new mandibles (younger individuals) harbored 14, 17, and 18 mites. This suggests that a small number of mites leave the acarinarium each time a female bee lays an egg in a brood cell during her nesting activity, as suggested by Madel (1975). The numbers of mites in the acarinarium were close to those reported for *X. caffra*, where females harbor 2 or 3 to 17 or 18 mites of *Dinogamasus braunsi* (Vitzthum) in the metasomal acarinarium (Skaife, 1952) but were slightly smaller than those in *X. flavorufa* that harbor an average of 21 mites (Madel, 1975). In the event that many mites were present in the acarinarium, they were neatly packed “like sardines” as described by Skaife (1952) (Fig. 4A).

Deutonymphs of *Sennertia* sp. mainly occurred in the mesosomal acarinaria or at its opening, in a small cavity under the tegula, and in the depression around the major foramen of T1 (Fig. 4D). In addition, with the exception of a single bee, some *Sennertia* mites occurred in the metasomal acarinarium intermingled with *Dinogamasus*. The total number of *Sennertia* was 5, 20, 34, 41, and 53 in the sampled specimens. Unlike *Dinogamasus* sp., no relationship was found between the number of mites and the estimated age of bees.

Bees and wasps seem to have evolved acarinaria independently in several families (Klimov et al., 2007). Although several authors have suggested antagonism, commensalism, and mutualism between the hosts and mites harbored in the acarinaria, the relationship has been quantitatively evidenced only in a few mutualistic associations in which the mites protect the hosts from parasitoids (Okabe and Makino, 2008) or keep nests clean by controlling microorganisms (Biani...
et al., 2009). In the great majority of mite-hymenoptera associations, functions of acarinaria and relationships between the mites and the hosts are unclear.

*Sennertia* sp. possibly feeds on stored pollen and/or fecal pellets in brood cells of the host as does *Sennertia alfkeni* (Okabe et al., 2008), suggesting commensalism or cleptoparasitism. Its usual positions on the host were the mesosomal acarinarium and the metasomal groove or depression, which were much less specialized compared to the metasomal acarinarium. This may suggest that the mite is of minimal significance to the host. On the contrary, the conspicuous morphology of the metasomal acarinarium of *X. ruficeps* indicates a great significance of its inhabitant *Dinogamasus*. However, despite the fact that the peculiar acarinarium in the subgenera *Koptortosoma* and *Mesotrichia* has been known for more than 100 years (Skaife, 1952; Madel, 1975), its adaptive significance (and of the mite) from the host perspective remains enigmatic. Although the food habits of *Dinogamasus* are unclear, a few authors consider it to be ectoparasitic on immature hosts (Skaife, 1963; Madel, 1975; Watmough, 1974). If *Dinogamasus* is a parasite, it may help the host by protecting it from its natural enemies as is the case in the parasitic–mutualistic mite *Ensliniella parasitica* (Vitzthum) (Winterschmidtiiidae) that protects the eume-

![Fig. 4. Mites symbiotic with female *Xylocopa ruficeps*. (A) Dorsal view of the metasomal acarinarium with a part of the upper wall removed to reveal adult mites of *Dinogamasus* sp. inside. (B) Same as A, but with all mites removed. (C) Mites of *Dinogamasus* sp. contained in the metasomal acarinarium of a single host. (D) Mites of *Sennertia* sp. (arrow) in or near the groove and depression near the major foramen of Tergite 1 of the metasoma. Scale bar = 1 mm.](image-url)
nine host wasp *Alodynerus delphinalis* (Giraud) (Vespidae) from the parasitoid wasp *Melittobia acasta* (Walker). *Ensliniella* mites that encounter the parasitoid on a host larva prevent it from laying eggs on the larva by attacking it (Okabe and Makino, 2008). *Xylocopa* species have a wide range of predators, cleptoparasites, or parasitoids that invade their nests (Watmough, 1974; Gerling et al., 1989). Close observation of the reaction of *Dinogamasus* mites to invading natural enemies could provide insights into the functions of the acarinarium and mites.

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