Ant fauna (Hymenoptera, Formicidae) associated to arboreal nests of *Nasutitermes* spp. (Isoptera, Termitidae) in a cacao plantation in southeastern Bahia, Brazil

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ABSTRACT. Ant fauna (Hymenoptera, Formicidae) associated to arboreal nests of *Nasutitermes* spp. (Isoptera, Termitidae) in a cacao plantation in southeastern Bahia, Brazil. Ants are among the most common arthropods that colonize termite nests. The aim of this study was to identify the ant fauna associated to termite nests found in a cacao plantation in the county of Ilhéus, Bahia, Brazil, with emphasis on the fauna that uses the nests as foraging and/or nesting environment. For this purpose, 34 active, decadent and abandoned nests of *Nasutitermes corniger*, *N. ephratae* and *Nasutitermes* sp., with different volumes and degrees of activity, were dissected. A total of 54 ant species, belonging to 23 genera and five subfamilies, was found in the constructions. The active, decadent and abandoned termite nests presented, respectively, six, eight and 48 ant species. *Crematogaster acuta* and *Ectatomma tuberculatum* were the most frequent species in the active and decadent nests, respectively, while the most frequent species in the abandoned nests were *Solenopsis pollux, Thaumatomyrmex contumax* and *Thaumatomyrmex* sp. Twenty-six ant species had true colonies within the termitaria. The Formicidae species richness in the nests was inversely related to the degree of termite activity in the nests. The occurrence of living, decadent or abandoned termitaria of *Nasutitermes* spp. in cacao plantations foments the heterogeneity of habitats available in the plantations and favors the maintenance of high diversity of organisms that use obligatory or opportunistically this substrate.

KEYWORDS. Agricultural forest system; diversity; nesting; *Theobroma cacao*.

RESUMO. Mirmecofauna (Hymenoptera, Formicidae) associada a ninhos arborícolas de *Nasutitermes* spp. (Isoptera, Termitidae) num cacaual do sudeste da Bahia, Brasil. As formigas estão entre os mais comuns artrópodes colonizadores de ninhos de térmitas. Este estudo teve como objetivo identificar a mirmecofauna associada a ninhos de térmitas encontrados em um cacaual no município de Ilhéus, Bahia, Brasil, com ênfase na fauna que utiliza os ninhos como ambiente de forrageio e/ou nidificação. Para tanto, 34 ninhos ativos, decadentes e abandonados de *Nasutitermes corniger*, *N. ephratae* e *Nasutitermes* sp., com diferentes volumes e graus de atividade, foram analisados. Um total de 54 espécies de formigas, pertencentes a 23 gêneros e cinco subfamílias, foi encontrado nas construções. Os ninhos de térmitas em atividade, decadência e abandonados apresentaram, respectivamente, seis, oito e 48 espécies de formigas. *Crematogaster acuta* e *Ectatomma tuberculatum* foram as espécies mais freqüentes nos ninhos em atividade e em decadência, respectivamente. Nos ninhos abandonados, as espécies mais freqüentes foram *Solenopsis pollux, Thaumatomyrmex contumax* e *Thaumatomyrmex* sp. Vinte e seis espécies de formigas possuíam colônias verdadeiras dentro dos termiteiros. A riqueza de espécies de Formicidae nos ninhos mostrou-se inversamente proporcional ao grau de atividade dos térmitas nos ninhos. A ocorrência de termiteiros ativos, em decadência ou abandonados de *Nasutitermes* spp. em cacauais amplia a heterogeneidade dos habitats disponíveis nas plantações e favorece a manutenção de uma elevada diversidade de organismos que utilizam obrigatoriamente ou oportunamente esse substrato.

PALAVRAS-CHAVE. Diversidade; nidificação; sistema agroflorestal; *Theobroma cacao.*

Ants and termites are among the most abundant invertebrates in the tropical regions of the planet (Wilson 1987). This high abundance, when combined to feeding, foraging, and nest construction habits, makes ants and termites important organisms for energy and matter flows in tropical and subtropical ecosystems, which strongly influence the chemical and physical composition of soils (Hölldobler & Wilson 1990; Martius *et al.* 1994). The intense activity of these insects in tropical ecosystems can greatly alter the availability of resources for other organisms, justifying the name of "ecosystem engineers" that is sometimes attributed to ants and termites, among other rare biological groups (Lavelle *et al.* 1997).

Nest construction to shelter the colony represents one of the striking characteristics of many termite and ant species. In particular, termite nests are structural elements characteristic of most of the ecosystems in the tropical region (Noirot 1970). In the forests of the Neotropical region, the Nasutitermitinae subfamily, especially species of the *Nasutitermes* genus, represents the taxon with the greatest number of species that construct conspicuous nests (Martius *et al.* 1994; Vasconcellos *et al.* 2008). In addition to the constructor termites, many

other organisms use the active and abandoned nests as sites for nesting, predation and temporary or permanent shelter (Wheeler 1936; Grassé 1986; Martius *et al.* 1994; Dejean & Bolton 1995; Dejean & Ruelle 1995).

The ants are among the main secondary occupying animals of termite nests (Wheeler 1936; Grassé 1986; Eggleton & Bignell 1997). Several studies have recently presented many data on the presence of these organisms inside the termitaria (Delabie 1995; Dejean *et al.* 1996; Cunha & Brandão 2000; Diehl *et al.* 2005). Ants have a natural tendency to install their colonies in termite nests, whether active or abandoned (Wheeler 1936), probably because of the numerous cavities available that offer the shelter of a semi-permanent structure. The aim of the present study was to identify the ant fauna associated to the arboreal termite nests of the *Nasutitermes* spp. found in a cacao plantation in the county of Ilhéus, Bahia, Brazil.

MATERIAL AND METHODS

The experiment was carried out from May 2006 to September 2007 in the experimental areas (Quadrant I, 14º45'16"S 39º13'50"W) of the Cacao Research Center (CEPEC/CEPLAC), Ilhéus county, State of Bahia, Brazil. The experimental station is formed by a planting system where the cacao trees are shaded by exotic legumes (*Erythrina fusca* and *Erythrina poeppigiana*, Fabaceae) and fruit plants (*Artocarpus heterophyllus*, Moraceae, and *Musa* spp., Musaceae). Every three months the area chosen goes through a system of hoeing and pruning. Procedures such as fertilization or insecticide or fungicide application are rarely practiced in this area and were not recorded during the year that anteceded our observations.

A total of 34 termite nests belonging to three species: *Nasutitermes corniger* (Motschulsky, 1855), *Nasutitermes ephratae* (Holmgren, 1910) and *Nasutitermes* sp., was sampled. These termitaria were different in size, shape, stage of maturity and degree of activity, and were found from ground level up to 3.5 m in height. The following measurements were taken in each one of the nests collected: length (cm), width (cm) and height (m) from the ground. The volume of each nest was estimated according to its shape, using the mathematical formulas of ellipse or hemi-ellipsoid. The nests were then carefully removed from the substrate, labeled, placed in plastic bags and transported to the Insectarium building at CEPEC.

In the laboratory, all the nests were sliced into 5 cm thick sections and each section was analyzed successively. All the sampled fauna (ants and eventual other organisms) was fixed in 80% alcohol in labeled flasks, with a reference number relative to the termite nest and the section in which it was present.

The ants were identified according to Bolton *et al.* (2007). Specimens were deposed in the collection at the Myrmecology Laboratory at CEPEC/CEPLAC (CPDC), under reference number #5509.

Each nest was categorized according to its degree of activity, as follows: (a) active nests: termite nests where the occurrence of the constructor species queen was verified, along with eggs, juveniles, soldiers and workers in large numbers; (b) abandoned nest: total absence of imagoes or immature termite individuals; (c) decadent nests: all those where there was a variable amount of termites, but eggs, immature individuals or the royal couple were absent, while workers occurred although in small number compared to the soldier caste.

Between the ants found in the termite nests, several species were represented only with a single or a few workers and were then considered foraging species, since they are supposed to frequent the nests in search of nutritional resources. The others were considered as forming true colonies in the termitaria, whether they consisted of an isolated founder queen or structured societies with eggs, larvae, workers and queens.

The Pearson correlation was used to compare the ant species richness per nest with nest volume and height from the soil. The Kruskal-Wallis ANOVA test, with Dunn test *a posteriori*, was performed to verify whether the ant species richness was affected by the nest activity degree (abandoned, decadent or active). The Mann-Whitney U test was used to verify whether species richness was affected by nest location (still in contact with its original substrate or fallen on the ground). In addition, the Kruskal-Wallis ANOVA test was used to verify whether the frequency of ant colonies varied among active, decadent and abandoned nests. Non-parametric tests were used because the data did not present normal distribution and homogeneity of variance. All tests were performed using the software *Statistica 6.0 for Windows*.

RESULTS AND DISCUSSION

Fifty-four ant species were collected from the 34 *Nasutitermes* nests analyzed, they belonged to 23 genera of the subfamilies Dolichoderinae, Formicinae, Myrmicinae, Ponerinae and Ectatomminae. Of these, the Myrmicinae subfamily was the best represented, with 29 species, followed by the Ponerinae subfamily with 12 species (Table I). These data follow the proportions observed by Dejean *et al.* (1996, 1997) when they analyzed the ant population that lived in *Cubitermes* spp. nests in African tropical forests. In addition, these authors sampled specimens from two other subfamilies, the Cerapachyinae and Dorylinae, that occur respectively rarely or not at all in the Neotropical region. The greater Myrmicinae richness in our samples may have been related to both the high number of species belonging to this subfamily and their very versatile habits (Fowler *et al.* 1991; Fernández 2003).

The ant species richness was negatively and significantly related to the termite nest height up to the ground ($r= -0.43$; $N= 30$; $P<0.05$), but there was no relation between the construction volume and the ant species richness ($r= -0.19$; $N= 30$; $P= 0.31$). This absence of correlation is possibly linked to the life story of these structures. Some factors such as the nest desertion time and sun exposition may influence the ant diversity living in. Abandoned nests and fallen on the floor for a long time, have more chance to have been colonized. When

Table I. Number of observations of Formicidae found in *Nasutitermes* spp. termitaria: active nests (AT) (n=14), decadent nests (DE) (n=3) and abandoned nests (AB) (n=17); *: nesting species.

Subfamily/ Species	Kind of activity in the termitaria AT	DE	AB
Subfamily Dolichoderinae Forel, 1878			
Azteca chartifex spiriti Forel, 1912		1*	4*
Azteca paraensis bondari Borgmeier, 1937	1	1	
Linepithema pulex Wild, 2007			1
Subfamily Formicinae Latreille, 1809			
Camponotus angulatus Mayr, 1870		1*	
Camponotus novogranadensis Mayr, 1870		1	
Camponotus trapezoideus Mayr, 1870	1		
Paratrechina sp. 1			1*
Paratrechina sp. 2			3*
Paratrechina sp. 3			1*
Paratrechina sp. 4			1*
Subfamily Myrmicinae			
Apterostigma sp.			1*
Crematogaster acuta (Fabricius, 1804)	5*		
Crematogaster brasiliensis Mayr, 1878			1
Crematogaster limata F. Smith, 1858	2		2*
Cyphomyrmex transversus Emery, 1894			4*
Lachnomyrmex victori Feitosa and Brandão,2008			1*
Mycocepurus smithii Forel, 1893			1
Octostruma iheringi Emery, 1887			1*
Octostruma rugifera Mayr, 1887			1
Pheidole gertrudae Forel, 1886			1*
Pheidole sp. 1	1		5*
Pheidole sp. 2			1
Pheidole sp. 3			1
Pheidole sp. 4			1
Rogeria foreli Emery, 1894			1*
Rogeria subarmata Kempf, 1961		1*	5*
Solenopsis pollux Forel, 1893			3*
Solenopsis geminata (Fabricius, 1804)			1
Solenopsis sp. 1			4
Solenopsis sp. 2		2*	2*
Solenopsis sp. 3			1
Solenopsis sp. 4			1
Strumigenys borgmeieri Brown, 1954			2
Strumigenys elongata Roger, 1863			2
Strumigenys saliens Mayr, 1887			1
Strumigenys spathula Lattke y Goitía, 1997			1
Strumigenys sublucida (Brown, 1953)			1*
Strumigenys (*Pyramica*) sp.			1
Wasmannia rochai Forel, 1912			2*
Subfamily Ectatomminae			
Ectatomma tuberculatum (Olivier, 1792)	1	2	
Gnamptogenys minuta (Emery, 1896)			1*
Gnamptogenys striatula Mayr, 1884			1
Subfamily Ponerinae			
Hypoponera opaciceps (Mayr, 1887)			1
Hypoponera sp. 1			1*
Hypoponera sp. 2			1*
Odontomachus haematodus (Linnaeus, 1758)			5*
Odontomachus sp.			1
Pachycondyla arhuaca (Forel, 1901)			1
Pachycondyla constricta (Mayr, 1883)			1
Pachycondyla stigma (Fabricius, 1804)			1
Pachycondyla villosa (Fabricius, 1804)		1*	1*
Prionopelta antillana Forel, 1909			1
Thaumatomyrmex contumax Kempf, 1975			3*
Thaumatomyrmex sp.			3
Number of species	06	08	48

the ant assemblage was analyzed in function of the degree of nest activity, it was observed that 48 ant species were collected from the 17 abandoned nests, while the three decadent nests and the 14 active nests sheltered, respectively, only eight and six ant species. The ant richness was significantly different in according with the degree of nest activity (Kruskal-Wallis test: H= 18.1; df=2; N=34; P<0.01). Abandoned nests had significantly higher species richness than the active and decadent nests, corroborating the results reported by Holt & Greenslade (1979) in Australia where a greater frequency was observed of ants in abandoned *Amitermes laurensis* (Mjoberg, 1920) mounds (87%) compared with active mounds (37%). Similarly, Holt (1990) studied the ant fauna associated to *Nasutitermes longipennis* (Hill, 1915) nests and attributed the lower ant incidence to defensive termite behavior.

Seven of the abandoned nests were located on soil and sheltered 28 ant species (Table I), found exclusively in this habitat within the context of this experiment. The most frequent among the species were *Solenopsis pollux*, *Thaumatomyrmex contumax* and *Thaumatomyrmex* sp., occurring in three nests.

Ants of the genera *Gnamptogenys*, *Hypoponera*, *Apterostigma*, *Prionopelta,* and *Thaumatomyrmex* were found exclusively in the abandoned nests that had fallen on the soil surface. This characteristic may be a reflection of the biology of these groups that include species nesting in the leaf litter, some of which use available cavities or rotting wood (Lattke 2003; Jahyny *et al*. 2007).

Eleven ant species were sampled exclusively in abandoned nests, but still aggregated to the original substrate, and *Crematogaster limata* and *Wasmannia rochai* were the most frequent. Some species were present both in nests abandoned at soil level and some still adhering to the substrate, of which *Azteca chartifex spiriti*, *Cyphomyrmex transversus*; *Odontomachus haematodus*, *Rogeria subarmata*, *Strumigenys borgmeieri*, and *Pheidole* sp.1, were the most frequent. The ant richness in abandoned nests that were still attached to the substrate was much lower than that of abandoned nests in contact with the soil (U=1.5; Z= 2.87; P< 0.01). Only one species of these ants, *Pachycondyla constricta* (Mayr), was also found during an ant survey in termite-abandoned nests studied during a flood period in the Amazon region (Martius *et al.* 1994).

In the active nests, *Crematogaster acuta* was the most frequent ant, occurring in five of them, while in decadent nests, the most frequent ants were *Ectatomma tuberculatum*

and *Solenopsis* sp.2 (n=2). In termite nests hanged on coconut trees in New Guinea, *Camponotus* sp. was the most frequent ant species (Leponce *et al.* 1999).

In a study on the ant fauna associated to *Nasutitermes longipennis* nests, the defensive behavior of the nasute was taken as responsible for the ant low incidence (Holt 1990), since in this genus, the soldiers excrete via *nasus* a substance well known as an effective ant repellent.

Of the 54 ant species found in the termitaria, 28 (52%) were considered foraging species, while the other 26 species (48%) formed true colonies (Table I), consisting of isolated founder queens or structured societies. Forty-eight ant colonies were found in the termite nests examined. The active nests sheltered five of these colonies, the decadent nests six, while the abandoned nests sheltered 37 colonies. There was a significant difference among active, decadent and abandoned nests regarding the number of true ant colonies (Kruskal-Wallis test: H= 15.6; df=2; N=34; P<0.01), with the number de colonies significantly higher in abandoned nests than in active nests.

The species that most frequently installed itself in the termite nests was *Rogeria subarmata*, that accounted for 12.5% (n=6) of the colonies formed. It is emphasized that only isolated females of this species were found and it is probable that this ant uses termite nests exclusively for foundation, migrating after the emergence of the first adult workers to install itself in a new substrate where a greater quantity of resources would be available, such as, for example, leaf litter. The ants belonging to this genus, for which there is practically no natural history data, are usually collected from leaf litter samples, rotting wood or very occasionally from soil samples associates to epiphytes (Kugler 1994; Delabie 2003).

The number of nesting ant species was smaller in active termite nests, where only *C. acuta* appeared forming true colonies and seems to be the single ant that usually nests in *Nasutitermes* constructions in the region. In all of these nests, the *C. acuta* societies were established in external galleries of the construction, isolated from *N. corniger* and *Nasutitermes* sp. that occupied the internal galleries. Howse (1984) suggested that this kind of division inside the nests may characterize a mutual relationship based on the common defense of the nests. The costs and benefits to each one of these groups in this type of association, however, are not very clear.

The permanence of *Nasutitermes* nests in cacao plantations is determinant for the maintenance of the biodiversity in these areas, because these structures result in an increase in the heterogeneity of the area and positively affect the occurrence of obligatory or facultative termitariophile organisms or those that simply depend on the nest structure for shelter, food or reproduction, or opportunistically use it.

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