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Termite communities in lemon tree plantations (*Citrus limon*, Rutaceae) in the Tiassalé region (South of Côte d'Ivoire)

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ABSTRACT: Conservation biologists are now studying how cultivated areas could be used to maintain good biological diversity. The aim of this study was to assess the assemblage of termites in lemon plantations in the Tiassalé region in southern Côte d'Ivoire. According to the standardized rapid estimation method (RAP) of biodiversity, termites were harvested from a 10-year-old lemon plantation in comparison with the primary forest. Three transects (100 m long and 2 m wide) were carried out in each environment. The results obtained showed that in total, 20 species of termites divided into 13 genera and 6 subfamilies were collected on the two plots. The specific richness was relatively low in the lemon plantation (12) compared to the primary forest (18 species). The Simpson index was higher in the forest (SI = 0.97) than in the plantation (SI = 0.77). The total abundance of termites was higher in the forest (71.33 ind./transect) than in the plantation (38 ind./transect). Fungus-growers were more abundant in the lemon plantation (24.33 ± 2.7 ind./transect) than in the forest which recorded an average abundance of 18.66 ± 2.87 ind./transect. Soil-feeders with 27.33 ± 1.36 ind./transect were more abundant in the forest than in the plantation. Grass-feeders, totally absent from the forest, were observed in the lemon plantation with a relative abundance of 2.66 ± 1.36 ind./transect. The lemon plantation would help restore termite communities in this area heavily disturbed by pineapple cultivation.

KEYWORDS: Lemon tree, termites, community, diversity, abundance, Côte d'Ivoire.

1 INTRODUCTION

In Côte d'Ivoire, the agricultural export diversification policy gives pride of place to fruit production [1]. Today, after the coffee-cocoa pairing, the "fruit" sector occupies an important place (8 to 10% of agricultural GDP) in the country's economy with an annual production of around 60,000 tonnes [2]. Côte d'Ivoire is the second largest producer of bergamot, the best valued citrus essence [3]. This citrus fruit production has really developed in the south of the Ivory Coast where it constitutes one of the main activities of the populations. Agricultural practices are considered today as the main cause of biodiversity degradation in many tropical countries [4], resulting in the elimination of sensitive species [5], [6]. However, given the vast tracts of land that are used for agriculture around the world, conservation biologists are investigating how cultivated areas might be used to maintain biological diversity [7], [8], [9]. In Côte d'Ivoire, [10] showed that cocoa plantations sheltered a diversity of ants close to that of primary forest. Termites are one of the major biotic components of tropical ecosystems where they represent, with earthworms and ants, true ecosystem engineers [11]. The ecological importance of termites is observed in particular through their role (1) in the food webs where they act as main decomposers and are the prey of many other organisms, (2) in the soil structure as well as storage and decomposition of organic matter of plant origin [12], [13] and finally (3) as the main bioturbator in some soils. Recently, the work of [14] showed that mango orchards in the north of Côte d'Ivoire contribute to the restoration of the hypogeal fauna of termite. However, to our knowledge, no study to date has been carried out to assess the contribution of citrus plantations, in particular, lemon orchards in the assembly of these termites. This study examined the diversity of termites in lemon plantations compared to natural forest. The objective was to answer the question regarding the role of lemon tree agrosystems in the conservation of soil fauna, in particular termites.

2 MATERIAL AND METHODS

2.1 STUDY AREA

This study was carried out in the south of the Ivory Coast, at the Bandama Agricultural Society (SAB) in the Tiassalé region (5 ° 50 'N and 4 ° 50'W) during the month of November 2018. The climate is of hot and rainy equatorial type with 4 seasons: a great rainy season from April to July; a short dry season from August to September; a small rainy season from October to November and a large dry season from December to March. The annual average temperature is 28 ° C and the minimum hygrometry is around 60%. The M'brimbo SAB is an estate with a total area of 1012 hectares. This site was used in the past, for several years for the cultivation of pineapples. Today the site is intended for Hevea cultivation, cocoa farming, fruit crops and beekeeping. Two plots were sampled:

The lemon orchard is a 10 years old plantation. A plot of 1 ha was delimited for this study. The plantation has about 400 feet of lemon trees at a rate of 4.5 m between the feet and 5 m between the rows. Weeding was done once a year with little use of pesticides.

The primary forest chosen as a control was adjacent to that of the lemon trees. It is a primary forest that has never been exploited for agricultural purposes. The canopy was dense and the undergrowth was rich in litter.

2.2 BIOLOGICAL MATERIAL

Plant material is all the lemon trees present on the site (Fig. 1A). Animal material consists of termites collected from different habitats (Fig. 1B).

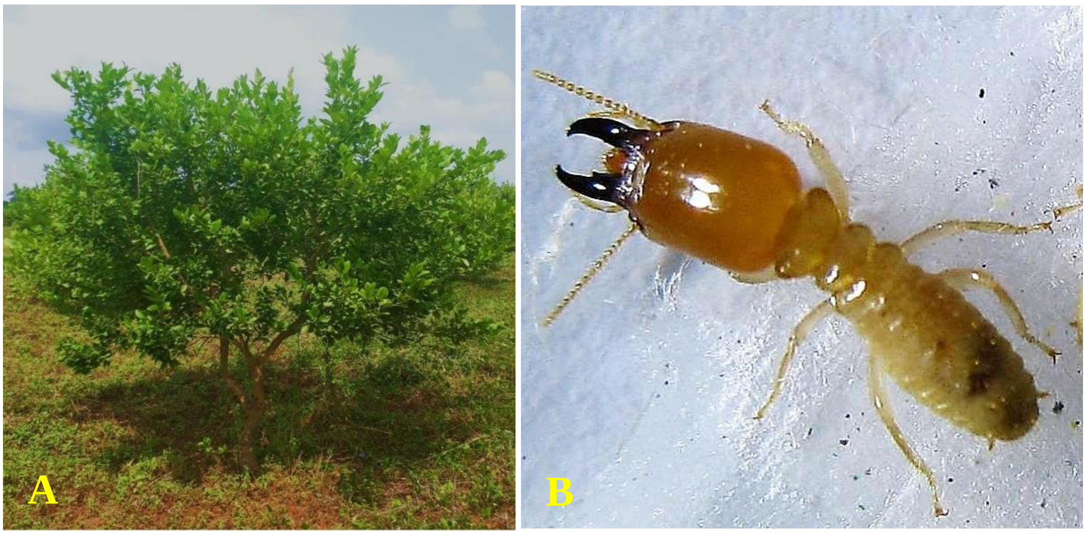

Fig. 1. Biological Material. A: Lemon tree (Citrus limon) B: Termite soldier Odontotermes sp

2.3 TERMITE SAMPLING

Termite sampling was performed using the standardized method for termite collecting [15]. It consists in delimiting, in each parcel, 20 sections of 10 m2 (5 m × 2 m) of surface along a transect 100 m long and 2 m wide (Fig. 2). The search is done in two stages by two people for 30 minutes. The first is to search litter, epigeic nests and the aerial part of plants up to 1.5 m tall (if possible) in search of termites. The second, after careful excavation of each section, all termites harvested were stored in 70% alcohol-labeled. Three (3) transects were conducted for termite sampling in each medium. In total, three transects of 100 m length were made in each area.

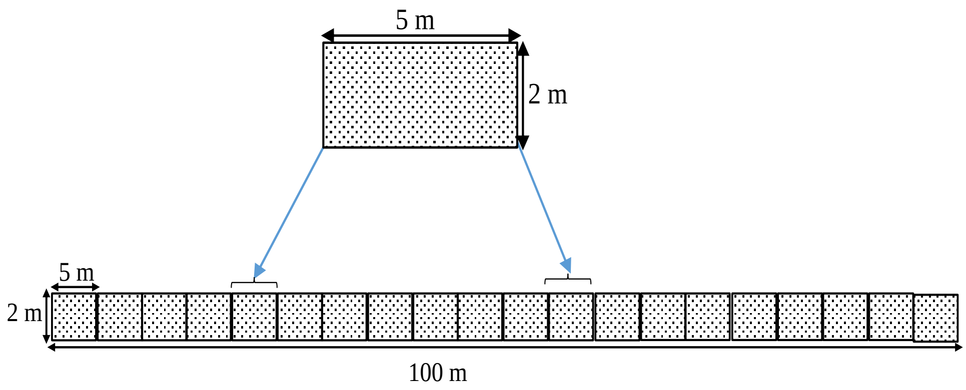

Fig. 2. Termite sampling device (transect, [15])

2.4 IDENTIFICATION OF COLLECTED TERMITES

The individuals were first determined to the level of the genus, then of the species under a binocular microscope, using the identification keys [16], [17], [18], [19], [20], [21]. In order to increase the chances of being able to correctly determine the problematic species, they were compared to the correctly identified specimens in laboratory of University Félix Houphouët Boigny in Côte d'Ivoire. After identification, each species was classified into one of the trophic groups (Fungus-growers, Soil-feeders, Wood-feeders and Grass-feeders).

2.5 DATA ANALYSIS

Sampling completeness was tested by constructing sample-based species accumulation curves. Using the program EstimateS (version 7.0) [22], rarefaction curves were constructed after randomizing 500 times the sample order to ensure the statistical representation of the target assemblage [23]. Following the description of [24] for incidence data, we chose the first order and non-parametric estimator Jackknife 1 as estimator of the species richness. The total species richness of termites was obtained by enumerating all species observed over transects. The Simpson index and the Equitability (E') were calculated for each habitat using the program PAST [25]. As we used presence/absence data, the relative abundance was defined as the number of encounters per transect, where the presence of one species in a section represented one encounter [26]. The similarity between the prospected habitats was calculated according to the following formula: S = c / (a + b + c); c = species common to both plots, a = number of species observed only on plot A; b = number of species observed only on plot B; this index varies from 0 (no similarity) to 1 (identical habitats) according to [27]. The frequency of termite species collected in the sections of the transects was calculated for each habitat. This frequency was calculated according to the formula:

$$F = \frac{Ex * 100}{Es}$$

With: F = Frequency of species x; Ex = Number of samples containing species x; Et = Total number of samples.

The coding of the frequency indices is given in Table I.

Table 1. Codification of frequency indices

Frequency classes (%)	Characteristics
F < 10	Very rare species
10 < F < 20	Accidental species
20 < F < 40	Accessory species
40 < F < 60	Fairly common species
60 < F < 80	Common species
F > 80	Very common species

3 RESULTS

3.1 SAMPLING EFFICIENCY

The efficiency of the method used for the sampling of litter termites was 85.91% in the forest and 92% in the orchard, ie an average coverage rate of 91.15%. Accumulation curves, the observed (Sobs) and expected (Jack 1) specific richness all approached the asymptote. These results indicated a high efficiency of the sampling method used for all habitats (Fig. 3).

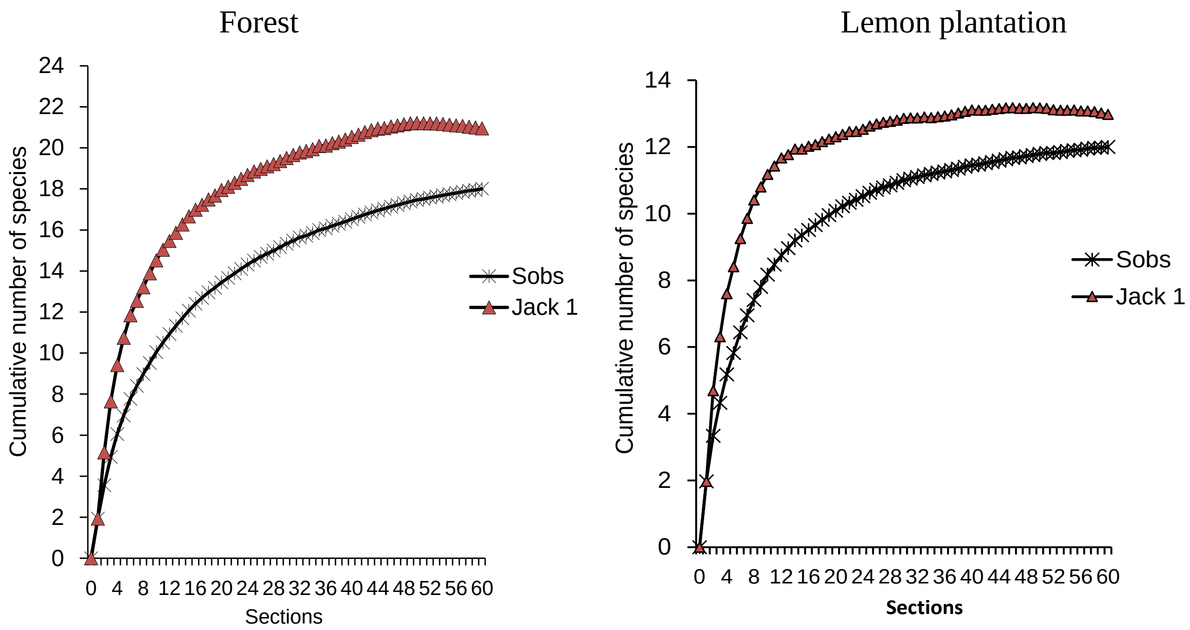

Fig. 3. Sample-based accumulation curves of observed (Sobs) and estimated (Jack 1) species richness of termites in each habitat type

3.2 SPECIES RICHNESS OF TERMITES IN BOTH HABITAT TYPES

A total of 20 species of termites belonging to 13 genera, 6 sub-families, 2 families (Rhinotermitidae and Termitidae) were collected from the two plots (Table II). Macrotermitinae and Termitinae with respectively 10 and 4 species were the most diverse subfamily. The subfamilies of Nasutitermitinae and Coptotermitinae each recorded 2 species.

The number of species varied from habitat to habitat. The primary forest with 18 species is the most diverse environment. Nine (9) species are common to the two environments surveyed. Two species were sampled only in the orchard: These species are *Odontotermes pauperans* and *Trinervitermes* sp.

Table 2. List of termite species collected in each habitat type

Familly	Sous-familly/ Species	Trophic group	Lemon plantation	Forest
	Termitinae			
	Amitermes evuncifer	w	*	*
Termitidae	*Microcerotermes fuscotibialis*	w	*	*
	Microcerotermes parvulus	w	*	*
	Promirotermes holmgreni	s	*	*
	Macrotermitinae			
	Macrotermes subhyalinus	f		*
	Macrotermes bellicosus	f	*	*
	Pseudacanthotermes militaris	f	*	*
	Ancistrotermes cavithorax	f	*	*
	Ancistrotermes guineensis	f		*
	Ancistrotermes crucifer	f	*	*
	Odontotermes pauperans	f	*	
	Microtermes toumodiensis	f	*	*
	Nasutitermitinae			
	Nasutitermes arborum	w		*
	Trinervitermes sp	g	*	
	Apicotermitinae			
	Hoplognathotermes sp	s		*
	Cubitermitinae			
	Cubitermes sp	s	*	*
	Basidentitermes potens	s		*
Rhinotermitidae	**Rhinotermitinae**			
	Schedorhinotermes lamanianus	w		*
	Coptotermitinae			
	Coptotermes intermedius	w		*
	Coptotermes sjöstedti	w		*
Total	**20**		**12**	**18**

f=Fungus-growers, s=Soil feeders, w=Wood-feeders and g=Grass-feeders

3.3 CHANGE IN FREQUENCY OF TERMITE SPECIES

The species frequencies had grouped the species into 4 classes in the forest plot and 3 classes in the lemon plantation (Table III). However, the specific composition of the frequency classes differ from one plot to another. The number of rare species harvested was higher in the forest (6 rare species) unlike the plantation where 2 rare species were harvested. The lemon plantation recorded more accidental species (8) compared to the forest plot which recorded 5 accidental species. Accessory species are strongly present in the forest (4 species) while the lemon plantation records only the species *Odontotermes pauperans* (33%). The species Promirotermes sp and *Microcerotermes parvulus* with respectively 53% and 42% of frequency were the two rather frequent species in the forest plot while in the plantation *Ancistrotermes cavithorax* (42%) was the only rather frequent species collected. The *Cubitermes sp* species with 75% frequency represented the class of frequent species collected in the forest.

Table 3. Frequencies of species collected in the prospected areas

Frequency characteristic	Lemon plantation	Forest
Very rare species F < 10	*Microcerotermes fuscotibialis* (8%) *Microtermes toumodiensis* (5%)	*Schedorhinotermes lamanianus* (8%) *Odontotermes pauperans* (5%) *Amitermes evuncifer* (2%) *Ancistrotermes guineensis* (8%) *Macrotermes subhyalinus* (7%) *Macrotermes bellicosus* (2%)
Accidental species 10 < F < 20	*Amitermes evuncifer* (10%) *Microcerotermes parvulus* (12%) *Promirotermes holmgreni* (10%) *Macrotermes bellicosus* (10%) *Pseudacanthotermes militaris* (13%) *Ancistrotermes crucifer* (18%) *Cubitermes* sp (15%) *Trinervitermes* sp (13%)	*Pseudacanthotermes militaris* (12%) *Microtermes thoracalis* (12%) *Nasutitermes arborum* (12%) *Haplognathotermes* sp *10%* *Microcerotermes fuscotibialis* (12%)
Accessory species 20 < F < 40	*Odontotermes pauperans* (33%)	*Ancistrotermes cavithorax* (25%) *Ancistrotermes crucifer* (25%) *Coptotermes intermedius* 23% *Coptotermes sjostedti* 28%
Fairly common species 40 < F < 60	*Ancistrotermes cavithorax* (42%)	*Promirotermes* sp (53%) *Microcerotermes parvulus* (42%)
Common species 60 < F < 80	-	*Cubitermes* sp (75%)
Very common species F >80	-	-

3.4 Termite Diversity Indices

The diversity indices vary from one habitat to another (Table IV). The Simpson's index was higher in the forest (SI = 0.97) than in the plantation (SI = 0.77) in the orchard. The equity index evolved in the same direction as the Simpson index with for primary forest (E = 0.84) and for orchard (E = 0.79). However, the similarity index between the two plots was relatively high (0.81).

Table 4. Variation in diversity indices

Diversity indices	Lemon plantation	Forest
Specific richness	11	18
Relative abundance	109	171
Simpson	0.77	0.97
Equitability	0.79	0.84
Similarity	**0.81**	

3.5 Relative Abundance Of Trophic Groups

The species harvested belong to 4 trophic groups: soil feeders, fungus-growers, grass-feeders and wood-feeders (Fig. 4). The results showed that the average relative abundance of fungus-growers was higher in lemon orchards (24.33 ± 2.7 ind./transect) than in primary forest which recorded an average abundance of (18.66 ± 2.87 ind./transect). The wood-feeders and soil feeders with respectively 25.33 ± 6.94 ind./transect and 27.33 ± 1.36 ind./transect were more abundant in the forest than in the plantation. Grass-feeders, totally absent from the forest, were harvested in the lemon plantation with a relative abundance of 2.66 ± 1.36 ind./transect. However, the total abundance of termites was higher in the forest (71.33 ind./transect) than in the plantation (38 ind./transect).

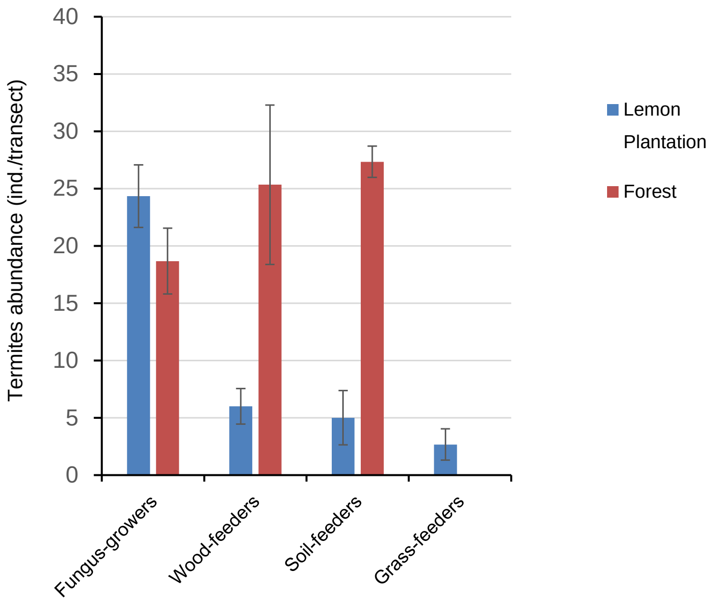

Fig. 4. ***Relative abundance of trophic groups in the habitat types***

4 Discussion

4.1 Sampling Efficiency

The coverage rate was relatively higher (91.82%) in the lemon orchard than in the primary forest (85.91%). These high coverage rates reflect the good efficiency of the sampling method used in this study. According to [15], the transect method allowed a rapid assessment of termite fauna because it was not very disturbing of the environment and facilitates the standardization of the sampling effort. This coverage rate obtained in the lemon plantation was very close to that obtained by [28] in the mango orchards of Korhogo (90.13%). The efficiency of the sampling method in lemon orchards would be linked to the fact that this environment offers a great possibility of mobility and access offered by the planting system. The system used offers wide spacing easily penetrated by termite collectors.

4.2 The Termite Assemblage

In total, twelve (12) species of termites were collected from the lemon plantation. This specific richness was identical to that obtained by [29], in 8-year-old rubber plantations on the same site. The specific richness was however low compared to that harvested in the forest plot. Several reasons could explain this low specific richness in plantations. First, the monocultural system of planting lemon trees. Indeed, according to [30], diversity and abundance are strongly influenced by the quality of plant species present in the ecosystem. They showed that monoculture disrupts the balance of termite communities in teak plantations.

This relatively low specific richness in these lemon plantations is also linked to the fact that these plantations were established from old plots of pineapple cultivation. However, to obtain quality pineapples, pineapple farmers used many chemicals such as insecticides, nematicides, herbicides and fungicides applied at least four times a year. The massive use of these chemical inputs, before the establishment of the lemon tree plantation, certainly contributed to the loss of the diversity of soil fauna in general and that of termites in particular. Several studies carried out in other area have linked the use of chemical inputs and the diversity of soil macrofauna [31], [32], [33]. This is probably what would explain the low presence of soil-feeders (less than 5 ind. / Transect). Soil-feeders feed on decaying organic matter in the soil [34].

The heavy use of chemical inputs in the past on the plot certainly had an impact on the availability and quality of soil organic matter [35].

However, this organic matter would gradually be reconstituted 10 after the plot was converted into a lemon tree plantation leading to the reappearance of certain soil-feeders species such as *Promirotermes holmgreni*. Fungus-growers, less affected by human activities, are abundant in the lemon plantation than in the forest. Their ability to live in these exploited environments is linked to their remarkable adaptation, favored by the symbiotic relationship they maintain with certain fungi of the genus *Termitomyces* [36], [37].

5 CONCLUSION

The purpose of this study was to assess their blend in lemon plantations in the Tiassalé region in southern Côte d'Ivoire. The results obtained showed that a total of 20 species of termites divided into 13 genera were collected from the two plots. The specific richness was relatively low in the lemon plantation (12) compared to the primary forest (18 species). However, more than half of the termite species collected in the forest were observed in the Lemon plantation. This would demonstrate that these cultivated areas could in the long term shelter a good specific wealth of termites comparable to that of the forest. Planting lemon would thus contribute to the regeneration of the diversity of termites in this area heavily disturbed by pineapple cultivation. This will be possible if the lemon cultivation on this site uses my chemical inputs.

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