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TERMITES ATTACKS AND DAMAGE IN A COROSSOL CROP (ANNONA MURICATA, LINNÉ 1753) IN M'BRIMBO (CÔTE D'IVOIRE)

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ABSTRACT

The objective of this study is to evaluate termite attacks and damages in corossol orchards in M'Brimbo (Southern Côte d'Ivoire). Sampling was done on 538 corossol trees using the Transect method over an area of 5000 m2. The work focused on the collection of termites at the level of the litter and the trunks of trees up to 1.5 m in height. Then, the damages caused on corossol plantation were evaluated. The results showed that the primary forest contained more diverse termite population with 15 species compared to the corossol plantation (8 species). Six (6) species common to both environments were identified.These are *Ancistrotermes guineensis* and *cavithorax, Macrotermes subhyalinus* and *belicosus, Microtermes thoracalis* and *Pseudacanthotermes militaris*. The main trophic groups responsible for the damage are the Fungus growers and the Wood-feeders. The group of Fungus growers is the most represented with 6 species. The quantitative study of the damages allowed us to identify four (4) types of damages observed on the corossol trees. Out of 538 trees observed, an infestation rate of 89.77% was recorded. Type 1 (DT1) damage recorded the highest rate with a percentage of 55.68. With a high attack rate on corossol trees, this fruit tree deserves special attention at the phytosanitary level in order to reduce yield losses.

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INTRODUCTION

Edible fruit in general and the corossol or *Annona muricata* in particular represent an economic stake thanks to the commercialization of its derivatives (beverages, ice, nectar or wine) in several countries such as the United States, Senegal and the West Indies (Tra-Bi, 2008; Le Ven, 2012; Soheil et *al*., 2015). In Côte d'Ivoire, *Annona muricata* or corossol is cultivated by the Société Agricole du 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, SAB is unable to cover the food needs of soursop fruit at national level. A drop in annual production (1.6 to 1.15 tons/year) has been noted in recent years on the production sites and the probable causes mentioned would be, among others, the climate, the presence of insects, in particular termites in the soursop plantations. Termites are considered the main pests of most food crops in Africa (Coulibaly et *al*., 2014; Diby et *al*., 2015). Studies on their involvement in the destruction of nurseries and fields are numerous. In Burkina Faso, Ouedraogo et *al*. (2015) 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) highlighted the involvement of termites in the destruction of fruit trees such as mango, cashew and coconut. The annual economic losses recorded at the global level are estimated at more than 22 billion euros (Fuchs et *al*., 2004). Work on termites associated with food (maize and rice) (Akpesse et *al*., 2008; Diby et *al*., 2015) and cash crops oil palm (Hans et *al*., 1998) rubber (Koudou et *al*., 2004; Tahiri and Mangue, 2007) and mango (Coulibaly et *al*., 2014), is extensive. But the literature does not mention any studies on termites associated with the corossol tree (*Annona muricata*) in Côte d'Ivoire. However, the therapeutic virtues of *Annona muricata* have been the subject of several studies in Côte d'Ivoire in the prevention and treatment of certain pathologies such as diabetes, hypertension, pneumonia and cancer (Le Ven, 2012; Soheil et *al*., 2015). The objective of this study is to inventory and evaluate termite damage associated with the corossol crop.

MATERIAL AND METHODS

Study zone: This study was carried out in the M'Brimbo area located 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 from Abidjan, south of the village of Singrobo. The climate of M'Brimbo is Guinean and is characterized by a sub-equatorial seasonal pattern with a long rainy season from April to July, a short dry season from August to September, a short rainy season from October to November and a long dry season from December to March. The average temperature is between 28°C and 29 C°. The minimum hygrometry is around 60% (Anonyme, 2016). Rainfall is estimated at over 1000 mm per year. The soils are ferralitic. They have, in general, a fine sandy-clay texture.

Biological material: The biological material consists of termites collected from the plot of soursop plants of *A. muricata* (Figure 1).

Figure 1. Leaf of *Annona muricata* L. plant

METHODS

Termite sampling: This sampling was done on a 100 m x 50 m (5000 m2) plot, two diagonal transects 112 m long and 2 m wide were made. Each diagonal transect was divided into 10 sections of 11 m x 2 m.

Each transect was systematically searched for termites in each section in two stages:

- The first step was to search through the litter. For this purpose, the debris of leaves and tree branches littering the ground are examined carefully. Also, the epigeous nests present on the ground are chipped and placed in sorting trays.
- The second step consisted in collecting termites present on tree trunks up to 1.5 m high. Thus, the epigenetic nests stuck to the trees were also chipped and placed in sorting trays.

Identification of collected termites: Termite identification was done in the laboratory using a binocular loupe according to termite morphometric parameters based on soldier morphology. Termites were grouped on the basis of visual resemblance. Termite soldiers from the pillboxes of each batch are observed. The genus and species of each batch are identified using the identification keys of (Hamad, 1950; Bouillon and Mathot, 1965; Roy-Noel, 1966; Sands, 1965; 1972; 1992).

DATA ANALYSIS

Calculation of the ecological index: Several indices were calculated to describe termite stands in the two study environments.

Species richness (S): The species richness (S) is the total number of termite species sampled in a given environment (Sjöstedt, 1926)

Frequency of occurrence (C): The constancy (C) expressed as a percentage (Dajoz, 1982) 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:

$$C(\%) = \frac{Pi}{P} \times 100 \quad (1)$$

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

Estimating the rate of termite attack: The termite attack rate is estimated based on the principle of Han et Ndiaye (1996) that the organ is said to be attacked when it bears galleries or veneers with or without termites. The termite attack rate per plot is calculated using the following formula:

$$Ta = \frac{Npa}{Ntp} \times 100 \quad (2)$$

Ta = termite attack rate on the plot
Npa= Number of feet attacked by termites
Ntp = Total number of plants observed on the plot

Assessment of the damage: Damage assessment consisted of examining the different parts (root, neck, branches) of all corossol plants present on the plot in order to note their health status: dead, healthy, attacked by termites, presence of earthy veneer on the bark or galleries in the wood. Also the signs of termite attacks on the trees were observed. The termites present on each corossol tree were collected in a pillbox bearing the number of the tree. At the end of the observations, the damage was classified into 4 groups. The classification is based on the density of the harvest veneers and especially on the progression of termites in the superficial anatomical structures to those deeper in the plant: bark and wood (Table 1).

Table 1. Description des dégâts

Type of damages	Characteristics
Type 1 (DT1)	Presence of termite galleries and earthen veneers on the bark of the tree
Type 2 (DT2)	Termites present on and in the bark of the tree
Type 3 (DT3)	Termites present in the wood of the tree
Type 4 (DT4)	Transition of termites in the heartwood with decomposition of the trunk

RESULTS

Inventory of termites found in Corossol plantations and in the contiguous forest: The inventoried and identified termites belong to 2 families (Rhinotermitidae and Termitidae) and six (6) subfamilies. These subfamilies are: Rhinotermitinae, Coptotermitinae, Apicotermitinae, Macrotermititinae, Nasutermitinae and Termitinae.
Nine (9) genera of termites were collected from all the samples. These are the genera *Ancistrotermes; Amitermes; Hoplognathotermes; Macrotermes; Microcerotermes; Microtermes; Nasutitermes; Pseudacanthotermes* and *Scheridorhinotermes*. Out of 15 species of termites recorded, six (6) species such as: *Ancistrotermes guineensis; Ancistrotermes cavithorax; Macrotermes subhyalinus; Macrotermes bellicosus; Microtermes thoracalis; Pseudacanthotermes militaris are common to both environments* (Table 2 and 3). Out of nine (9) genera, only four (4) (*Ancistrotermes; Macrotermes; Microtermes; Pseudacanthotermes*) have been collected in soursop orchards. The other five (5) genera are common to the forest ecosystem.

Table 2. Termite species found in the litter of the corossol plantation

Family	Sub-Family	Species	Trophic group
Termitidae	Macrotermitinae	*Ancistrotermes guineensis*	Fungus growers
		Ancistrotermes cavithorax	Fungus growers
		Macrotermes bellicosus	Fungus growers
		Macrotermes subhyalinus	Fungus growers
		Microtermes thoracalis	Fungus growers
		Pseudacanthotermes militaris	Fungus growers

Table 3. Termite species found in the 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 guineencis*	Wood-feeders
		Microcerotermes parvus	Wood-feeders

Table 4. Termite species found on the corossol trees

Family	Sub-Family	Species	Trophic group
Rhinotermitidae	Coptotermitinae	*Coptotermes intermedius*	Wood-feeders
		Coptotermes sjöstedti	Wood-feeders
Termitidae	Macrotermitinae	*Ancistrotermes cavithorax*	Fungus growers
		Ancistrotermes guineensis	Fungus growers
		Macrotermes bellicosus	Fungus growers
		Macrotermes subhyalinus	Fungus growers
		Microtermes thoracalis	Fungus growers
		Pseudacanthotermes militaris	Fungus growers

Table 5: Frequency of occurrence of plantation litter termites

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

Table 6. Frequency of occurrence of forest litter termites

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

Inventory of termites found on the corossol plants: Eight (8) species and 5 genera of termites were recorded on the trees and are divided into two families: the Rhinotermitidae with the subfamily Rhinotermitinae and the Termitidae with the subfamily Macrotermitinae (Table 4).

Trophic diversity: In this study, the termite species sampled belonged to three trophic groups and only Fungus growers and Wood-feeders were found on the corossol plants.

Frequency of Occurrence: The analysis of the frequency of occurrence of termite species in the plantation litter, shows two types

of species. Five (5) species with an occurrence between 5- 25%, are considered accessory and one species with an occurrence between 50-100% is considered constant (Table 5). On the other hand, at the level of the forest litter, the analysis shows us 3 species with an occurrence between 5 - 25% and 3 others lower than 5%. All belonging to the group of Wood-feeders. It is noted at the level of Fungus growers, the presence of 4 species with an occurrence between 5-25% and 4 others lower than 5%. For the group of Soil-feeders, only one species was found with an occurrence of 5% (Table 6).

Termite Damage Assessment

Type of damage

A total of 538 trees were sampled. The number of attacked trees with type 1 harvest galleries (DT1) was 294 or 55.68%. The number of trees with termites colonizing the inside and outside of the bark was 101, i.e. 19% of type 2 damage (DT2). Type 3 damage was visible on 72 attacked trees, i.e. 13.63% (DT3). 55 trees or 10.41% did not suffer any attack (DT0).

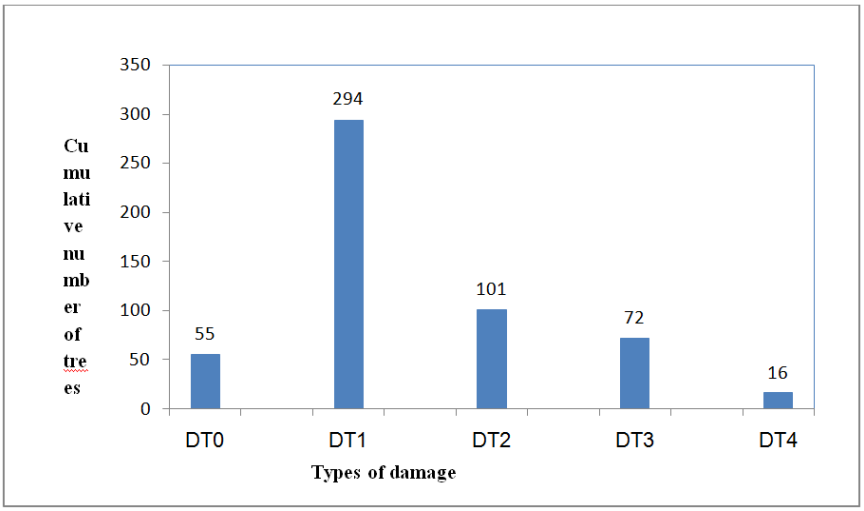

Figure 2. Cumulative number of damage types according to the rating scale (Total plant name, N=538)

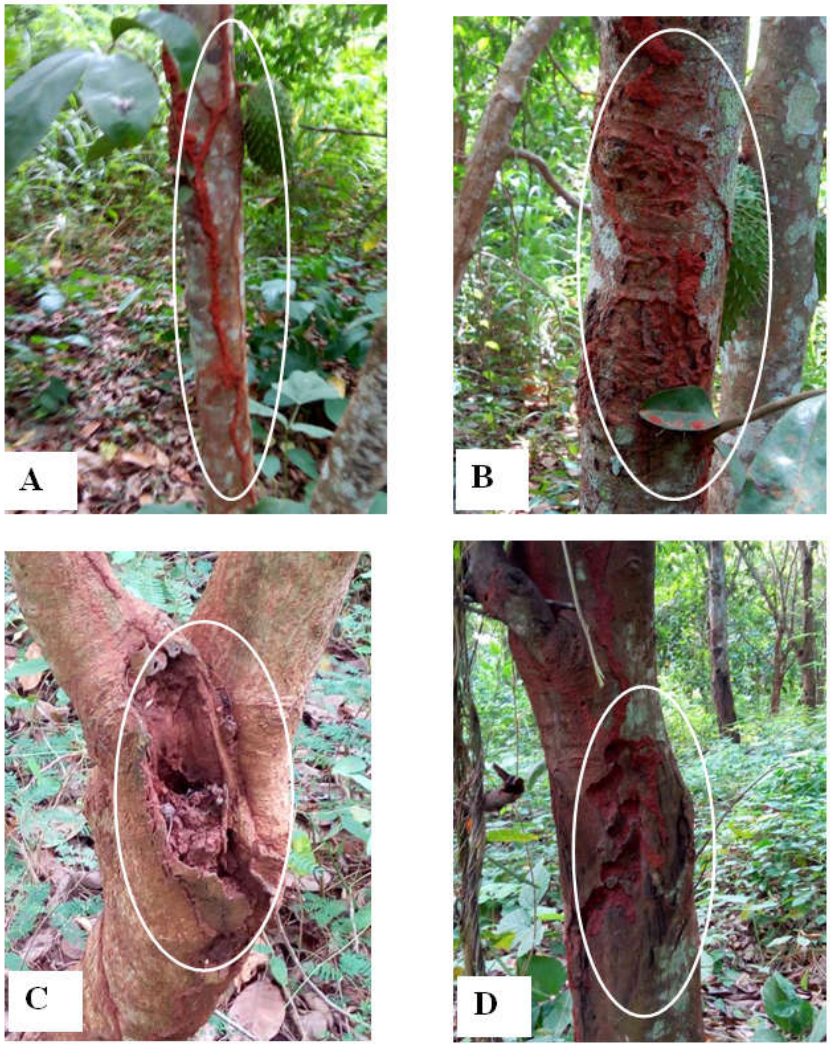

Figure 5. Some types of veneers encountered on *Annona muricata:* A: type 1 damage (DT1); B: type 2 damage (DT2); C: type 3 damage and D: type 4 damage (DT4)

Trees with heavy xylem gnawing numbered 16 or 3.03% (DT4) (Figure 2). The termite attack rate on the plantation is 89.77%.

Attack and damage pattern: The species *Coptotermes intermedius* and *Coptotermes sjöstedti* are responsible for the damage of type 3 (DT3) and type 4 (DT4), constructing veneers of crop on the external parts of the plant (trunk and branches) and digging galleries in the internal structures of the tree. Type 3 (DT3) and type 4 (DT4) damage is less numerous in the plot and is caused by *Ancistrotermes cavithorax* and *Ancistrotermes guineensis*. These termites attack corossol plants by constructing harvest galleries or veneers. These veneers are generally narrower at the base of the plant, with numerous branches.

These termites perforate the bark, then reach the wood. Once in the heart of the tree, *Ancistrotermes* proceeds to stuff the stem with soil as it advances. It attacks the roots and collars of the tree from the inside out. As a result, we sometimes observe apparently healthy plants, but completely emptied of their internal structures.This termite is often responsible for the degradation of the bark and the consumption of dead parts of trees. *Macrotermes bellicosus* and *Macrotermes subhyalinus* are responsible for the four types of damage (DT1, DT2, DT3 and DT4). Attacks by these two species start with the construction of epigeous nests around the corossol plant. From inside the termite mounds, these termites destroy the large roots to feed. They gnaw the bark and attack the wood of the tree, causing the leaves to fall off and eventually the tree to die. Exposed galleries or veneers show *Macrotermes* workers actively moving on the trunks of attacked trees. *Microtermes thoracalis* is responsible for type 1 damage (DT 1). The species digs several tunnels in the trunk and branches of the attacked trees. The attacks observed are limited to the bark of the trees. *Pseudacanthotermes militaris* is responsible for type 2 damage (DT2). The most frequently observed attacks are in veneers that can cover the whole trunk and continue towards the branches (Figure 3).

DISCUSSION

A total of fifteen (15) termite species were collected in the primary forest. Our results obtained in the primary forest are lower than those observed by Gbenyedji *et al.* (2016) in the Toys primary forest (44 species) and Tra-Bi *et al.* (2014) in the primary forest in Oumé (20 species). The observed difference could stem from the difference in sampling methods. The standardized method of Jones and Eggleton (2000) was used by the former authors. In contrast, for the latter, in Taï, work was done on two layons of 625 m² and 2,500 m², using an auger. The species harvested from the corossol plants are eight (8), which is low compared to the primary forest.This could be explained by the fact that the primary forest contains several plant species while the corossol plantation is monospecific. In addition, the corossol orchard of the M'Brimbro estate undergoes annual phytosanitary treatments and regular cleaning sessions. This could be the reason for the low specific richness of the plantation in termites (8 species) (Diby *et al.,* 2018). As for trophic diversity, the pest termite species collected, belong to the Fungus growers and Wood-feeders groups. These two trophic groups are recognized as the main pests of fruit trees such as cocoa (Tra-Bi *et al*. (2014); Jones and Eggleton (2000) and mango (Coulibaly *et al.,* 2014) in Côte d'Ivoire and Senegal (Ndiaye and Han, 2000; 2002; 2006). They attack fruit trees because of their consumption pattern, mainly based on cellulose. Observations by Diby *et al.* (2018) also showed that most of the termite species responsible for tree damage on the Lomé campus, belong to the Wood-feeders and Fungus growers groups.

The termites of the Fungus growers group attack fruit trees by making veneers that can cover the entire trunk and continue towards the branches, sometimes over 3 meters high (Guedegbe *et al.,* 2008). The resistance of Fungus growers to anthropogenic activities would be linked on the one hand to their remarkable adaptation, favored by the symbiotic relationship they maintain with certain Fungus of the genus Termitomyces present on hypogeous millstones, which would facilitate the digestion of complex molecules such as cellulose, lignin and tannins (Anani *et al.,* 2010) and on the other hand by their hypogeous nest, difficult to access during anthropogenic activities. On the other hand, Soil-feeders, organisms exclusively bound to decomposing organic particles in the humic fraction of the soil (N'Diaye, 1998), are the most affected by land degradation.

The strong dominance of Fungus growers in the analysis of the frequency of occurrence in the litter of planted plots, confirms the resistance and abundance of this group in fruit tree plantations (Akpesse et al., 2019).

The analysis showed an estimated attack rate of 89.77% on corossol trees. This rate is higher than that of Akpesse et al, (2019) who obtained an infestation rate of 52.66% in a cocoa plot and Ndiaye and Han (2006), who obtained 13.6% in a corossol orchard in Thies, Senegal. This difference in rate would show that the corossol tree is more attacked than the cocoa tree on the one hand, and on the other hand, the corossol monoculture could be the cause of this strong attack by Fungus growers

In Thiès, the cultivation of several fruit trees in one plot greatly reduced termite attacks on corossol trees at the expense of other citrus trees. However, this rate is close to that of Anani et al. (2010) who obtained 92.4% of infected trees. This high rate could be explained by the nature of the soil, which favors the proliferation of termites in this plantation. Indeed, the M'Brimbo region is characterized by a ferralitic, loose and deep soil of red or brown color. This type of soil would allow the genesis of termite mounds whose individuals would be at the origin of plant infestations. The termite damage observed during our work shows a high rate of type 1 damage (DT1). These types of damage can lead to dieback and death of trees using galleries and earthen veneers. These results are similar to those of Anani et al. (2010). According to these authors, the covering of the tree by tunnel galleries can lead to leaf drop which would be the cause of the decrease in photosynthetic activity. Furthermore, Logan et al. (1990) indicated that the presence of tunnel galleries and earthen veneers on trees causes stress, which would be a real source of future termite attacks.

CONCLUSION

The inventory of termites associated with corossol plantations recorded eight (8) species and five (5) genera of termites recorded on the trees and divided into two families: that of Rhinotermitidae with the subfamily Rhinotermitinae and those of Termitidae including the subfamily Macrotermitinae. Two trophic groups (Fungus growers and Wood-feeders) are responsible for the damage on corossol trees. Fungus growers and Wood-feeders are the main pests of the corossol tree. The attack rate of the trees by termites is 89.77%. The genus Ancistrotermes is responsible for most of the damage to the corossol tree. This should be an indicator when cultivating corossol trees in this region in order to take appropriate measures to control these Fungus growers.

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