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Akpesse Akpa Alexandre Moïse
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire

Diby Yao Kan Séraphin
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire

Konan Akissi Klamansoni Manuela S
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire

Coulibaly Tenon
UFR Sciences Biologiques, University Péléforo Gon Coulibaly of Korhogo, Department of Animal Biology, BP 1328, Korhogo, Côte d'Ivoire

Kouassi Kouassi Philippe
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire.

Koua K Hervé
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire

Correspondence
Diby Yao Kan Séraphin
UFR-Biosciences, Université Felix Houphouet Boigny de Cocody, Laboratoire de Zoologie et de Biologie Animale, 22 BP 582 Abidjan 22, Côte d'Ivoire.

Diversity and abundance of termites in a Corossol tree culture (*Annona muricata*, Linné 1753) in M'Brimbo (Southern Côte d'Ivoire)

Akpesse Akpa Alexandre Moïse, Diby Yao Kan Séraphin, Konan Akissi Klamansoni Manuela S, Coulibaly Tenon, Kouassi Kouassi Philippe and Koua K Hervé

Abstract
Termites are one of the most important components of soil invertebrates and often cause several damages to fruit trees and cash crops, infecting their productivity. The objective of this study is to inventory the termite species that make up a primary forest and a corossol tree plantation in M'Brimbro (southern Côte d'Ivoire). The Transect standard method was used to sample over an area of 5000 m2 of corossol tree planting, i.e. half a hectare composed of 528 corossol trees in the plantation and 5000 m2 in the primary forest. Sampling made it possible to collect termites from the litter and tree trunks up to 1.5 m high. The obtained results have shown that the primary forest contained a more diversified termite population, with 15 species, than the corossol tree plantation (8 species). 6 species common to both environments have been identified. These are: *Ancistrotermes guineensis*, *Ancistrotermes cavithorax*, *Macrotermes subhyalinus*, *Macrotermes bellicosus*, *Microtermes thoracalis* and *Pseudacanthotermes militaris*. Among those species, the group of fungus-growers is the most represented with 8 species. All the identified species were grouped into 9 genera all found in primary forests and only 5 in corossol tree plantations. This study will allow us to know the biological diversity of the corossol plantation in this area of Côte d'Ivoire.

Keywords: *Annona muricata*, termites, diversity, fungus growers, wood-feeders, soil-feeders

1. Introduction

Edible fruit plants in general and fruit of corossol tree or *Annona muricata* in particular represent a real economic challenge thanks to the marketing in various forms (drinks, ice, nectar or wine) in several countries such as the United States, Senegal and the West Indies (Tra-Bi *et al.* 2008, Le ven, 2012) [1, 2].

In Côte d'Ivoire, *Annona muricata* is grown by the Agricultural Society of Bandama (SAB), which is responsible for marketing at both regional and sub-regional levels. With an estimated annual production of 1.6 tons per year, the SAB is unable to meet the food needs of corossol tree fruit at the national level. In recent years, a decrease in annual production (1.6 to 1.15 tons per year) has been observed on the production sites and the probable causes mentioned would include the climate, the presence of insects, especially termites, in corossol tree plantation. Termite are considered to be the main pests of most food crops in Africa (Coulibaly *et al.* 2014; Diby *et al*. 2015) [3, 4]. There are many studies on their involvement in the destruction of nurseries and fields. In Burkina Faso, Ouedraogo *et al.* (2015) [5] showed that termites were responsible for the destruction of maize fields in two agro-ecological zones. In Senegal, the work of Sané *et al.* (2016) [6] highlighted the involvement of termites in the destruction of fruit trees such as mango, cashew and coconut. Annual global economic losses are estimated at more than 22 billion euros (Fuchs *et al*. 2004) [7].

The work of Tra-Bi *et al.* (2014) [8] in Oumé on cocoa and Coulibaly *et al.* (2014) [3] in the north in the Korhogo region on mango nurseries has highlighted the damage caused by termites on these plants. There are many studies on termites associated with food crops (maize and rice) (Akpesse *et al.* 2008; Diby *et al.* 2015) [9, 4] and rents such as oil palm (Han *et al*. 1998) [10]. Rubber (Koudou *et al*. 2004; Tahiri and Mangué, 2007) [11, 12] and mango (Coulibaly *et al*. 2014) [3]. However, the literature does not mention any studies on termites associated with the corossol tree (*Annona muricata*) in Côte d'Ivoire. However, the therapeutic properties of

Annona muricata have been the subject of several studies in Côte d'Ivoire in the prevention and treatment of certain diseases such as diabetes, hypertension, pneumonia and cancer (Tra-Bi *et al*. 2008; Le Ven, 2012) [1, 2].

The objective of this preliminary study is to inventory the termite species associated with the cultivation of the corossol tree and the forest located nearby.

2. Materials and Methods

2.1 Study zone

This study was carried out in the M'Brimbo estate located in the Agnéby-Tiassa Region, in the Tiassalé Department and precisely in the Pakobo Sub-Prefecture on the Abidjan-Yamoussoukro axis. M'Brimbo is located 41 km north of Tiassalé and 135 km south of Abidjan from the village of Singrobo. M'Brimbo's climate is Guinean in nature and is characterized by a sub-equatorial seasonal pattern with a high rainy season from April to July, a low dry season from August to September, a low rainy season from October to November and a high dry season from December to March. The average temperature is between 28°C and 29°C; the minimum humidity is around 60% (Anonymous, 2016) [13]. Rainfall is estimated at more than 1000 mm per year. The soils are ferralitic. They generally have a fine sandy-clayey texture.

2.2 Biological Material

The biological material is composed of the plants of *A. muricata* (Fig 1).

The animal material consists of termite samples taken from the corossol tree plot and the adjacent primary forest (Fig 2)

Fig 1: Fruit of Annona *muricata* L.

Fig 2: Soldier Pseudacanthotermes militaris (in dorsal view)

2.3 Methods of operation

2.3.1 Termite sampling

It was carried out on a 100 m x 50 m (5000 m2) plot, two diagonal transects 112 m long and 2 m wide were carried out. Each transect, diagonally, was divided into 10 sections of 11 m x 2 m.

A systematic transect search was conducted to remove termites from each section in two stages (Jones and Eggleton, 2000) [14].

- The first step was to search the litter box. To this end, debris from leaves and tree branches littering the ground is carefully examined. Also, the epigeous nests on the ground are chipped and placed in sorting trays.
- The second step consisted in harvesting termites from tree trunks up to 1.5 m high. Thus, the epigeous nests plated to the trees are also chipped and placed in sorting trays.
- Termites are collected using entomological forceps. The samples from each section are stored in a pill box three-quarters full of 70% alcohol.

2.3.2 Termite identification

Termite identification was done in the laboratory using a binocular magnifying glass according to termite morphometric parameters based on soldiers morphology. The contents of each pillbox are spilled into a petri dish. Then the termites are grouped together on the basis of visual similarity. Termite soldiers from the pill boxes in each batch are observed. The genus and species of each lot are determined using the identification keys of Hamad (1950) [15], Bouillon and Mathot (1965) [16], Roy-Noel (1966) [17], Sjöstedt (1926) [18] and Sands (1965, 1972, 1992) [19, 20, 21].

2.3.3 Data Analysis

2.3.3.1 Calculation of ecological indices

Several indices were calculated to describe termite stands in the two study environments.

- **Frequency of occurrence**

The constancy (C) expressed as a percentage (Dajoz, 1982) [22] is the ratio of the number of surveys containing the species studied (Pi) to the total number of surveys (P). The general formula is as follows:

$$C\ (\%) = \frac{Pi}{P} \times 100$$

50% ≤ C < 100%: constant species
25% ≤ C< 50%: frequent species
5% ≤ C< 25%: accessory species
C<5%: rare species
C= 100%: omnipresent species

- **Specific richness (S)**

Specific richness (S) is the total number of termite species sampled in a given environment (Morin and Findlay, 2001) [23].

- **Estimation of specific richness**

The non-parametric estimator Jackknife 1 was calculated using Estimate S (Version 7.0) software (Colwell, 2004) [24] to estimate the expected specific wealth in the two environments studied. Brose *et al.* (2003) [25] showed that Jackknife 1 and 2 estimators are the best, especially for environments with equity between 0.74 and 0.96.

2.3.3.2 Biodiversity Index

- **Shannon's Index**

The Shannon index (H') takes into account the number of taxa encountered on a plot. It neglects the rare species present in the environment (Magurran, 2004) [26]. It is nil when there is only one taxon and its value is maximum when all taxa have the same abundance. This index was calculated using the software Estimate S (Version 7.0) Colwell (2004) [25] according to the following formula:

$$H = -\sum pi \times \log 2\,(pi)$$

Pi = Probability of encounter of species i

- **Equitability Index**

Equitability (E), measures the equitable distribution of species. It makes it possible to compare stands with different numbers of taxa (Dajoz, 1982) [22]. Its objective is to observe the balance of the populations present.

$$E = \frac{H}{\log 2(s)}$$

H' = Shannon Diversity Index; S = Specific Richness; E tends towards 0 when a taxon largely dominates a stand and is equal to 1 when all taxa have the same abundance.

- **Simpson Index**

The Simpson Index (D) (Morin and Findlay, 2001) [23] evaluates the probability that two individuals, randomly selected from an infinite population of N individuals, belong to the same species. It is calculated according to the following formula:

$$D = \sum_{i=1}^{s} Pi^2$$

Avec Pi = ni / N

D = Simpson's index, ni = number of individuals of species i, N = total number of individuals.

The "derived" Simpson index index (IS = 1-D) was used. This index varies between 0 and 1, with a minimum diversity for an index equal to = 1 and a maximum diversity for an index equal to 0.

3. Results

3.1 Specific diversity of termites in corossol tree and Forest plots

The termites harvested and identified belong to 2 families (Rhinotermitidae and Termitidae) and six (6) sub-families. These subfamilies are: Rhinotermitinae, Coptotermitinae, Apicotermitinae, Macrotermitinae, Nasutermitinae and Termitinae.

From all two study sites, 9 genera of termites were collected. These are the genera *Ancistroterms; Amitermes; Hoplognathotermes; Macrotermes; Microcerotermes; Microtermes; Nasutitermes; Pseudacanthotermes* and *Schedorhinotermes* (Fig 1). Out of 15 registered termite species, six (6) species such as: *Ancistrotermes guineensis; Ancistrotermes cavithorax; Macrotermes subhyalinus; Macrotermes bellicosus; Microtermes thoracalis; Pseudacanthotermes militaris* are common to both environments (Table I and II).

Out of 9 genera, only 4 (*Ancistrotermes; Macrotermes; Microtermes; Pseudacanthotermes*) were collected in corossol tree orchards. The other five genera are common to the forest ecosystem and agrosystem.

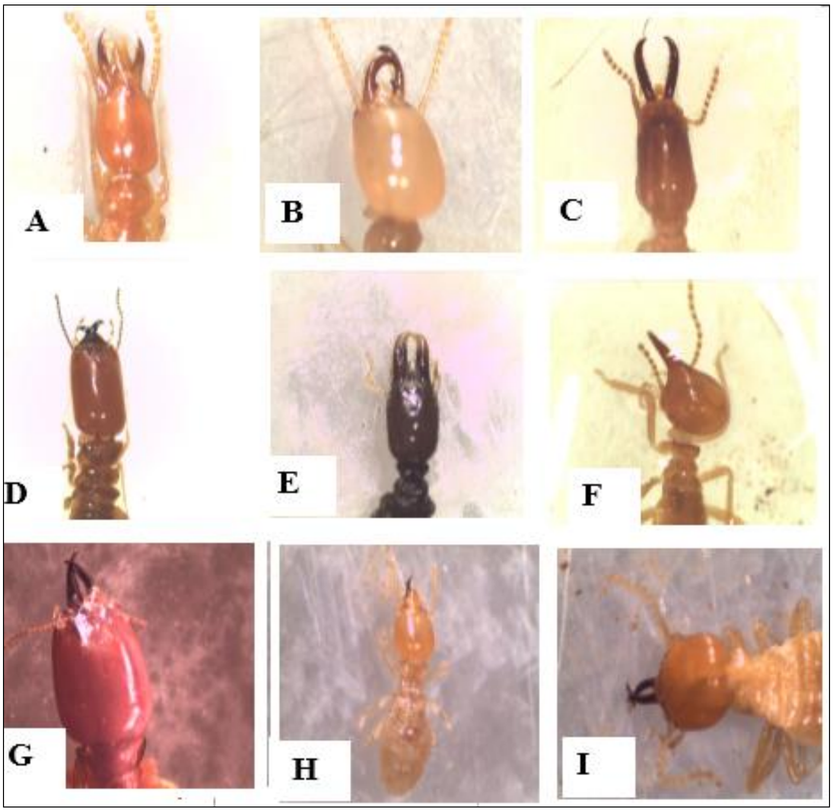

Fig 1: Different genera of termites encountered (A: Schedorhinotermes sp; B: Coptotermes sp; C: Microcerotermes sp; D: Pseudacanthotermes sp; E: Hoplognathotermes sp; F: Nasutitermes sp; G: Macrotermes sp; H: Microtermes sp; I: Ancistrotermes sp

Table 1: Species found in the bedding of the corossol tree plantation

Family	Sub-Family	Species	Trophic group
Termitidae	Macrotermitidae	Ancistrotermes guineensis	Fungus growers
		Ancistrotermes cavithorax	Fungus growers
		Macrotermes bellicosus	Fungus growers
		Macrotermes subhyalinus	Fungus growers
		Microtermes thoracalis	Fungus growers
		Pseudacanthotermes militaris	Fungus growers
Total		6	

Table 2: Species found in forest litter

Family	Sub-Family	Species	Trophic group
Rhinotermitidae	Coptotermitinae	Coptotermes intermedius	Wood-feeders
		Coptotermes sjöstedti	Wood-feeders
	Rhinotermitinae	Schedorhinotermes lamanianus	Wood-feeders
Termitidae	Macrotermitinae	Ancistrotermes cavithorax	Fungus growers
		Ancistrotermes crucifer	Fungus growers
		Ancistrotermes guineensis	Fungus growers
		Macrotermes bellicosus	Fungus growers
		Macrotermes subhyalinus	Fungus growers
		Microtermes thoracalis	Fungus growers
		Pseudacanthotermes militaris	Fungus growers
		Pseudacanthotermes spiniger	Fungus growers
	Apicotermitinae	Hoplognathotermes sp	Soil-feeders
	Nasutitermitinae	Nasutitermes arborum	Wood-feeders
	Termitinae	Amitermes guineensis	Wood-feeders
		Microcerotermes parvus	Wood-feeders
Total		15	

3.2 Termite diversity

The diversity of termites was highlighted by the determination of several ecological indices such as: Shannon's diversity index, Simpson's index and Equitability (Table III).

The Shannon diversity indices for both environments, the corossol tree plot and the primary forest, are almost identical with values of 2.01 and 2.65 respectively.

The primary forest records the highest Simpson Index (SI) value (0.93) relative to the corossol tree plot (0.87).

The Equitability (E) values of termites in the corossol tree plot (0.96) and the primary forest (0.98) are greater than 80% (E > 0.80) and are essentially identical.

3.3 Effectiveness of the sampling method.

The effectiveness of the method used for sampling litter termites varies between 82.38% and 88.75%, representing an average coverage rate of 85.56% (Table IV). The accumulation curves, of the expected (Jack 1) and observed (Sobs) specific richness, all approach the asymptote (Fig 2), indicating a high efficiency of the sampling method used at these two sites.

Table 3: Termite diversity index

Index	Plantation	Forest
Specific richness	8	15
Shannon (H’)	2,01	2,65
Equitability (E)	0,96	0,98
Simpson (Is)	0,87	0,93

Table 4: Specific diversity observed and expected of litter termites

	Plantation	Forest
Observed	8	15
Expected	8,98	16,9
Efficacity (%)	88,75	82,38

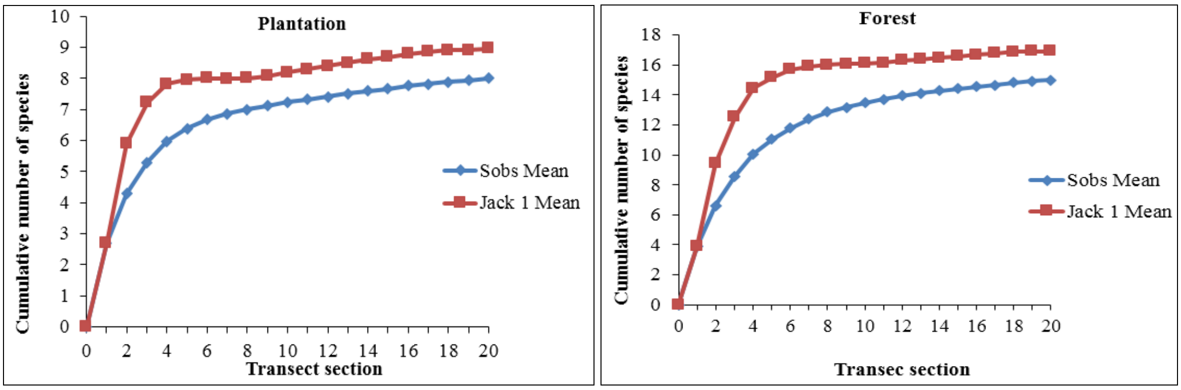

Fig 3: Accumulation curves of observed specific richness (Sobs) and expected (Jack 1) from the termites of the litter

3.4 Frequency of occurrence

Analysis of the results shows that among the termites sampled in the litter, the group of fungus growers is constant in the forest and omnipresent in the corossol tree orchard (Table V).

In addition to Fungus growers, species of the wood feeders group are frequently encountered while the soil feeders group is represented by a single species in the forest (Table VI).

Table 5: Frequency of occurrence of litter termites in the plantation

Trophic group	Species	Frequency of occurrence(%)	Total (%)
	Ancistrotermes cavithorax	7	
	Ancistrotermes guineensis	51	
Fungus growers	*Macrotermes bellicosus*	3	100
	Macrotermes subhyalinus	15	
	Microtermes thoracalis	9	
	Pseudacanthotermes militaris	15	

Table 6: Frequency of occurrence of forest litter termites

Trophic group	Species	Frequency Of occurrence (%)	Total (%)
	Amitermes guineensis	2	
	Coptotermes intermedium	8	
Wood feeders	*Coptotermes sjostedti*	1	32
	Microcerotermes parvus	2	
	Nasutitermes arborum	13	
	Schedorhinotermes amanianus	5	
	Ancistrotermes cavithorax	15	
	Ancistrotermes crucifer	6	
	Ancistrotermes guineensis	1	
Fungus growers	*Macrotermes bellicosus*	4	63
	Macrotermes subhyalinus	9	
	Microtermes thoracalis	3	
	Pseudacanthotermes militaris	2	
	Pseudacanthotermes spiniger	23	
Soil feeders	*Hoplognathotermes sp*	5	5

4. Discussion

The transect method recommended by Jones and Eggleton (2000) [14] has resulted in an efficiency in corossol tree planting (89.38%) than in primary forest (82.75%). These values are similar to those obtained by Akpesse *et al.* (2018) [27] and Tra- Bi *et al.* (2014) [8] in the cocoa zone and in the primary forest, which obtained 88.89 in M'Brimbo South of Côte d'Ivoire and (66.94-98.41%) in Oumé in the western centre of Côte d'Ivoire respectively. However, our values are higher than those obtained by Konaté *et al.* (2005) [28] in the forests of Haute Dodo and Cavally (65% efficiency). This difference would be related to the fact that the work of these authors took place in the primary forest with sometimes impenetrable undergrowth and often inaccessible micro-habitats, making it difficult to harvest termites. Unlike this type of natural ecosystem, corossol tree and cocoa orchards offer great freedom of mobility and access to all micro-habitats because of the open undergrowth. This would facilitate access to almost all the species present in the environment.

Analysis of the results of the specific wealth allowed to record 15 species in the primary forest. These results are similar to those obtained by Akpesse *et al.* (2018) [27] who obtained 19 species in a cocoa and primary forest plantation and Tra-Bi *et al.* (2014) [8] in the primary forest in Oumé (20 species). However, our results are significantly lower than those observed by Gbenyedji *et al.* (2016) [29] in the Toys primary forest (44 species). The difference observed could be due to sampling methods. The first authors used the standardized method of Jones and Eggleton (2000) [14], which was used to conduct our sampling. On the other hand, for the second, in Taï, the work was carried out on two layons of 625 m² and 2,500 m², using an auger, the number of aftershocks of which was not mentioned.

The specific richness of termites is high in the primary forest and low in the corossol tree plantation. This could be explained by the fact that the primary forest contains several plant species while the corossol tree plantation is monospecific. In addition, the orchard of corossol tree of the M'Brimbro estate undergoes phytosanitary treatments and regular cleaning sessions every year. This could be at the origin of the low specific richness of termite planting (8 species) given the massive use of insecticides and other inputs during these interviews (Diby *et al*. 2018) [30]. In addition, regular cleaning and maintenance would affect the physical structure of the soil, which could be a cause of the low specific wealth observed in plantations (Lavelle *et al*. 1995) [31]. This argument is consistent with that of Donovan *et al.* (2007) [32] who reported that land use would affect the trophic structure and specific richness of termites.

The study of termite trophic diversity revealed the variation in termite types from one trophic group to another, regardless of the study setting. Indeed, cultivation would have an impact on trophic groups. However, Fungus growers are less affected by soil cultivation, which would explain their abundance in both study environments. Their ability to live in these exploited environments would be linked to their remarkable adaptation, favoured by the symbiotic relationship they maintain with certain fungi of the genus *Termitomyces*, which would facilitate the digestion of complex molecules such as cellulose, lignin and tannins (Guedegbe *et al*. 2008; Tra Bi *et al.* 2014) [33, 8]. Humivores, on the other hand, are the organisms linked exclusively to decomposing organic particles in the humic fraction of the soil (Yapi, 1991) [34], and are the most affected by land degradation. In this study, the primary forest, which is likely to support high plant diversity, is a low soil feeders environment (1 species). This difference in result could be explained by the presence in the soil of possible impermeable structures such as gravel that could contribute to the depletion of organic matter in the soil

(Gbenyedji *et al*. 2016) [29]. This result is different from that observed by Donovan *et al.* (2007) [32]. According to these authors, soil Feeders termites are more diverse and abundant in humid forests.

5. Conclusion

This study in the corossol and primary forest plantations recorded fifteen (15) termite species grouped into nine genera. Six (06) species are common to both environments sampled These termite species belong to 3 trophic groups: fungus growers, wood feeders and soil feeders. This study showed a low specific richness in corossol plantations compared to the natural primary forest. Fungus growers constituted the most diversified group with 8 species. This preliminary study will study the impact of its termites on corossol plantations.

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