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Short Communication

Sharing of termites (Blattodea: Isoptera) between sugarcane matrices and Atlantic Forest fragments in Northeast Brazil

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ABSTRACT

The Atlantic Forest of South America is one of the most degraded tropical forests and the cultivation of sugarcane is considered one of the main causes. In humid forests termites stand out with regard to their abundance and functional importance. The present study aimed to compare termite assemblages of fragments of the Atlantic Forest with that of the sugarcane matrices that surround them. Collections were performed in two sugarcane plantations in Northeast Brazil. In each plantation a fragment of Atlantic Forest and an adjacent sugarcane field were sampled using a standardized termite sampling protocol. A total of 39 species and 302 encounters were recorded. Species richness, relative abundance and composition differed significantly between forests and the matrices, with the presence of exclusive species in each environment—25 in the forests and seven in the matrices. Soil feeding species of the subfamily Apicotermitinae and species of open areas were found in the matrices. There was a marked difference between the assemblages of the matrices, possibly due to soil characteristics. The majority of the species found in the matrices do not cause damage to the crop, but instead act in the processes of soil decomposition and formation, thereby contributing to increased productivity.

The Atlantic Forest of South America is considered one of the largest biodiversity repositories on the planet and one of the most degraded tropical forests (Galindo-Leal and Câmara, 2005; Marchese, 2015). It is estimated that the current area of the Atlantic Forest represents just over 11% of its original coverage (Ribeiro et al., 2009) and sugarcane is one of the crops whose expansion has been identified as a main cause of the current scenario of degradation. In the Northeast Brazil, sugarcane matrices surrounding remnants of Atlantic Forest comprise a common feature of the landscape (Ranta et al., 1998). A total of 866.5 thousand hectares of sugarcane was harvested in this region in 2016/2017 (CONAB, 2017).

In humid forests, such as the Atlantic Forest, termites stand out with regard to their abundance and functional importance. They are important eusocial organisms in the dynamics of the ecological processes related to energy flow and the nutrient cycling of vegetable necromass (Vasconcellos, 2010; Vasconcellos and Moura, 2010). The conversion of natural areas to monocultures and the selective cutting of trees are recognized as being responsible for reduced species richness and abundance of termites, as well as changes in the proportion of feeding groups, with soil feeding species (feeding groups III and IV according to the classification of Donovan et al., 2001) being the most sensitive to environmental changes (Bandeira and Vasconcellos, 2002; Eggleton et al., 1996).

In this context, the objective of this study was to compare termite assemblages of Atlantic Forest fragments with that of the sugarcane matrices that surround them, seeking to evaluate (i) species richness, relative abundance and the composition and distribution of feeding groups in matrices and forest fragments; and (ii) the habits and pest-status, based on literature records, of the termite species living in the sugarcane matrices.

The research was carried out in two sugarcane plantations in Northeast Brazil. The first, Usina São João, is located in the municipality of Santa Rita, Litoral Centro of the Paraíba state (07°09′45.8″S, 35°03′51.5″W), where collections were carried out between October 2014 and April 2015. The mean annual temperature is 25.2 °C, the mean relative humidity of the air is 83% and annual rainfall is 2193.6 mm. During the field work the rainfall varied between 13.3 and 40.7 mm (INMET, 2019). The soil originates from clay-sandy sediments and is classified as Red-yellow Argisol with sandy to

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loamy sandy texture, and is deep and with low fertility (Santana, 1987). The vegetation of the forest fragments is classified as semideciduous seasonal forest characterized by a mixture of secondary Atlantic Forest with isolated areas of open Cerrado called 'tabuleiros' (Rodrigues et al., 2013). The second plantation, Usina São José, is located in the municipality of Igarassu, Mata Norte of the Pernambuco state (7°49′7″S, 35°00′45″W), where collections were carried out between September 2015 and January 2016. The mean annual temperature is 26.3 °C, the mean relative humidity of the air is 83.9% and annual rainfall is 1455.6 mm. During the field work the rainfall varied between 16.6 and 91.8 mm (INMET, 2019). The soil originates from sediments of the Barreira Group and is classified as Red-yellow Latosol with texture varying from sandy clay to clayey, and is deep and with low to medium fertility (Koffler et al., 1986). The vegetation of the studied fragment is classified as Semidecidual Seasonal Lowland Forest (Thomas and Barbosa, 2008). The sugarcane variety cultivated in the study areas of the two plantations was RB92579. The areas had not been receiving pesticides for at least 18 months and had not experience fires for at least six months.

The collection protocol proposed by Cancello et al. (2014) was applied in each area, which consists of the demarcation of six 65 m × 2 m transects containing five 5 m × 2 m plots spaced at 10 m. The transects were established at least 30 m from the plantation/forest borders. The collection time at each plot corresponds to a sampling effort of 1 hour by person. During this time, termites were searched for in all possible microhabitats and then specimens were collected for species identification and classification by feeding group according to the proposal of Donovan et al. (2001). This protocol was originally developed for the collection of termites in tropical forests, but has since been applied in open ecosystems such as Caatinga (Vasconcellos et al., 2010; Viana et al., 2014). Voucher material was deposited in the Coleção de Isoptera of Universidade Federal da Paraíba. The observed species richness and number of encounters were obtained for each forest fragment and sugarcane area, the latter of which was used as an indicator of relative abundance (Cancello et al., 2014).

Assemblages were ordered using non-metric multidimensional scaling (nMDS) with Jaccard similarity. Differences in the composition of species and feeding groups between forest and adjacent

Table 1
Observed species richness, number of encounters and feeding group in Atlantic forest fragments and sugarcane fields in Northeast Brazil. *N*, number of plots in which a species was encountered; S_{obs}, observed richness; Us., Usina. AF, Atlantic Forest; S, sugarcane field; FG, feeding group.

Family/subfamily/species	Us. São João		Us. São José		
	*N*AF	*N*S	*N*AF	*N*S	FG
Rhinotermitidae					
Heterotermes longiceps (Snyder, 1924)	4	–	3	–	I
Termitidae					
Apicotermitinae					
Apicotermitinae sp. 1	–	–	1	–	III
Apicotermitinae sp. 2	–	–	2	–	III
Apicotermitinae sp. 3	–	–	–	1	III
Apicotermitinae sp. 4	–	–	–	1	III
Anoplotermes sp. 1	–	–	16	–	III
Anoplotermes sp. 2	10	–	5	9	III
Anoplotermes sp. 3	1	–	8	2	III
Aparatermes sp. 1	–	–	–	4	III
Aparatermes sp. 2	1	–	–	–	III
Aparatermes sp. 3	–	–	–	4	III
Grigiotermes sp.	1	–	1	–	IV
Tetimatermes sp.	–	–	1	–	IV
Nasutitermitinae					
Atlantitermes sp.	1	–	–	–	IV
Diversitermes diversimiles (Silvestri, 1901)	6	–	3	–	II
Nasutitermes callimorphus (Mathews, 1977)	10	–	10	–	II
Nasutitermes corniger (Motschulsky, 1855)	7	–	8	–	II
Nasutitermes coxipoensis (Holmgren, 1910)	–	–	–	10	II
Nasutitermes ephratae (Holmgren, 1910)	–	–	10	–	II
Nasutitermes gaigei Emerson, 1925	–	–	2	–	II
Nasutitermes jaraguae (Holmgren, 1910)	1	–	–	–	II
Nasutitermes macrocephalus (Silvestri, 1903)	2	–	–	–	II
Nasutitermes obscurus (Holmgren, 1906)	3	–	–	–	II
Nasutitermes sp.	–	–	1	–	II
Velocitermes velox (Holmgren, 1906)	1	–	4	–	II
Syntermitinae					
Embiratermes neotenicus (Holmgren, 1906)	6	–	–	–	II
Embiratermes parvirostris Constantino, 1993	7	–	–	–	III
Labiotermes labralis (Holmgren 1906)	7	–	4	–	IV
Silvestritermes holmgreni (Snyder, 1926)	3	–	3	–	II
Syntermes grandis (Rambur, 1842)	–	–	–	4	II
Syntermes nanus Constantino, 1995	–	–	–	2	II
Termitinae					
Amitermes amifer Silvestri, 1901	7	2	1	–	II
Amitermes nordestinus Mélo & Fontes 2003	–	16	–	–	II
Cavitermes tuberosus (Emerson, 1925)	1	–	1	–	III
Cylindrotermes sapiranga Rocha & Cancello, 2007	1	18	–	4	II
Microcerotermes indistinctus Mathews, 1977	23	–	15	1	II
Neocapritermes opacus Hagen, 1858	2	–	2	14	III
Orthognathotermes sp.	1	–	–	–	IV
Termes medioculatus Emerson, 1949	3	–	–	–	III
S_{obs}	24	3	21	12	
Number of encounters	109	36	101	56	

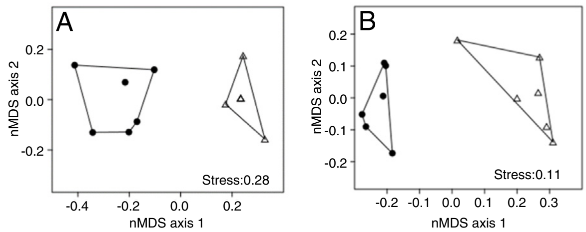

Fig. 1. Non-metric multidimensional scaling for termite assemblages of two Atlantic Forest fragments and adjacent sugarcane plantations. Usina são João (A) and Usina São José (B). ●, Atlantic Forest. **Δ**, sugarcane field.

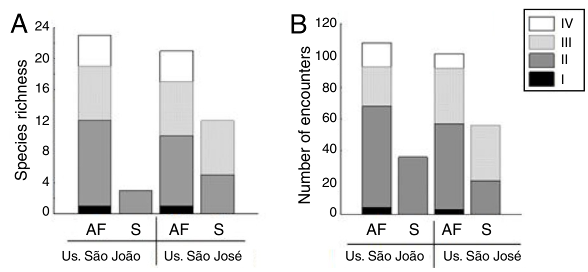

Fig. 2. Species richness (A) and number of termite encounters (B) per food group of two Atlantic Forest fragments and adjacent sugarcane fields of two plantations in Northeast Brazil. Us., Usina; AF, Atlantic Forest; S, sugarcane field; I, feeding group I; II, feeding group II; III, feeding group III; IV, feeding group IV (Donovan et al., 2001).

matrix were tested through non-parametric permutation analysis of variance (PERMANOVA) with 9999 permutations. All of these analyses were performed using PAST v. 3.20 software (Hammer and Harper, 2006).

A total of 39 species and 302 encounters were recorded, with 31 species and 210 encounters recorded for the Atlantic Forest fragments, 14 species and 92 encounters in the sugarcane areas. In Usina São João (fragment + matrix) were recorded 25 species and 145 encounters (Table 1). A total of 109 encounters and 24 species were recorded in the Atlantic Forest fragment, 22 of which were exclusive to this environment, while 36 encounters and only three species were recorded in the sugarcane matrix, with *Amitermes nordestinus* Silvestri, 1901, being exclusive to this environment. In Usina São José (fragment + matrix), 29 species and 157 encounters were recorded (Table 1). A total of 101 encounters and 21 species were recorded in the Atlantic Forest fragment, of which 17 were exclusive to this environment, while 56 encounters and 12 species were recorded in the sugarcane matrix, eight of which were exclusive to this environment.

The nMDS indicated that the structure of the assemblages of the forest fragment and the matrix differed in the both plantations (Fig. 1). The PERMANOVA showed that the species composition differed significantly in the two plant formations, both for Usina São João ($F = 20.2$, $p < 0.05$), and for Usina São José ($F = 9.93$, $p < 0.05$).

The Atlantic Forest fragments had similar results regarding the structure of the feeding groups, with a greater number of species and encounters recorded for feeding group II, followed by feeding groups III, IV and I. However, in the matrix of Usina São João only feeding group II was recorded, while in the matrix of Usina São José feeding groups II and III were recorded (Fig. 2).

This is the first record of species belonging to the subfamily Apicotermitinae in sugarcane fields in Northeast Brazil. There is a record of this subfamily in the Southeast Brazil, but the species was only identified to the subfamily level (Junqueira et al., 2015). All of the species found in sugarcane fields of Usina São João belong to genera that were previously associated with sugarcane in the Northeast Brazil (Guagliumi, 1972/73; Novaretti and Fontes, 1998; Miranda et al., 2004).

In Usina São João, the species richness of the Atlantic Forest fragment was eight times greater than that recorded in the sugarcane field, while in Usina São José the species richness in the forest fragment was approximately 1.7 times greater. It is important to note that the assemblages found in the matrices do not correspond exactly to a subgroup of the assemblages found in the adjacent forest fragments, and possess a considerable number of exclusive species, which, on a landscape scale, represents an increase in total species richness. Other studies comparing assemblages of termites between forest fragments and nearby plantations also recorded a decrease in species richness and abundance, as well as differences in taxonomic and feeding group composition (Attignon et al., 2005; Basset et al., 2016; Eggleton et al., 1996). Another factor that may have contributed to the decrease in termite species richness in the sugarcane matrix is the type of management performed. The practice of preharvest burning is still common in sugarcane cultivation and reduces the amount of organic matter in the soil compared to green or mechanized harvest, as well as significantly reducing the abundance of arthropods (Sajjad et al., 2012; Wiedenfeld, 2009).

The lower species richness and abundance, coupled with the simplification of the structure of the feeding groups, in the matrices in relation to those recorded in the Atlantic Forest fragments indicates that the matrix functions as a filter for the great majority of species but favors the permanence of other populations, especially species of open areas such as *Amitermes nordestinus*, *Nasutitermes coxipoensis* (Holmgren, 1910), *Syntermes grandis* (Rambur, 1842) and *Syntermes nanus* Constantino, 1995 (Alves et al., 2011; Constantino, 1995; Cunha and Morais, 2010; Garcia et al., 2006; Mathews, 1977).

In the sugarcane field of Usina São João, all of the species were included in feeding group II, while in the sugarcane field of Usina São José, of the 12 species recorded, six of the subfamily Apicotermitinae and the species *Neocapritermes opacus* (Termitinae) are included in feeding group III. The species *S. grandis* and *S. nanus*, despite being in feeding group II, have a strong connection with the soil since their nests are subterranean (Constantino, 1995).

The species compositions of the two sugarcane fields were quite different. This difference may be related to a greater amount of clay in the soil of Usina São José (see the description of the areas). Clay is a key component for ensuring structural stability of termite nests (Jouquet et al., 2004). Therefore, sandy soils make nest building difficult and decrease gallery stability (Lee and Wood, 1971). The termite assemblages of two restinga areas in the Paraíba state, whose soil texture resembles that of the soil of the Usina São João sugarcane field, had a low occurrence of species of the subfamily Apicotermitinae, which was associated with soil properties (Vasconcellos et al., 2005). Thus, the differences found indicate that even matrices formed by the same monoculture, including the same variety of sugarcane and management practices, can support very different assemblages.

Although termites are considered important pests of the sugarcane crop in Northeast Brazil (Novaretti and Fontes, 1998), publications that study termite assemblages in sugarcane fields in this region are generally scarce and relatively old (Guagliumi, 1972/73; Miranda et al., 2004; Novaretti and Fontes, 1998). In the present research, the species *S. grandis* and *S. nanus* were observed damaging the leaves of plants still in development, while the other species were not observed causing injuries to the plants and were feeding on straw or organic matter in the superficial layers of the soil, thus contributing to the process of nutrient cycling.

There is a drastic simplification of the taxonomic and functional structures of termites with the conversion of Atlantic Forest into sugarcane field. On the other hand, the matrix is not a completely inhospitable environment for the presence of termites and is able to maintain species that are not found in the adjacent Atlantic Forest fragments, especially species typical of open areas. Apparently, most of the species found in the matrix do not damage the crop, and instead feed on straw and organic matter contained in the superficial layers of the soil, thus contributing to nutrient cycling. Variation in soil type, especially the amount of clay, of the same monoculture apparently can influence the composition of termite assemblages, and alter the permeability of the matrix.

Conflicts of interest

The authors declare no conflicts of interest.

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