Sociobiology 61(4): 428-434 (December, 2014) DOI: 10.13102/sociobiology.v61i4.428-434

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Register of a New Nidification Substrate for *Melipona subnitida* Ducke (Hymenoptera: Apidae: Meliponini): The Arboreal Nest of the Termite *Constrictotermes cyphergaster* Silvestri (Isoptera: Termitidae: Nasutitermitinae)

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Article History

Edited by
Denise Araujo Alves, ESALQ-USP, Brazil
Received 09 October 2014
Initial acceptance 10 December 2014
Final acceptance 14 December 2014

Keywords
Stingless bees, nest, Carrasco, jandaíra, adaptation.

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Abstract

The bee species *Melipona subnitida* Ducke is the most frequently domesticated bee in the dry northeastern part of Brazil. Like most other stingless bee species, *M. subnitida* nests in hollow spaces in trees. However, in a small region of Chapada do Araripe plateau (Ceará State of Brazil) the nest of this bee can also regularly be found inside living arboreal termite nests of *Constrictotermes cyphergaster* Silvestri. Here we describe the structure and content of such a bee nest when we transferred it from a formerly collected termite nest into a wooden nest box, and complement with information based on an untouched, feral nest. We hypothesize whether or not this nesting habit of *M. subnitida* is an adaptation to shortage of pre-existing cavities in trees locally.

Introduction

The presence of nesting sites is essential to the survival, maintenance and reproduction of stingless bees (Meliponini) (Hubbell & Johnson, 1977; Batista et al., 2003; Eltz et al., 2003; Roubik, 2006). Although their nesting habits are variable, most of the stingless bee species build their nests in pre-existing cavities of trees, in termite and ant nests, or in other hollow spaces in the ground (Roubik, 1983; 2006). Nesting habits and nest architecture of stingless bees for long has been object of study (*eg*. Ihering, 1930; Schwarz, 1932; 1948; Michener, 1946; 1961; 1974; 2007; Wille & Michener, 1973; Sakagami, 1982; Wille, 1983; Roubik, 1979, 1989; 2006; Nogueira-Neto, 1997; Camargo & Pedro 2003; Pedro & Camargo, 2003, Barbosa et al., 2013), still the nesting ways of many species are understudied or completely unknown. The lack of this knowledge is critical in face of the growing human impacts on ecosystems, with special importance to the development of managing guidelines that help conserving these animals that are so important in pollination services.

Among the neotropical Meliponini, the genus *Melipona* (Apidae, Meliponini) stands out for being the most specious and the most productive in terms of honey production (Nogueira-Neto, 1997; Camargo & Pedro 2013). Out of the 70 described species (Camargo & Pedro, 2013; Ascher & Pickering 2014), the great majority build their nests in pre-existing cavities of living trees (Schwarz, 1932; Camargo 1970; Wille & Michener, 1973). However, other nidification habits are also known for the genus, like for *Melipona quinquefasciata* Lepeletier that nests in pre-existing cavities in the ground (Ducke, 1916; Lima-Verde & Freitas, 2002) and *Melipona bicolor schencki* Gribodo that nests preferably in holes between tree roots (Wille, 1983; Bego, 1983). Alternative nesting sites have been reported for some species, like *Melipona marginata* Lepeletier found in the crevices of human-constructed walls (Kerr et al., 1996; Nogueira-Neto,

Open access journal: http://periodicos.uefs.br/ojs/index.php/sociobiology
ISSN: 0361-6525

1997) and *Melipona quadrifasciata quadrifasciata* Lepeletier (as *Melipona vicina*) in the ground (Schwarz, 1932) and in a termite nest (Ihering, 1930; Kerr et al., 1967 apud Nogueira-Neto, 1997), but without more details.

Melipona subnitida Ducke, 1910 [1911], popularly known as jandaíra, is one of the most frequently domesticated stingless bee species in the dry parts of Northeastern Brazil. It also has a preference to nest in hollow trunks and branches of living trees, especially of *Commiphora leptophloeos* (Mart.) J.B. Gillett (Burseraceae) and *Poincianella pyramidalis* (Tul.) L.P. Queiroz (Fabaceae) (Martins et al., 2004; Bruening, 2006). Those two plant species held more than 75 % of the nests so far encountered (Martins et al., 2004; Medeiros, 2011, Barbosa 2013).

In the current work we describe for the first time nests of *M. subnitida* found inside the arboreal termitaria of *Constrictotermes cyphergaster* Silvestri (Termitidae, Nasutitermitinae) and discuss the possibility that these bees use this type of substrate for nesting as a response to a local shortage of pre-existing cavities in trees.

Materials and methods

Bees and locality

Melipona subnitida is a middle sized *Melipona* described by Ducke based on bees collected in the Serra do Baturité, Maranguape and Miguel Calmom, state of Ceará, and Alcantara, state of Maranhão (Ducke, 1911; 1916; Rêgo & Albuquerque, 2006). The current geographic distribution is considered to be the dry northern portion of Caatinga in Brazil, predominantly interior low land areas, but also the coastal areas of Piauí and Maranhão. Although in the original species description the information about nesting habits is lacking, the nest and products of this species have been known by the local people for a long time (Galvão & Noronha, 1886 apud in An. Bibl. Nac 111:133-273, 1991 p. 249).

We visited the municipality of Mourelândia, Pernambuco, located on Chapada do Araripe plateau, from 31/01/2014 to 03/02/2014. Bees and termites samples were deposited in the "Coleção ASA – Abelhas Semiárido, da Universidade Federal Rural do Semi-árido", Mossoró, Rio Grande do Norte, Brazil.

Nest description

The description presented here is based on the transference of a single nest of *M. subnitidia* from an arboreal termite nest to a bee nest box, and on observations made at an untouched feral bee nest located in the same area. The terminology used follows Camargo (1970), and we describe the general nest appearance, entrance and gallery system, brood area (number and size of brood combs), and pot area with food stocks (number and estimated volume of honey pots). Dimensions were measured with a digital calliper and a measuring tape. Termite and bee nest volumes were estimated using the formula for a hemi-ellipsoid body: V = 2/3 S h.D .d, where h = nest height, D = ½ of the wider diameter and d = ½ of the narrower diameter in cubic centimetres, and transformed to litres. The volume of honey pots was determined with the help of a 10 ml syringe (precision of 0,1ml).

Nests of ***M. subnitida*** *in termitaria*

Four nests of *M. subnitida* in termitaria of *Constrictotermes cyphergaster* previously found by local beekeepers in the municipality of Mourelândia, in the Chapada do Araripe region, state of Pernambuco, Brazil were studied. Three of these termite nests had already been collected from their natural location and had been transported to a beekeeping stand (Paulo Nogueira Neto Bee Refuge). The bee nest in one of these formerly collected termite nests was transferred to a wooden nest box. The fourth, feral bee nest was studied at its site of origin, Mata Grande (7°26'41" S, 39°28'23" W; alt. 853 m). In this case, the active termite nest was located on a branch of *Plathymenia reticulata* (Fabaceae), at a height of about 50 cm (Fig 1).

Fig 1. Feral nest of *Melipona subnitida* in termite nest of *Constrictotermes cyphergaster* at Mata Grande, Mourelândia, Pernambuco, Brazil.

According to traditional knowledge of local beekeepers, *P. reticulata* is often host to *M. subnitida* nests, but termite nests are very common nesting substrates. Besides *M. subnitida*, a variety of other bees' nests are associated with this tree species, like *Scaptotrigona* sp., *Frieseomelitta varia* (Lepeletier), *Frieseomelitta doederleini* (Friese), *Melipona asilvai* Moure and *Partamona* cf. *seridoensis* Pedro & Camargo to termites (Carvalho AT et al. unpublished data).

Results and discussion

General structure of the nest

The bee nest was localized in a hemi-ellipsoid cavity of approximately 6,018 cm^3, in the interior part of a nest of the termite *C. cyphergaster*. The termite nest was approximately 24,178 cm^3 in volume. The bee nest was fully enclosed with a layer of batumen up 2 to 3 cm (Fig 2), isolating it from the termite nest. The batumen layer was solid, and pores, commonly seen in species of other *Melipona* nests, were absent (Nogueira-Neto, 1948; Roubik 2006).

Fig 2. The thick, irregular layer of batumen enveloping the bee nest. The darker, batumen layer is under the lighter termitarium formation.

The bee nest lumen, enveloped by batumen, lacked free spaces; the superior part was filled with the brood and beneath it were the food pots (Fig 3). The bee nest in the termite nest was located off center. At one side the termite nest space between the batumen layer and the external environment measured 16 centimetres. On the opposite side, the termite construction measured just six centimeters. At the apex of the bee nest only two centimeters of termite construction separated it from the outer environment. At some point in time after its collection from nature, termites had vanished.

Fig 3. Open termitarium of *Constrictotermes cyphergaster* revealing the location and general structure of a *Melipona subnitida* nest; several brood combs on top of a dense cluster of food pots, all surrounded by a solid layer of batumen.

Nest entrance and gallery

The bee nest entrance consists of a simple round hole (7.2 mm), located in the upper region of the termite nest, in its lower outward part having a structure of three lines constructed of geopropolis (Fig 4). The gallery was 2.3 cm in diameter, with a length of about 8 cm, running laterally upwards, in this way connecting the entrance with the brood section. Close to the brood area, the gallery widened somewhat before reaching near the last brood comb. At the end of this funnel, small deposits of reddish, sticky plant resin were visible (Fig 5), likely used to defend their nest. At breaking the termitarium open to reach the bee nest several bees were seen with the same sticky material on their corbiculae, while attacking the investigators and leaving the material on to their hair.

Brood and involucrum

The brood region was 13 cm height and 10 cm wide, protected by two to three sheets of a fine and delicate involucrum. There were six brood combs, one on top of the other supported by small waxen pillars. The two lower ones had old brood with emerging individuals, the three middle ones had young brood, whereas the most upper one also had young bees emerging. The total number of brood cells was estimated to be approximately 500.

Fig 4. Entrance of a feral nest of *Melipona subnitida* in an arboreal termitarium, Mourelândia, state of Pernambuco, Brazil.

Food pots

The food pot region was situated just below the brood section. Individual pots were built closely interconnected, forming a dense cluster. Although it was hard to distinguish individual pots, they were sphere-like and some of them had thick walls, even up to one centimeter. In the superior part of the food pot section, bordering the brood section, we found four pots with pollen. Nearby, eight pots with honey were found, and the volumes measured 6 to 15.5 ml (N=8, mean ± standard deviation =11.45 ± 3.20 ml). The pollen pots had their opening more vertically distended than the honey pots, but their overall volumes were quite similar. The protuberance of two pollen pots had tiny holes, probably in order to facilitate the process of pollen fermentation.

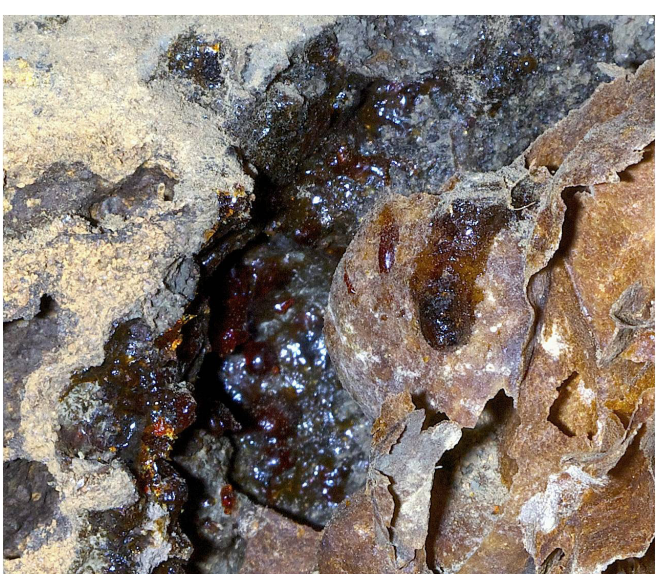

Fig 5. Bee deposits of reddish, sticky plant resin near the end of the gallery where it connects with the inner part of the bee nest.

Bee presence and external termite mud lane characteristics

Entrances of bee nests in termite nest are well camouflaged and hard to find by an untrained observer. However, one aspect of the termite nest, according to local bee keepers and hunters, seems to reveal the presence of bees in the termite nest; a typical castle-like protuberance present on the termite mud trail, near the ground (Fig 6). These protuberances are irregular expansions of the trail, built by the termites, and their occurrence is almost uniquely linked to termitaria that hold bee nests. Termite nests that lack bees, did not have these typical protuberances, but additional observations are necessary to confirm this anecdotal popular knowledge.

Fig 6. Small protuberances on the mud trail of *Constrictotermes cyphergaster*, near the ground. According to local bee keepers and hunters, these structures reveal the presence of a bee nest.

Habitat of termitaria with bee nests

The Chapada do Araripe area is an exceptional area of the Caatinga domain (Andrade-Lima, 1982; Tabarelli & Santos, 2004). It is a sedimentary plateau of Mesozoic origin of about 2,580 km^2, at an altitude varying between 640 a 900 meters, and stretches from the south of the state of Ceará to the eastern part of the state of Pernambuco. The larger, southern part is practically level, mainly covered by Cerrado vegetation (Neotropical savanna), with patches of Carrasco and evergreen and semi-deciduous humid forest (Fernandes, 1990; Campelo et al., 2000; Lima-Verde & Freitas, 2002).

Studies by Hubbell & Johnson (1977) in Costa Rica and Eltz et al. (2003) in Borneo strongly suggest that in undisturbed forests suitable cavities in trees are unlikely to be limited for stingless bee to make nests. Brazilian Carrasco is characterized by a dense, variable vegetation of predominantly shrubs with many lianas, little stratification, on sandy soils (Andrade-Lima, 1978; Araújo, 1998). The vegetation of the locality Mata Grande, where the host termite nests were found, is Carrasco with elements of Cerrado and Caatinga vegetation. Still, tree density is characteristically low (Araújo, 1998). In addition, human disturbance is apparent through the activity of firewood collection and the presence of cattle pasture. In all, this would explain an absence of suitable trees for bees to nest in which could signify that the occurrence of bee nests in termitaria in this locality represents an opportunistic means to survive. This view is supported by a study that shows that several stingless bee species readily occupy artificial nesting substrates like empty plastic bottles (Oliveira et al., 2012). On the other hand, population genetics has to show whether or not we are dealing with a subspecies of *M. subnitida* living in these high lands. In this respect, two lineages of *M. subnitida* have already been identified that split up about 390,000 years ago; one occurring in the coastal Maranhão region and another occurring in the Caatinga low land interior (Bonatti et al., 2013).

Reuse of birds' nest cavities in termitaria

Some indications that *M. subnitida* did not build the nest cavity were found. For instance food rests, probably from birds, were found stuck to the batumen at the lower part of the cavity. Local beekeepers state that *M. subnitida* bees reuse existing cavities resulting from former nesting activities of a small caatinga parrot *Eupsittula cactorum* (Kuhl). This corroborates several observations on *Partamona* species that build nests in termitaria (Camargo & Pedro 2003; Lorenzon et al., 1999; Barreto & Castro, 2007). For example, *P.* cf. *seridoensis*, a common species in the same studied area, is exclusively found in termite nests. At Milagres, in the state of Bahia, Barreto and Castro (2007) found a strong relationship between two *Partamona* species and the termite *C. cyphergaster*, using abandoned holes made by the same species of Psitacidae.

Termitaria of *C. cyphergaster*, one of the most abundant termite species of Caatinga and Cerrado areas in the northeast of Brazil (Moura et al., 2006), have many associations with several different species of birds, mammals and insects including social bee species (Carrijo et al., 2012). In general, the typical microclimatic conditions and the physical and biological protection the nests of various species of termites offer are seen as reasons why so many associations between termitaria and other animals have evolved (Grassé, 1986; Brightsmith, 2000; Carrijo et al., 2012). Some of these associations are mutualistic, while others can be facultative or opportunistic (Carrijo et al. 2012). Based on knowledge that tree cavities are its preferred nesting substrate, the association of *M. subnitida* with *C. cyphergaster* termitaria seems to be opportunistic, different of the supposed mutualistic relationship between the genus *Partamona* and termites (Carrijo et al., 2012).

The bee nest described here shows many similarities with nests in tree cavities of other species of the same genus (Schwarz, 1932; 1948; Camargo, 1970; Wille & Michener, 1983; Melo, 1996). However, the significant differences lie in the use of a living substrate, being arboreal nests of termites, and also in the complete and practically impermeable state of a thick layer of batumen isolating the bee nest completely from the external circumference of the internal termite nest cavity. Normally, nests of *M. subnitida* found in tree hollows have only their upper and lower ends separated from the rest of the cavity by batumen constructions (Bruennig, 2006; Nogueira-Neto, 1997) and these structures have pores (Nogueira-Neto, 1948). The use of a dense and solid batumen lining may be an adaptation to the regulation of inner nest climate, and protection against host nest invaders.

Acknowledgments

We thank Francisco das Chagas e Selma Carvalho for field support and productive discussions, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for funding ATC (Proc. 150335/2013-0) and VLIF and Fundação de Amparo a Pesquisa do Rio Grande do Norte for funding DK (DCR/ CNPq-FAPERN 350434/2012-3).

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