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RESEARCH ARTICLE

ATTACKS OF TERMITES (INSECTA: ISOPTERA) IN COCOA FARMS (*THEOBROMA CACAO* L.) IN OUMÉ (CÔTE D'IVOIRE)

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ABSTRACT

The objective of this study is to evaluate the damage caused by termites in cocoa plantations of Oumé (Central West, Ivory Coast). Six (6) age classes of farms (less than one year, 5 years, 8 years, 20 years, 25 years and 30 years) were studied. Four types of damage (ranked on a scale of 1 to 4) are observed on the cocoa trees. A total of 14 species have been harvested. Termites identified as being responsible for the damage all belong to the fungus grow and xylophagous groups. The totality of termite damage on the seedlings of the plot of less than 1 year is 99.1% caused by *Microtermes toumodiensis*. *Nasutitermes latifrons*, *Coptotermes sjöstedti, Microcerotermes fuscotibialis*, *Schedorhinotermes lamanianus* and *Neotermes aburiensis* generally attack older cocoa trees between 20 cm and 30 cm in diameter. Young seedlings less than one-year-old and cocoa trees over the age of 20 are therefore the most vulnerable to termite attacks, unlike those aged 5 and 8 years.

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INTRODUCTION

Côte d'Ivoire, an agricultural country since independence, has based its economy on coffee and cocoa (world's largest producer of cocoa). Thus, cocoa occupies an important place in the economy and produces about 40% of export earnings and 10% of Gross Domestic Product (GDP) (Anonymous 2005). At the same time, there is a significant loss of bean production, particularly in the center-west of Côte d'Ivoire, formerly known as the "cocoa loop". Thus, the production of Oumé estimated at 45.422 thousand tons at the beginning of the 2001/2002 marketing year increased to 34:172 thousand tons in the 2006/2007 marketing year. That is a decrease of 24.76% in 6 years (Anonymous 2008). The factors that can explain this loss are many and varied. These include climate change (Kassin *et al.,* 2008), the aging of the orchard (Deheuvels 2003), the decline in soil fertility due to overexploitation and bio-aggressors such as insects (Coulibaly *et al.,* 1996). In fact, termites belonging to the order of insects have been reported in other media as being responsible for damage to crop plants (Wood *et al.,* 1980; Mora 1992; Mirinda *et al.,* 2006; Werner *et al.,* 2007). In Ivory Coast, most of the work on termites has focused on their beneficial role in maintaining and monitoring natural and processed ecosystems (Sangaré and Bodot 1980; Tano 1993; Konaté 1998; Yapi 2001; Konaté *et al.,* 2005; Boga 2007). On the other hand, the "plague" action of these organisms remains very little studied. The first works began in the plantations of yams (Foua-Bi 1983), palm oil in low Ivory Coast (Han *et al.,* 1998), rubber (Goudou 2000) and crops food crops (rice and maize) (Akpesse *et al.,* 2008). However, the attacks on cocoa plantations could not be really studied apart from the observations made by Sands (1977) on *Neotermes aburiensis* and *Schedorhinotermes lamanianus* and those of Grasse (1982) and Harris cited by Roy-Noël (1966) on *Coptotermes sjöstedti.* The objective of this study is to evaluate the damage caused by termites in cocoa plantations in this region in order to understand the role these termites may have played in the decline in cocoa production.

MATERIALS AND METHODS

Study site: The work was carried out in the cocoa farms of Oumé (6 °31 north latitude and 5 °30 west longitude) in west-central Ivory Coast. The climate is of the equatorial type with an average annual rainfall of 1656.55 millimeters and monthly temperatures between 24.1 °C and 29.6 °C. The soil is ferralitic (Angui *et al.,* 2005). Six (6) cocoa farms of 0.25 ha

(50m x 50m) each of different ages (less than 1 year 5 years old, 8 years old, 20 years old, 25 years old and 30 years old) were chosen. The reluctance of cocoa farmers to put their plantation at our disposal did not allow us to make a replication of the different classes of cocoa age during this study.

Sampling method: All cocoa trees on each plot have been mapped. The feet of cocoa thus present are prospected in search of termites. At the end of the observations, the attacks were photographed. And, the collected termites are put in alcohol at 70 °C. The observed damage was classified in 4 groups according to the density of the harvest veneers and especially the termite progression from the superficial anatomical structures to the deeper ones of the plant: bark, sapwood and heartwood (Table 1). This damage was then organized into two types: minors and adults.

Termite identification: Harvested termites were identified in the Laboratory of Biology and Animal Zoology of the University Felix Houphouet-Boigny (Abidjan). Specimens were determined to the level of the species using various classification documents such as: Hamad (1950); Bouillon and Mathot (1965); Roy-Noel (1966); Sands (1965; 1972 and 1998) and Sjöstedt (1926).

Data analysis: The rate of attack of termites is estimated based on the principle of Han and Ndiaye (1996) according to which the organ is said to be attacked when it carries galleries or veneers with or without termites. The rate of attack of termites per farm is calculated according to the formula below:

Ta = Npa x 100 / Ntp,
Ta = termite attack rate per plot,
Npa = Number of feet attacked by termites,
Ntp = Total number of feet observed per plot.

The attack intensity index was calculated according to the method of Désirée *et al.,* (2006) to determine the stages of plant development most vulnerable to termite attack. Attack intensity values were calculated as follows.

I = [(P0 x 0 %) + (P1 x 25 %) + (P2 x 50 %) + (P3 x 75 %) + (P4 x 100 %)] / [P0 +P1 + P2 + P3 + P4],

I: index of intensification of damage per plot,
P0: number of healthy feet,
P1: number of feet with type 1 damage,
P2: number of feet with type 2 damage,
P3: number of feet with type 3 damage**,**
P4: number of feet with type 4 damage.

To evaluate the importance of the infestations, the indices of intensification of the damage were classified in an ascending order according to the classification of Aléné *et al.,* (2006) (Table 2).

RESULTS

Description of the damage observed on the parcels: In total two (2) large groups of damage were observed. We note the damage of minor and major types. Minor type damage is subdivided into two groups (Figure 1D). Damage type 1 (Figure D1a and Figure D1b) is characterized by simple recognition veneers built by the termites. On the other hand, the damage of type 1 (D2a and D2b) is characterized by veneers. The termite attacks the superficial bark of the plant. Major type damage (Figure 2) is also subdivided into two groups. We note the damage of types D3 and D4. In stage D3 the termite corrodes the bark and attacks the sapwood. In stage D4, the termites crosses the sapwood barrier and attacks the plant's heartwood (Figure 2D). But in the seedling, the D4 stage is characterized by the cutting of the stem of the plant at the collar (Figure 2D4d).

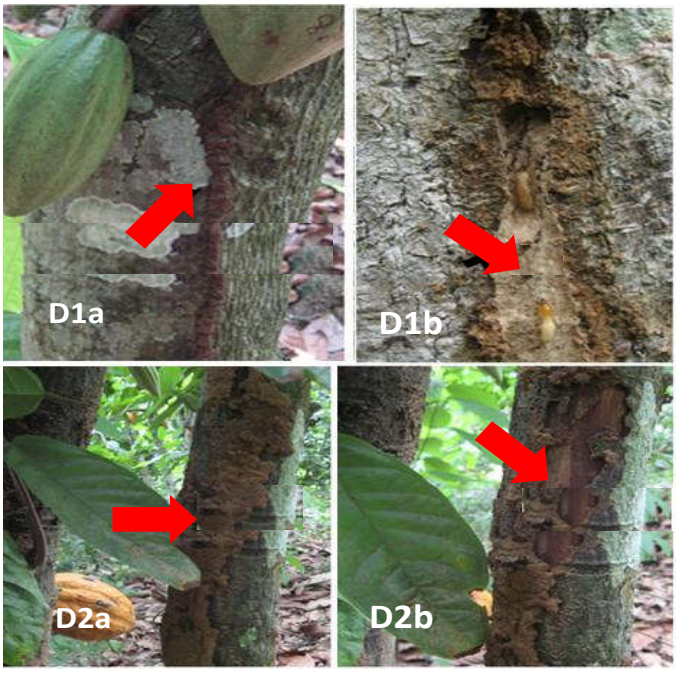


Figure 1. Different types of minor damage caused by termites on cocoa trees

Figure 2. Different types of major damage caused by termites

Inventory of termites harvested on cocoa trees: A total of fourteen (14) termites species were sampled (Table 3). They are divided into three (3) families, six (6) Sub-families and ten (10) genera. These species belong to the group of fungus-grow and xylophagous. The xylophages are the most diversified with 8 species belonging to 5 genera. The fungus-grow are represented by 6 species belonging to 3 genera.

Table 1. Scale of damage rating

Damage types	Rating groups	Characteristics
Minors	D1	Reduced number of harvesting galleries
	D2	Increased number of harvest veneers and termite installation between bark and sapwood
	D3	High recovery of cocoa trees by harvest veneers and installation of termites in the sapwood and abundance of harvesting individuals.
Majors		
	D4	Transit of termites from sapwood to heartwood with decomposition of trunk for older plants and systematic cutting of seedlings in young plots

Table 2. Qualification of termite damage index

Classe	Indice (%)	Qualification
I	$0 \leq I < 20$	Extremely
II	$20 \leq I < 40$	Middle
II	$40 \leq I < 50$	Extremely
IV	$50 \leq I < 100$	Very Extremely

Table 3. Assessment of the attack of the termites on the feet of cocoa

Trees characteristics	Deferent ages of Cacao farms					
	<1 year	5 years	8 years	20 years	25 years	30 years
Healthy	56	326	315	131	88	121
Attacked	112	57	85	61	130	52
Proportion of Attack (%)	66.66	14.88	21.25	31.77	59.63	30.05

Table 4. List species of termites collected on cocoa plantations.

Family	Sus Family	Species	1 year	5 years	8 years	20 years	25 years	30 years	Trophic Group
Kalotermitidae	Kalotermitinae	*Neotermes aburiensis*						*	X
Rhinotermitidae	Coptotermitinae	*Coptotermes intermedius*					*	*	X
		Coptotermes sjfoestedti			*	*	*	*	X
	Nasutitermitinae	*Nasutitermes latifrons*		*	*		*	*	X
	Rhinotermitinae	*Schedorhinotermes lamanianus*				*	*	*	X
Termitidae	Macrotermitinae	*Microtermes toumodiensis*	*						F
		Microtermes thoracalis						*	F
		Microtermes subhyalinus		*	*	*	*		F
		Pseudacanthotermes militaris		*		*		*	F
	Termitinae								
		Ancistrotermes crucifer		*	*	*	*	*	F
		Ancistrotermes guineensis	*	*	*	*			F
		Microcerotermes fuscotibialis		*		*		*	X
		Microcerotermes sp1				*	*		X
		TOTAL	**3**	**6**	**6**	**8**	**7**	**9**	

F: Fungus-grow ; **X**: Xylophagous, **GT**: Trophic group

Table 5. Distribution of intensity of termites attacks on cocoa plantation

Farms	Index (%)	Class of the attacks	Qualification
< 1 year	45	III	Extremely
5 years	8.14	I	Weak
8 years	9.30	I	Weak
20 years	15.5	I	Weak
25 years			

Termite attack rate according to cocoa age: In total, 66.66% of the cocoa stock was cut in the farm of less than one year by *Microtermestoumodiensis*. The 5 years old plot has an attack rate of 14.88%, with 56 feet of cocoa infected with termites. In the 8 years old farm, 21.25% of the feet were attacked. The most important attacks were observed in the farms of 20, 25 and 30 years old, with rates of attacked plants respectively of 31.77, 59.63 and 30.05% (Table 3). Four (4) damage groups were recorded in each of the plots studied (Figure 3). However, the major damage that may affect production has been observed in plantations of less than one year, and plantations of 20 years, 25 years and 30 years older. Thus, 48.65 and 43% of major damage type 4 (D4) were recorded respectively in the plot of less than one year and 30 years. plantation of 20, 25 and 30 years old with respectively 40.91%, 26.23% and 25% record asignificant proportion of major damage type 3 (D3). The minor damage of type 1 (D1) which affects less the health of the tree, is mainly observed, in the parcels aged 5 years (41.38%), 8 years (65.06%) and 20 years (47.54%). Indices of intensity of termite attack in the plots revealed 3 intensity classes (Table 4). Plots aged 5, 8 and 20 years had the lowest attack indices of 8.14%, 9.30% and 15.5%, respectively. On the other hand, these indices are high in the farms of less than one year and 25 years respectively with rates of 45 and 35.6%.

Abundance of termite species according to the types of damage: In the plantation of less than a year, *M. toumodiensis* dominates the stand involved in the damage.

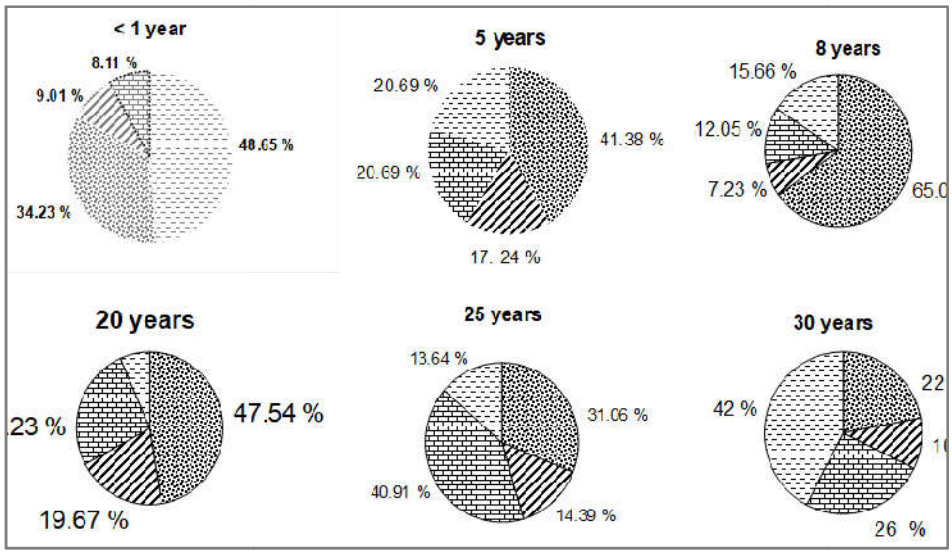
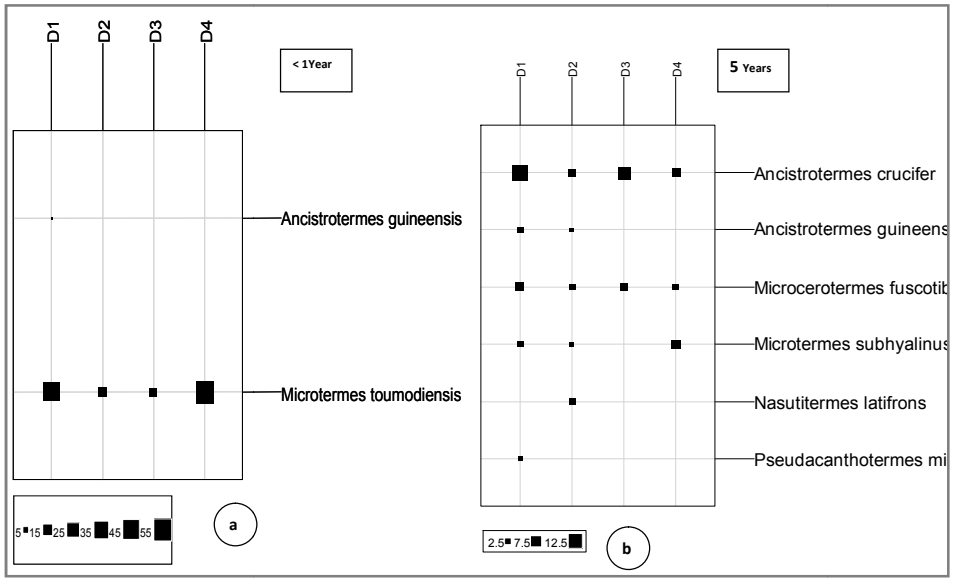
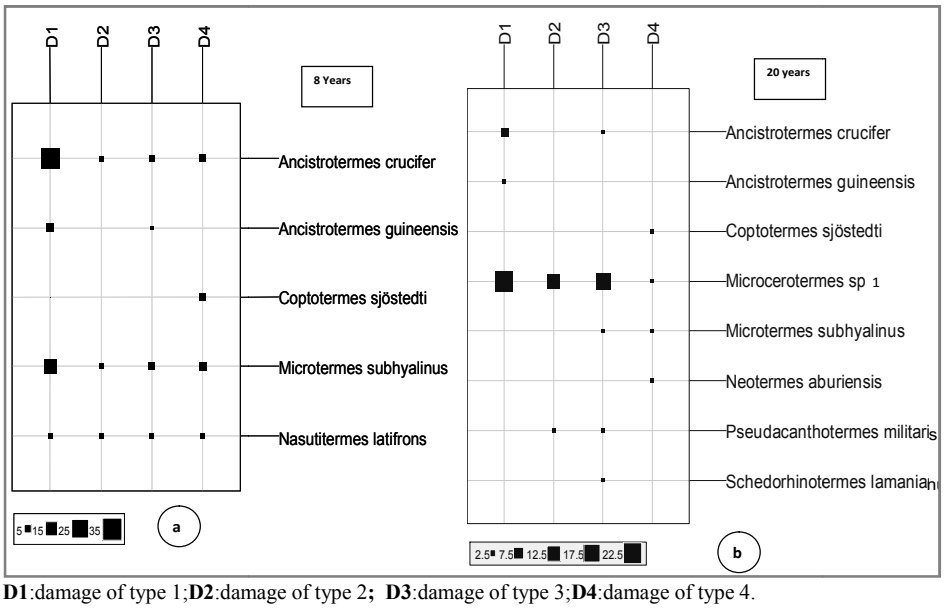


Figure 3. Distribution of different types of damage in the cocoa farms



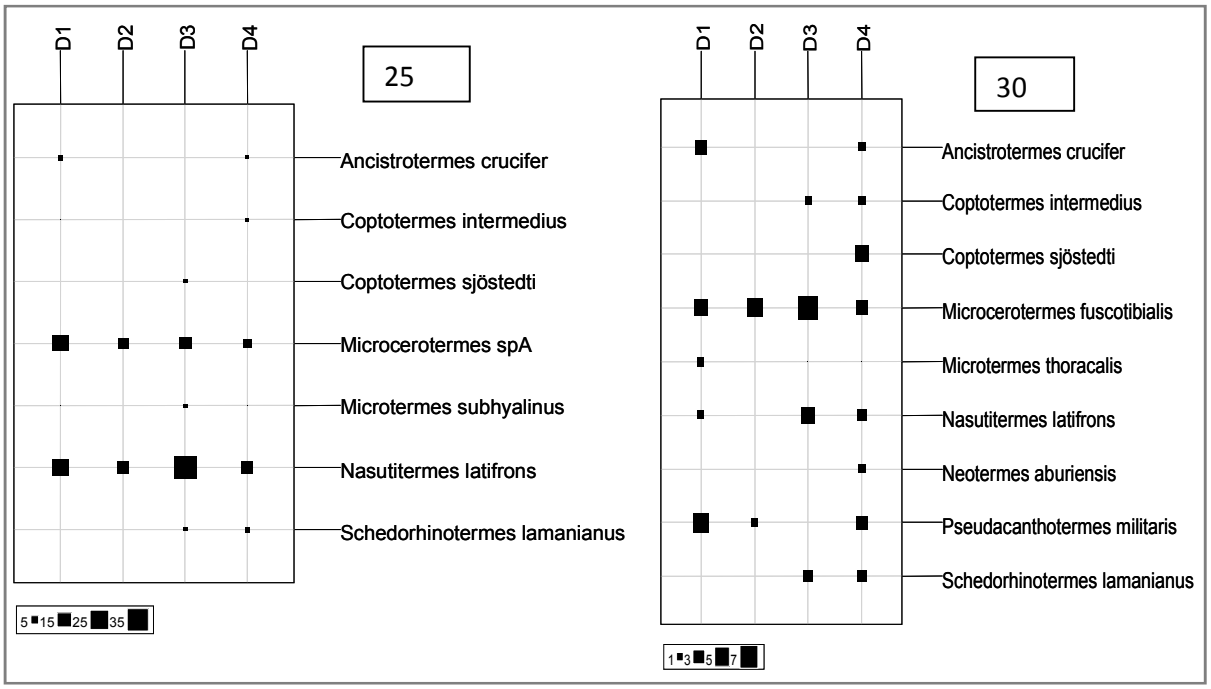
D1:damage of type 1; **D2** :damage of type 2; **D3**: damage of type 3; **D4**:damage of type 3.

Figure 4. Abundance of the various species of termites according to the type of damage on the plot of less than one year and 5 years. The plot of less than one year and 5 years



D1:damage of type 1;**D2**:damage of type 2**; D3**:damage of type 3;**D4**:damage of type 4.

Figure 4. Abundance of the various species of termites according to the type of damage on the plot of less than one year and 5 years. The plot of less than one year and 5 years



D1 :damage of type 1**; D2:** damage of type 2**, D3** :damage of type 3; **D4 :** damage of type 4

Figure 6. Abundance of the various species of termites according to the type of damage on the plots of 25 and 30 years

This species, which is responsible for the four types of damage, is involved in 66.66% of the attacks, 112 feet infested on 168. In this plantation, *A. guineensis* caused only type I damage (Figure 4a). Six (6) species attacks cocoa trees in the 5years old plantation: *A. crucifer*, *A. guineensis*, *M. fuscotibialis,M. subhyalinus, N. latifrons*, and *P. militaris* (Figure 4b). *A. crucifer* and *M. fuscotibialis* are responsible for the four types of damage. In the 8 years old plot, there are fewer types 3 and 4 damage (Figure 5a). They are mainly caused by *A. crucifer, A.guineensis, C. sjöstedti, M. subhyalinus* and *N. latifrons*. Among them, the most aggressive species is *M. subhyalinus* involved in 4 and 5 damages respectively types 3 and 4.The 20 years old plantation is affected by *Microcerotermes* sp1. This species causes the majority of damage to the cocoa tree, with 14 damagesof types 3 damage. The species *Microcerotermes* sp1 and *N. latifrons* dominate the stand in the 25 years old plantationand are responsible for damages types 4 (Figure 6a). *N. latifrons* is very harmful to the cocoa trees at this stage of its development. It is involved in 38 damagesof type 3 and 10 damages of type 4. *Microcerotermes* sp1 with 11 damage oftype 3 and type 4. Is one of the species harmful to cocoa.As in the 25years old (plantation), *M. fuscotibialis* appears to be detrimental to advanced-aged (30 years) cocoa trees (Figure 6b). This caused 8 damage of type 3 and 5 damageof type 4.*N. aburiensis* was found in the respective 20 years old and 30 yearolds plantation with damage of type 4. This is also the case of *C. sjöstedti* responsible for damage of type 4 in older farms. *S. lamanianus,* poorly represented in plantations, causes only damage of type 3 and 4 (Figure 4b, 5a and 5b).

DISCUSSION

A total all cocoa farms comprises, 13 genera and 20 species are collected. All species have already been reported in different studies in Ivory Coast (Bodot 1966; Josens 1972; Sangaré and Bodot 1980; Tano 1993; Kouassi 1999; Boga 2007). Termites are very well represented on older cocoa trees, notably *C. sjöstedti* (Harris 1966), *S. lamanianus* (Harris 1968).

According to this author*, S.lamanianus* would not be able to feed on live wood. This observation is partly verified on the 25-years old plot. This species was found on weak resistance feet (partially faded, dry, injured) causing type 4 damage. On the other hand, some feet in perfect physiological state were the same types of damage. The high rate of cocoa plantation infestation is thought to be due to the decrease in plot maintenance and the decline in the use of plant protection products due to the declining purchasing power of farmers.

In the plantation of less than one year, *M. toumodiensis* causes all the damage to the seedlings. Han *et al.,* (1998) and Tahiri (2010) also showed that in perennial crops (oil palm and rubber tree), young cultivated feet are most prone to termite attack, especially those of the fungus-growers group. Mora (1992) reports that the genus *Microtermes* is very harmful in plantations. Thus, the age of the plantations would be a determining factor during termite attacks in cultivated areas. *Microcerotermes* proliferates rapidly in old plantations by the construction of numerous harvesting galleries and arboreal nests (Leponce 1996; Ndiaye 1998). The attack of termite cocoa trees would be favored by the relative abundance and quality of food present in the environment and especially of the type of crop (monoculture). In this regard, Jactel *et al.,* (2014) reports that insect attacks and damage in monoculture forests are significantly higher than those of mixed-species forests (polyculture). The species *N. aburiensis* does not build a nest, it digs the dead wood or more or less altered. It attacks older cocoa trees digging galleries in the wood. Cachan (1950) observed *Proneotermes madagascaquiensis* inside cacao branches in Madagascar. According to this author, the zones of attack of these termites constitute foci of contaminations and proliferation of other harmful insects. Attacks that can lead to decreased production and plant death are caused by Type 3 and Type 4 damage. The cacao trees of 5 years and 8 years of age are the least attacked, unlike the young plants and the feet of 20, 25 and 30 years. This resistance to attack could be explained by the strong growth activity that gives the plant its vigor. Mora (1992) reports that termite attacks in sugarcane

plantations in Central Africa are directed towards young plants. In cocoa cultivation, termites preferentially attack the diameter class [20-30 cm] and] 30-40 cm]. These targeted attacks would explain the high rate of damage to plantations of 25 and 30 years. Mikus *et al.,* (1997) showed that *S. lamanianus* on *Paramacrolobium coeruleum* (Cesalpiniacea) only attacked trees between 30.5 cm and 51.3 cm in diameter. On our plots, S. lamanianus was observed only on the feet of diameter varying between 29.44 and 36.76 cm. Like *S. lamanianus, C. sjöstedti* selects diameter tree classes during attacks (Apolinario *et al.,* 2004; Werner *et al.,* 2007). It mainly attacks the feet of diameter between 20 and 30 cm in our experimental plots.

Conclusion

Termites attack cocoa trees regardless of age. Young (seedling) and older plants are the most attacked. It appears that *M. toumodiensis* infested young cocoa trees (seedlings). On the other hand, *C. sjöstedti, C. intermedius, M. fuscotibialis* and *N. latifrons* cause damage to aged cocoa trees.Of all termites, xylophages group reveal themselves the most harmful by their irreversible action. To reduce harmful action of termites cocoa plantation, preventive control against these pests is desirable. The regular weeding and reasoned insecticides use is privileged.

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