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Attacks and damage of termites (Insecta: Isoptera) in different cocoa agroforestry systems (Nawa, Côte d'Ivoire).

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1 ABSTRACT
To maintain its status of leading producer of cocoa in the world, Côte d'Ivoire must be contain the different types of threats, including the emergence of termites in cocoa farms. This study was conducted in the south-west of the country to evaluate the effect of cropping systems (full sun system, intermediate system and shaded system) on termite attacks. The study was conducted in four localities with different cocoa agroforestry systems. The sampling was made on cocoa trees in quadrats of 30mx30m and the attack rate was calculated. Eleven (11) termite species were identified. The wood-feeders groups were dominant. These termites were responsible for 41.82% of the damage on cocoa trees. Termite Attacks vary between different cropping systems. Full sun systems were most attacked comparing to intermediate shade systems that were least attacked by termites. This work shows that the shade system has an effect on termite attacks in cacao trees. The choice of right system can help to significantly reduce termite attacks in cocoa farms.

2 INTRODUCTION
Cocoa is a commercial crop of great importance around the world. With a worldwide production of more than 4 million tons of beans in 2019, cocoa has become a vital export product for many countries, especially in West Africa (Vos *et al.,* 2003, ICCO, 2019). Two-thirds of world cocoa production is grown in Africa and the majority is produced by Côte d'Ivoire and Ghana. Côte d'Ivoire supplies about 40% of the world supply of cocoa beans and has been leader producer among the 50 or so produce countries for more than 30 years (Anonymous, 2007). Cocoa cultivation occupies a key place in the economy and is a main source of income for thousands of small farmers in rural areas. Cocoa cultivation accounts 40% of export earnings and contributes more than 15% to Gross Domestic Product (Dufumier, 2016). In the Nawa' region of the country' south-west, which is now considered as the new Ivorian cocoa loop, much agricultural exploitation supports thousands of people. This crop is now subject to high parasite pressure due to diseases and pests (Tra Bi, 2013). The most common cacao pests in Côte d'Ivoire are mirids, stem borers and brown pod rot. To this, the swollen shoot advent and the termites emergence wreak havoc in cocoa farms. In Côte d'Ivoire, there is little data on termite attacks on cocoa trees.
Termite's impact is important in tropical soils evolution (Bignell and Eggleton, 2000). They influence pedogenesis, physicochemical

properties and soil functions (Su, 2002). Termites are also considered important decomposers in the semi-arid tropic areas where they are an important role in nutrient cycle (Holt, 1996). In spite of their important roles in ecosystems, termites are also known for the damage they cause. According to Wood (1976), termites are one of the largest groups of pests. About 10% of termite species have negative impacts on homes and crops (Constantino, 2002). Termite crop losses are enormous and are in the range of 20-45% (Wood and Pearce 1991). In Côte d'Ivoire, Akpesse *et al.* (2001) showed termite damage on rice and maize crops. In cocoa farms, Tra bi *et al.* (2013) showed that termites are veritable attackers of cocoa trees in Oumé area. Termite attacks in cocoa farms are growing year by year due to massive deforestation and climate change. Given that overriding interest of cocoa farming, it is important to identify termite's pest's species in cocoa agroforestry systems and to assess the importance of termite damage in different agroforestry systems in order to develop cocoa agroforestry system allow to limit the risk of termite attacks and the development of adequate control methods.

3 MATERIAL AND METHODS

3.1 Study area: This study was conducted in four localities in the Nawa region of southwestern Côte d'Ivoire (**Figure 1**). Sixteen (16) cocoa plots were selected in the four localities at the rate of four (4) plots per locality. The Plots differ from one locality to another depending on shade intensity. In the localities of Takoragui (05° 45' 18" N, 06° 47' 30" W) and Gnaboya (06° 04' 31" N, 6° 54' 35" W), respectively the full sun system and the shaded system were selected. The localities of Petit Bouaké (05° 56' 47" N, 06° 19' 46" W) and Bobouho 1 (05° 35' 33" N, 06° 01' 53" W) are characterized by and intermediate system. Between the two cropping systems, the first is close to full sun system (Petit Bouaké) while the second is close to shaded system (Bobouho 1). Nawa region is one of the largest areas of cocoa production in Côte d'Ivoire. It accounts for about 20% of national production of cocoa beans. This region is located in Guinean forest area and has a typical equatorial climate. The region is characterized by two rainy seasons and two dry seasons. The rainy seasons are from April to June and September to October, while the dry seasons are from November to March and July to August. The annual rainfall varies between 1600 mm and 2000 mm. the average temperature varied from 24 ° C and 27 ° C. The soils of the region are ferralitic types (Ageroute, 2013).

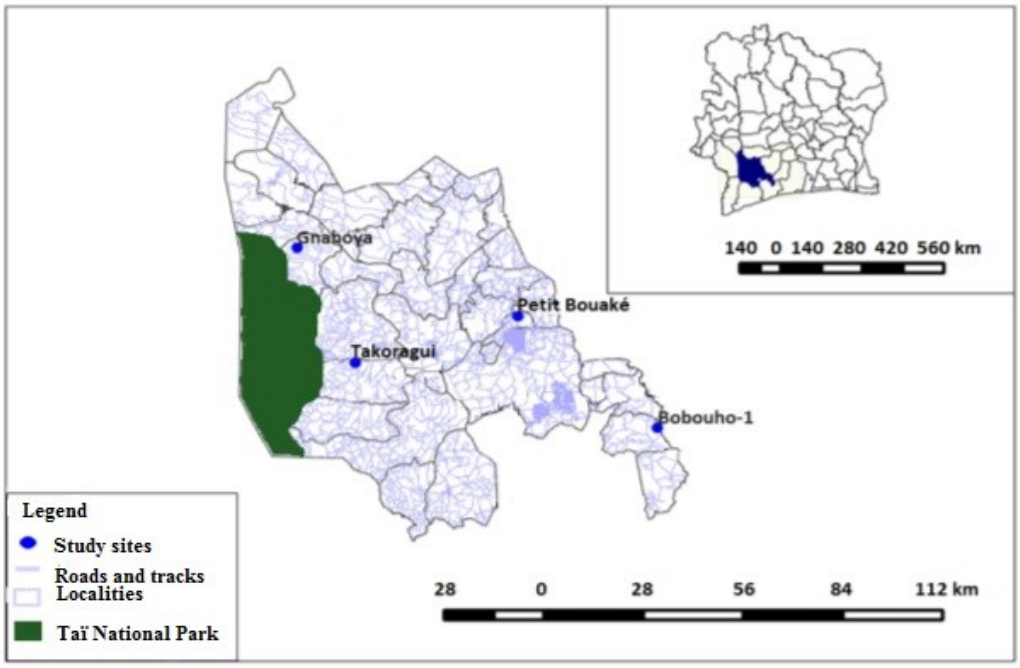


Figure 1: Localisation of the study area

3.2 Data sampling: Termites were collected on cocoa trees (young, mature and aged cocoa trees) in quadrats of 30mx30m. In each cocoa plot, four (4) quadrats of 30mx30m were installed and in each locality, four (4) plots were selected. In total, sampling was carried out in sixty-four (64) quadrats. For each sampling unit, termites were collected from roots, stems, fissures, nests, galleries and cocoa veneers. The presence of trace, veneer, gallery or termite nest on a cocoa tree was considered as an attack. All cocoa trees in the sampling area were examined to determine the proportion of these cocoa trees with termite damage.

3.3 Termite identification: Termites harvested were identified in the laboratory of biology and tropical ecology of the University Jean Lorougnon Guédé of Daloa. Specimens were determined up to the level of species using various documents such as Hamad (1950), Bouillon and Mathot (1965), Sands (1965, 1972, 1998). After identification, each species was classified into one of the trophic groups.

3.4 Data analysis: Termite attack rate is estimated based on the principle of Han and Ndiaye (1996). Organ is said to be attacked when it carries galleries or veneers with or without termites. Termite attacks on cocoa trees have been classified into 2 groups. The classification was based on the density of the veneers and especially on the progression of termites in the anatomical structures of the plant. Thus, cocoa trees were classified into three categories: (0) absence of termites, (1) presence of tracks, nest and superficial damage (type I damage), and (2) internal damage, i.e. damage below the bark (type II damage).

Termite attack rate by locality were calculated according to the following formula:

Ta= Npa x 100 / Ntp

Ta = Termite attack rate by locality

Npa= Number of cocoa feet with termite attacks

Ntp = Total number of cocoa feet observed by locality.

The frequencies obtained made it possible to group species into different classes based on the coding of the frequencies index (Ouedraogo *et al.*, 2015).

Data were subjected to variance (ANOVA) analysis and were compared with the Kruskal-Wallis test at 5% threshold with statistica software version 7.1.

4 RESULTS

4.1 Termite's diversity: A total of 11 termite species grouped divided into 7 genera, 4 subfamilies and 3 families were collected into cocoa plants (Table 1). Wood-feeders with 7 species are the most diversified. Three species of fungus-growers were harvested. Grass-feeders are least represented with one species. Two species are common to all localities: *Microcerotermes fuscotibialus* and *Nasutitermes arborum*. Gnaboya' locality with 6 species, records the largest number of termite species. Wood-feeders termites were the most common group in the four localities with rates ranging from 80 to 100% of the sampled population (table 4). Fungus-growers rate was greater in the shaded system (Gnaboya) with 20% of populations sampled compared to 3.03% in full sun system (Takoragui). This group does not exist in intermediate shade systems. The last group (grass-feeders) was observed only in the intermediate shade system (Petit Bouaké) with 4.54% of the samples collected.

Table 1: List of termite species collected in cocoa trees of the different habitats

Family	Sub-family	Species	Takoragui	Petit Bouaké	Bobouho 1	Gnaboya	TG
Rhinotermitidae	Rhinotermitinae	*Schedorhinotermes lamanianus*			*		X
Termitidae	Macrotermitinae	*Ancistrotermes cavithorax*				*	C
		Ancistrotermes guineensis	*			*	C
		Microcerotermes fuscotibialus	*	*	*	*	X
		Microcerotermes parvus		*			X
		Microtermes thoracalis				*	C
	Nasutitermitinae	*Nasutitermes arborum*	*	*	*	*	X
		Nasutitermes diabolus	*			*	X
		Nasutitermes latifrons	*	*	*		X
		Trinervitermes geminatus		*			F
Kalotermitidae	Kalotermitinae	Postelectrotermes sordwane			*		x
Total		11	5	5	5	6	

C: fungus-growers; H: Soil-feeders; X: Wood-feeders; F: grass-feeders; TG: Trophic group

Table 2: Rate of the different trophic groups in the different localities (%)

Locality	Takoragui	Petit Bouaké	Bobouho 1	Gnaboya
Fungus-growers	3.03	-	-	20
Wood-feeders	96.97	95.45	100	80
Grass-feeders	-	4.54	-	-

4.2 Assessment of termite attacks on cocoa trees in different agroforestry systems: Eleven (11) species of termite collected are responsible for 41.82% damage on cocoa trees. Traces of termite activities have observed in a large number of cocoa trees in the different shade systems. Termite attacks mainly concern the roots, the stems and the branches of cocoa trees. Data analysis showed a significant difference between termite attacks in different shade systems ($p = 0.001$, Kruskal-Wallis test). Termite attacks are higher in the full sun system, while the intermediate systems have least attacked. In intermediate management systems, the average attack rate is 29.1% and 27.87% respectively for the localities of Petit Bouaké and Bobouho 1. However, in the full sun system, the average infestation rate was 61.49%. In shaded systems, the infestation rate was 44.32%. Two categories of damage were observed on cocoa trees (figure 2). Minor damage (T1) with 87.97% of rate on the damage observed is the largest, while Major Damage (T2) accounted for 12.03% of damage

to cocoa trees. The categories (two) of damage are higher in full sun systems (T1=54.23%; T2=7.26%) (Figure 3). The lowest rates of the two categories of damage were observed in the intermediate systems. In all cocoa trees observed, 36.79% of cocoa trees bear Type I of termite attacks while the major damage accounts for 5.03% of the cocoa trees. There was a rate of 58.18% of healthy cocoa trees. From the analysis of quantitative results, it appears that type I damage is numerically higher compared to type II damage in all localities. However, these types of attacks differ and vary according to age of the plantations and shade system type. Attack rate of the 11 species were compared across shade systems to identify the most aggressive species on cocoa trees. In all management systems, the average attack rate of the termite species is statistically identical (ANOVA, p = 0.057). However, the comparison of termite attacks by locality and species reveals that the species *Nasutitermes latifrons* and *Nasutitermes diabolus* are the most aggressive species in the full sun system (figure 4). In the intermediate shade systems *Nasutitermes latifrons, Nasutitermes arborum* and *Microcerotermes fuscotibialus* species caused the most damage. The species *Nasutitermes diabolus, Nasutitermes arborum* and *Microcerotermes fuscotibialus* are the termites caused the most damage in the shaded system (table 3), termite species can be divided into four classes at Petit Bouaké; three classes in Takoragui and Gnaboya; two classes at Bobouho 1 (Table 4). Thus, at Takoragui two accessory species, one accidental species and two very rare species were sampling. The first intermediate system (Petit Bouaké) contends one quite common species, one accessory species, one accidental species and two very rare species. Three accessory species and two very rare species characterize the second intermediate system (Bobouho 1) and the shaded system in which we also find an accidental species.

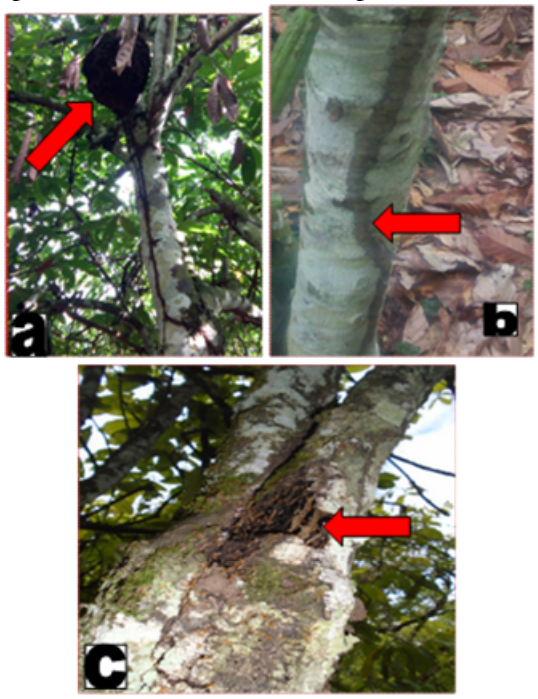
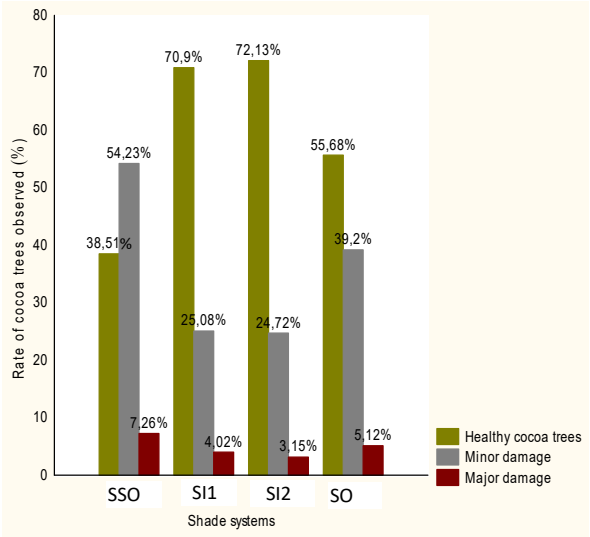
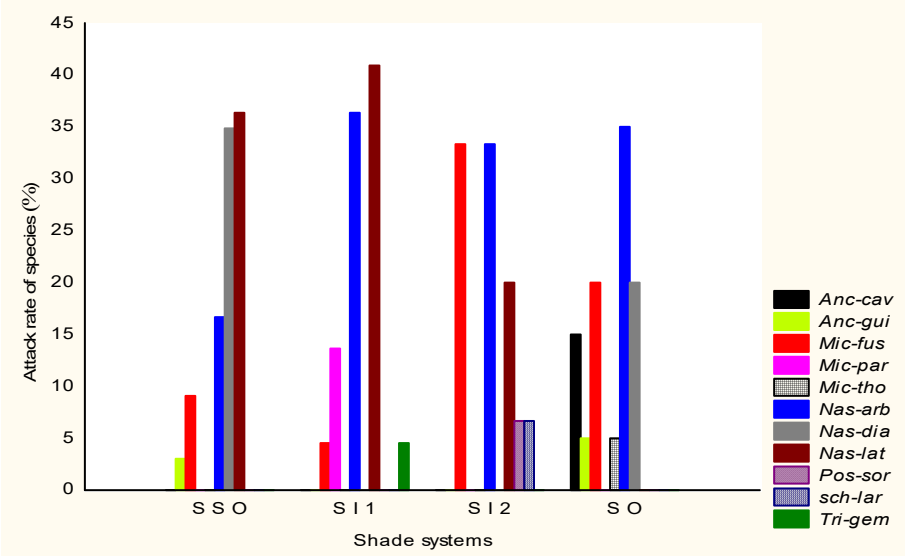


Fig. 2: Termite damage on cocoa trees (b: minor damage; a & c: major damage)



SSO : Full sun system ; SI : Intermediate system ; SO : Shaded system

Fig.3: Type of damage observed on the cocoa trees



Anc-cav : Ancistrotermes cavithora ; Anc-gui :Ancistrotermes guineensis ; Mic-fus : Microcerotermes fuscotibialus ; Mic-par : Microcerotermes parvus ; Mic-tho : Microtermes thoracalis ; Nas-arb : Nasutitermes arborum ; Nas-dia : Nasutitermes diabolus ; Nas-lat : Nasutitermes latifrons ; Pos-sor : Postelectrotermes sordwane ; Sch-lar : Schedorhinotermes lamanianus ; Tri-gem : Trinervitermes geminatus. ; SSO: Full sun system; SI: Intermediate system; SO: Shaded system.

Fig. 4: Attack rate according to termite's specie

Table 3: Codification of rate indexes (Ouedraogo *et al.*, 2015)

Frequency classes (%)	
F < 10	Very rare species
10 < F < 20	Accidental species
20 < F < 40	Accessory species
40 < F < 60	Quite frequent species
60 < F < 80	Frequent species
F > 80	Very frequent species

Table 4: Classification of species according to frequencies

Frequencies (%)	Characteristics	Full sun system (Takoragui)	Intermediate system(Petit Bouake)	Intermediate system (Bobouho 1)	Shaded system (Gnaboya)
40 < F < 60	**Quite frequent species**		*Nasutitermes latifrons* (40.91%)		
20 < F < 40	**Accessory species**	*Nasutitermes diabolus* (34.85%) *Nasutitermes latifrons* (36.36%)	*Nasutitermes arborum* (36.36%)	*Microcerotermes fuscotibialus* (33.33%) *Nasutitermes arborum* (33.33%) *Nasutitermes latifrons* (20%)	*Microcerotermes fuscotibialus* (20) *Nasutitermes arborum* (35%) *Nasutitermes diabolus* (20%)
10 < F < 20	**Accidental species**	*Nasutitermes arborum* (16.67%)	*Microcerotermes parvus* (13.65%)		*Ancistrotermes cavithorax* (15%)
F < 10	**Very rare species**	*Ancistrotermes guineensis* (3.03) *Microcerotermes fuscotibialus* (9.09)	*Microcerotermes fuscotibialus* (4.54%) *Trinervitermes geminatus* (4.54%)	*Postelectrotermes sordwane* (6.67%) *Schedorhinotermes lamanianus* (6.67%)	*Ancistrotermes guineensis* (5%) *Microtermes thoracalis* (5%)

5 DISCUSSION

Eleven (11) species of termites on cocoa trees in the four cocoa agroforestry systems were sampled. These results are similar to those obtained by Ano *et al.* (2018) and very close to the result of Tra Bi (2013) who obtained respectively 11 species and 12 species in the cocoa plantations of Abengourou for the first and Oumé for the second. Most of these species belonging to the wood-feeders and fungus-growers. These two groups of termites are responsible for the damage observed on mango trees in northern Côte d'Ivoire (Coulibaly *et al.*, 2014). No soil-feeders species were harvested from cocoa trees. The species of *Microcerotermes fuscotibialus* and *Nasutitermes arborum* are common to all localities. These species build galleries that show perforations in the bark of infested cocoa trees that often cause their death. The work in tropical Africa has shown that Macrotermitinae (Mora *et al.*, 1990, Wood and Pearce, 1991) and Nasutitermitinae (Pretorius *et al.*, 1991, Mampouya, 1997) are responsible for important plantation damage. According to the results, most of the infestations are type I (87.97% of the cocoa trees attacked). These results are in agreement with those obtained by Coulibaly *et al.* (2018) who observed higher rates of Type I termite damage on trees at the Korhogo University campus in northern Côte d'Ivoire. This high rate is due to the attack mode of different species of termites. Indeed, most termites build veneers on the trunks of plants. These veneers serve as protection to attack the plant (Gbenyedji *et al.*, 2016). The evaluation of termite attack rates showed that attacks were more common in full sun systems (61.49%), while in intermediate management systems were the least attacked. The attack rate of termites is variable according to plots and shade systems. Cocoa farmers who estimated that termite infestations increased with the growing elimination of shade trees (Djuideu *et al.* 2019) observed this state of fact. The high rate of termite attacks in full sun systems could be explained by the vulnerability of the full sun system from attack of insect pests. The plots of full sun systems in the study area are older plantations and this could have an effect on installation and termite attacks. Tra bi (2013) showed that the age of plots influence termite attacks. Anani Kotoklo *et al.* (2010b) observed that the incidence and intensity of termite attacks vary according to the species, the locality and the edaphic factors. Termite attacks can be related on nature of soil (ferralitic red soil) that would favour the installation of termite mounds, sources of plant infestations (Gbenyedji *et al.*, 2016). The study showed that intermediate systems are the least attacked by termites, especially those close to shaded systems. Indeed, the plots of this system recorded less termite attack than the plots of other management systems. This low attack rate of termites in this intermediate system very close to the shaded system could be explained by composition and complexity of this system. Several factors, including the shade and diversity of shade trees, would also influence termite's installation in these plots. Face to the proliferation of termites in cocoa plantations, intermediate management systems could reduce the emergence of termites and limit the risk of attack.

6 CONCLUSION

This study highlights the effect of cultivation systems on termite attacks and show that termites are important pests for cocoa farming. Eleven species of termite's pests were collected from cocoa trees in different shade systems. These termites were responsible for 41.82% of attacks on cocoa trees. These species were classified into three trophic groups in which, Wood-feeders were the most important. The results obtained show that the type of agro system cultivation influences the termite attack.

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