Scientific Research Publishing

American Journal of Plant Sciences, 2024, 15, 996-1009
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

# Termite Attack and Damage in Cocoa Plantations in Daloa Department, Central-Western Côte d'Ivoire

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**How to cite this paper:** Siapo, Y.M., Ano, E.J., Diby, Y.K.S. and Tahiri, A.Y. (2024) Termite Attack and Damage in Cocoa Plantations in Daloa Department, Central-Western Côte d'Ivoire. *American Journal of Plant Sciences*, **15**, 996-1009.
https://doi.org/10.4236/ajps.2024.1510063

**Received:** May 22, 2024
**Accepted:** October 26, 2024
**Published:** October 29, 2024



## Abstract

Cocoa farming faces numerous constraints that affect production levels. Among these constraints are termites, one of the biggest scourges in tropical agriculture and agroforestry. The aim of this study is to assess the level of damage caused by termites in cocoa plantations. To this end, 3 plantations were selected. In each of the 3 plantations, 18 plots containing an average of 47 ± 6 cocoa plants were delimited. Sampling was based on 25 cocoa plants per plot. The study consisted in sampling the termites observed on the plants and noting the type of damage caused by them, taking into account the density of the harvest veneers and, above all, the termites' progress through the anatomical structures of the plant, *i.e.* the bark, sapwood and heartwood. A total of 8 termite species were collected from cocoa plants. These species are responsible for four types of damage (D1, D2, D3 and D4), grouped into minor damage (D1 and D2) and major damage (D3 and D4). D1 damage ranged from 24.67% ± 5.64% to 39.55% ± 7.43%. D2 damage ranged from 6.88% ± 1.31% to 9.33% ± 2.79%. D3 damage ranged from 2.88% ± 1.55% to 6.44% ± 1.55%. D4 damage ranged from 1.11% ± 1% to 3.11% ± 1.37%. Among the termite species collected, Microcerotermes sp, *C. sjostedti*, *A. crucifer* and *P. militaris* were the most formidable on cocoa trees in our study locality. In view of the extensive damage caused by termites, biological control measures should be considered, using insecticidal plants.

## Keywords

Termites, Attacks, Damage, Cocoa Trees, Côte d'Ivoire

## 1. Introduction

Cocoa is an export product of major interest worldwide. In Côte d'Ivoire, cocoa is a product of strategic importance for economic and social development, as well as an important instrument in the fight against poverty [1]. Indeed, cocoa accounts for 30% of the country's export earnings and represents between 15% and 20% of Gross Domestic Product (GDP) [1]. Cocoa farming employs 700,000 farmers and provides a livelihood for around five (5) million people, *i.e.*, 25% of the Ivorian population [2].

Despite this remarkable performance, the sustainability of cocoa farming in Côte d'Ivoire is compromised by numerous constraints, such as the ageing of cocoa trees and pest attacks [1]. Pest attacks involve diseases, insect pests, rodents and parasitic plants. In terms of diseases, Swollen shoot viral disease transmitted by mealybugs and brown pod rot due to *Phytophthora spp.* are the most significant, with over 23% and 60% damage, respectively [3] [4]. With regard to insect pests, an inventory of the cocoa entomofauna showed the presence of termite pests [5], mirids, green bugs, defoliator caterpillars, stem and pod borers, and several other minor predators [2] [6].

Termites are one of the major scourges of tropical agriculture and agroforestry [7] [8]. Damage caused by termites is considerable, and repair costs are estimated at over 22 billion euros each year [9].

In Côte d'Ivoire, termites regularly attack and destroy food and industrial crops, such as rubber [10], mango [11], rice [12], papaya [13] and cocoa [5].

Several methods are used to curb termite attacks. Among these methods, natural enemies such as ants are favoured [14] [15]. Entomopathogenic fungi such as *Metharizium anisopliae* [16] and *Beauveria bassina* [17] have been used in the laboratory. Synthetic pesticides such as chlorpyrifos-ethyl [10], fipronyl [18] and thiamethoxam [19] were used. The plant extracts *Azadirachta indica* [20], *Calotropis procera* [11] and *Tithonia diversifolia* and *Senna occidentalis* [21] were tested effective against termites.

In view of termite attacks and the various control methods proposed by several authors [16]-[21], it is important to ask what the current level of termite damage in cocoa trees is.

In Côte d'Ivoire, studies carried out on termite attacks in cocoa plantations concern the departments of Oumé [22], Abengourou [23], Tiassalé [24], Man and Biankouma [25]. However, few studies have been carried out on termite attacks in cocoa trees in the Daloa department, one of the areas of high cocoa production in Côte d'Ivoire. The aim of this work is to assess the level of damage caused by termite pests in cocoa plantations in the Daloa department.

## 2. Methodology

### 2.1. Study Area

The study was carried out in Daloa, 385 km north-west of Abidjan. Daloa is characterized by a hot, humid tropical climate with rainfall ranging from 1000 to 1500

mm per year [26]. The soil is ferralitic, derived from clay-rich quartzite schists, with good water retention capacity. The mean annual temperature is 25.6˚C. Sampling was carried out in three cocoa plantations in the Djèkro camp on the Daloa-Abidjan axis between Daloa and Gonaté (Figure 1).

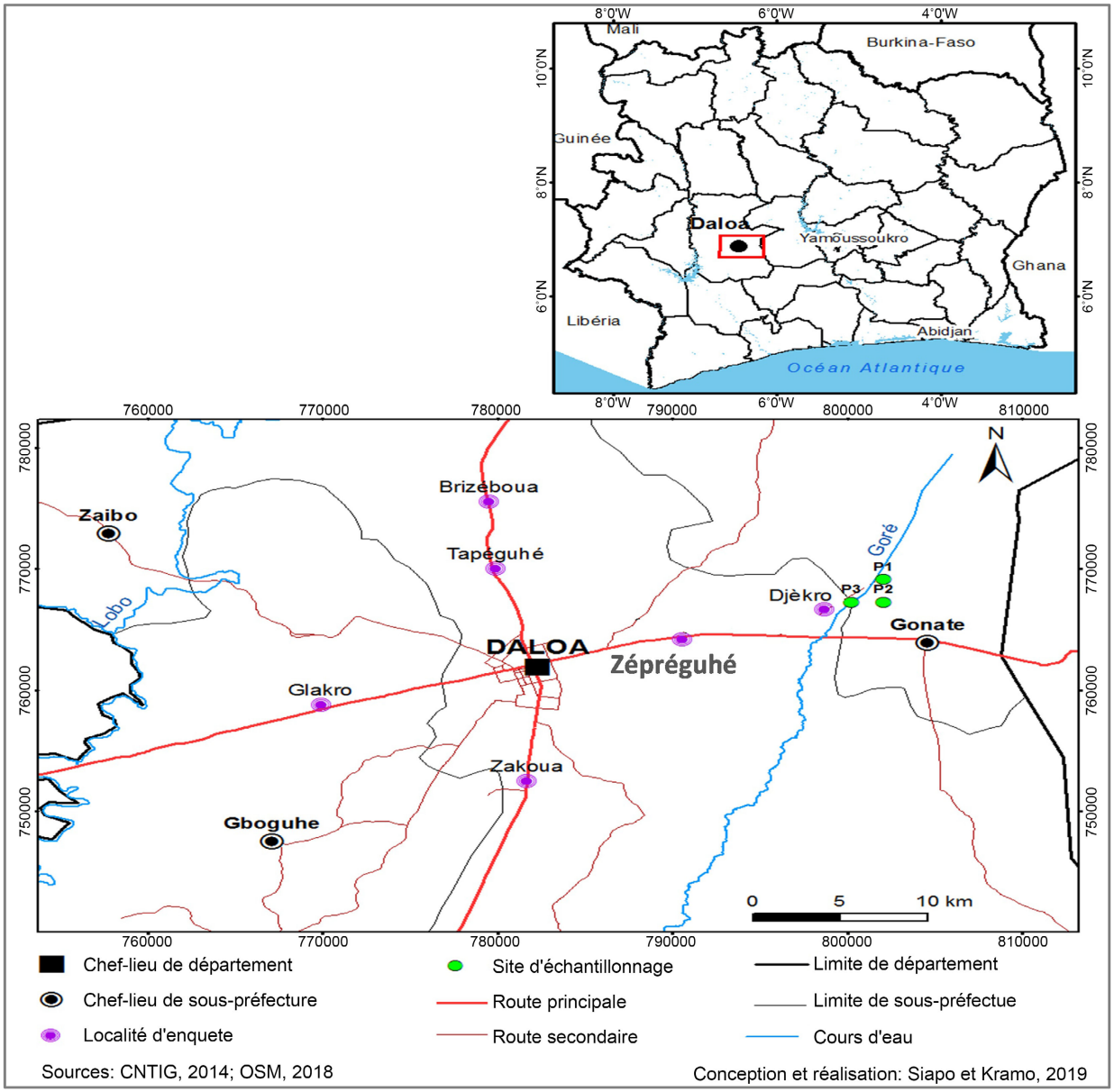


Figure 1. Map of sampling site locations.

## 2.2. Characteristics of Sampled Plantations

The plantations sampled have different cocoa varieties and have undergone different insecticide treatments (Table 1).

## 2.3. Termite Sampling on Cocoa Trees

The study was carried out in the three (3) plantations, P1, P2 and P3 of the Djèkro

camp in the Daloa department from December 2017 to June 2018. The experimental set-up used was a Fisher block in complete randomization with three (3) replications. In each of the 3 plantations, 18 plots containing an average of 47 ± 6 cocoa plants were delimited. Sampling was carried out on 25 cocoa plants per plot. In all, 450 cocoa plants (25 plants × 18 plots) were observed in each of the 3 plantations, making a total of 1350 plants (450 × 3 plantations) in all 3 plantations. The study consisted firstly in sampling the termites observed on the cocoa plants and noting the type of attack caused by them. The soil was then dug up to observe root damage and collect termites. The collected termites were preserved in labelled dry haematological tubes containing 70% ethanol. Termite attacks and damage in the various plots were estimated.

**Table 1.** Characteristics of sampled plantations.

| Cocoa plantations sampled | Cocoa variety used | Ages (years) | Crop history (sowing methods) | Number of manual weeding operations per year | Number of treatments | Chemical inputs used |
|---|---|---|---|---|---|---|
| P1 | "Tout-venant" | 15 | *Yam* (*direct sowing of seeds*) | 1 | 1 | Néonicotinoïde + Pyréthrinoïde |
| P2 | "Mercedes" | 8 | *Yam* (*nursery planting*) | 2 | 2 | Néonicotinoïde + Pyréthrinoïde |
| P3 | "Tout-venant" | 8 | *Yam* (*direct sowing of seeds*) | 2 | 2 | Néonicotinoïde et Néonicotinoïde + Pyréthrinoïde |

### 2.3.1. Estimating Termite Attack

The termite attack rate (Ta) is estimated on the basis of [16] principle whereby an organ is said to be attacked when it bears galleries or veneers with or without termites. The termite attack rate per plantation was calculated using the following formula:

$$\mathrm{Ta} = \frac{\mathrm{Npa}}{\mathrm{Ntp}} \times 100 \quad (1)$$

*Ta = Termite attack rate per plantation*;
*Npa = Number of plants attacked by termites*;
*Ntp = Total number of plants observed per plantation*.

### 2.3.2. Characterization of Termite Damage

Termite damage to cocoa trees is classified into 2 major groups. The classification is based on the density of harvest veneers and, above all, on the termites' progress through the plant's anatomical structures, *i.e.*, bark, sapwood and heartwood.

Minor damage: This damage is divided into D1 damage and D2 damage. Type D1 damage is characterized by harvesting (or prospecting) veneers, which are food reconnaissance veneers. They are characterized by a reduced number of veneers. Opening these veneers shows that the bark is in perfect health. Type D2 damage is characterized by sufficient coverage of the cocoa plant by harvest veneers. When these veneers are opened, the bark is degraded by termites that settle between the bark and the sapwood, often accompanied by sap flow.

Major damage: This damage is divided into D3 damage and D4 damage. D3 damage is characterized by termites settling in the sapwood. D4 damage is characterized by termites moving into the heartwood. Dead cocoa plants or decomposed trunks characterize this type of damage.

#### 2.3.3. Sorting and Identifying Termites

Identification was based on the soldier caste and the worker caste for termite groups lacking the soldier caste. The identification keys of [27]-[29] were used to identify the termites.

### 2.4. Statistical Analysis

In this study, a one-factor analysis of variance (ANOVA, $p < 0.05$) was performed using Statistica software (version 7.1), then the homogeneous means were grouped using Newman-Keuls tests. These tests were used to separate the environmental variables (termite attack and damage).

## 3. Results

### 3.1. Termite Pest Species

A total of 8 termite species were collected from cocoa plants in plantations P1, P2 and P3. The termite species collected on cocoa plants belong mainly to the fungus gnat and wood-boring trophic groups. With 5 species, fungus gnats have the highest species richness. Three xylophagous species were collected. Six of the 8 species are common to all the plantations sampled: *Coptotermes sjostedti*, *Ancistrotermes crucifer*, *Ancistrotermes guineensis*, *Microtermes* sp1, *Pseudacanthotermes militaris* et *Miceocerotermes sp*. Plantation P1, with 8 species, records the highest number of species harvested, while plantation P2 is the least rich, with 6 species harvested (**Table 2**)

**Table 2.** Distribution of termite species on cocoa plants in different plantations.

| Families | Subfamilies | Species | P1 | P2 | P3 | GT | Nid |
|---|---|---|---|---|---|---|---|
| Rhinotermitidae | Coptotermitinae | *Coptotermes sjostedti* | * | * | * | X | H |
| Temitidae | Macrotermitinae | *Ancistrotermes crucifer* | * | * | * | C | H |
| | | *Ancistrotermes guineensis* | * | * | * | C | H |
| | | *Microtermes* sp1 | * | * | * | C | H |
| | | *Microtermes* sp2 | * | | * | C | H |
| | | *Pseudacanthotermes militaris* | * | * | * | C | H |
| | Termitinae | *Microcerotermes sp* | * | * | * | X | A |
| | Nasutitermitinae | *Nasutitermes sp* | * | | | X | E |

GT: Trophic group; P1 = Plantation P1; P2 = Plantation P2; P3 = Plantation P3 A: Arboricolous, C: Mushroom termites, E: Epigeous termite, H: Hypogeous termites, X: Xylophagous termites, *: Presence.

### 3.2. Assessment of Termite Pest Attacks

A total of 1350 cocoa plants (*Theobroma cacao* L.) were examined in all three sampled plantations. Nearly 45.78% ± 11.32% of the sampled plants were attacked by termites. The highest rate of termite attack was recorded in plantation P1, which was 15 years old and consisted of "Tout-venant" cocoa trees. Plantation P2, made up of 8-year-old "Mercedes" cocoa trees, recorded the lowest attack rate. Analysis of variance revealed a highly significant difference ($P < 0.001$) between termite population attacks observed in the different plantations (Figure 2).

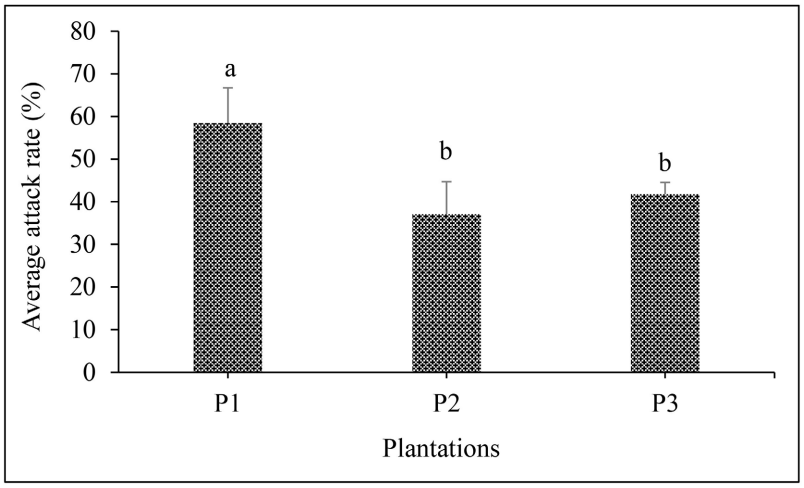


Figure 2. Average rate of termite attack in sampled plantations. Means followed by the same letter are not significantly different ($P < 0.05$).

### 3.3. Assessment of Termite Damage to Cocoa Trees

Four types of damage, D1, D2, D3 and D4, grouped into minor damage (D1 and D2) and major damage (D3 and D4) were recorded in the 3 plantations sampled. Damage classified as minor (D1 and D2) generally concerns superficial damage. Damage classified as major (D3 and D4) is damage that can affect the physiological state and production of the cocoa tree.

D1 damage was recorded in all 3 plantations sampled. This type of damage varied very significantly ($P < 0.001$) between the different plantations. The Newman-Keuls test revealed 2 homogeneous groups: the first group was made up of plantation P1, which recorded the highest rate of D1 attacks, while the second group was made up of plantations P2 and P3 (Figure 3(a)).

D2 damage was also observed in the 3 plantations sampled. The rate of this type of damage was low in the different plantations sampled and varied from one plantation to another. Analysis of variance followed by the Newman-Keuls test showed no significant difference ($P > 0.05$) between the rates of D2 damage observed in the 3 plantations (Figure 3(b)).

D3 damage was recorded in all 3 plantations sampled. Analysis of variance showed that the rates of these types of damage in the plantations were significantly different ($P < 0.05$). The Newman-Keuls test yielded 2 homogeneous groups. The

first group comprises plantations P1 and P3. The second group is represented by plantation P2 (Figure 3(c)).

D4 damage, the least represented numerically, was most abundant in plantations P1 and P3 (Figure 3(d)). Analysis of variance ($P < 0.05$) followed by the Newman-Keuls test showed that the rate of this type of damage can be classified into 3 groups, P1, P2 and P3. In these plantations, termites caused the death of 6 and 4 cocoa trees. In plantations P1 and P3, termites caused the death of 6 and 4 cocoa trees, respectively. Plantation P2 recorded the lowest rate of D4 damage, with the death of 4 cocoa trees due to termites.

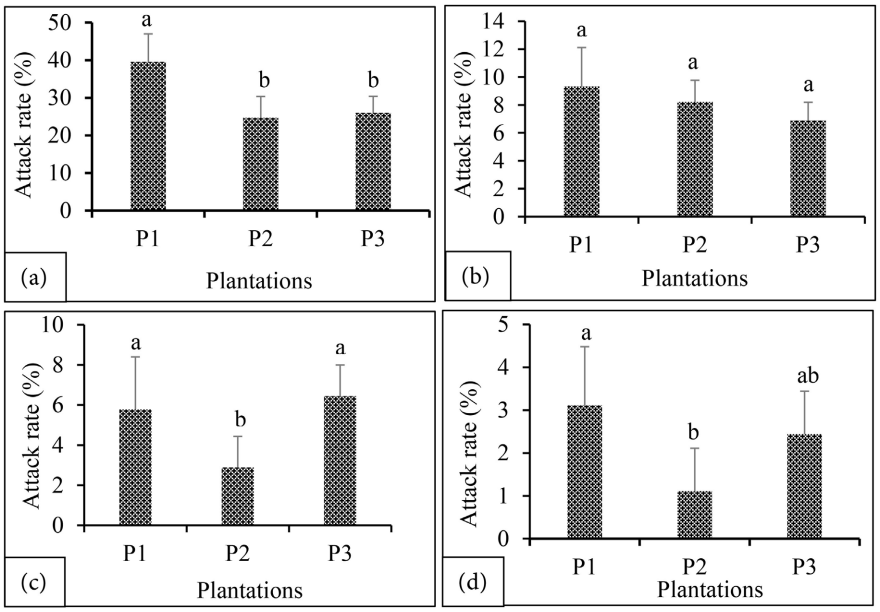


Figure 3. Distribution of different types of damage in sampled plantations. (a): Type D1 damage, (b): Damage type D2, (c): Damage type D3, (d): Damage type D4. Means followed by the same letter are not significantly different ($P < 0.05$).

## Termite Species Responsible for Major Damage

A total of 5 termite species are responsible for the major damage. These species are *P. militaris*, *A. crucifer*, *C. sjostedti*, *Microcerotermes sp* and *A. guineensis*.

In plantation P1, *P. militaris* and *A. crucifer* are the species causing the most damage. They were respectively responsible for 38.45% ± 24.19% and 31.54% ± 15.87% of attacks on "Tout-venant" cocoa trees. Two other species, *C. sjostedti* and *Microcerotermes sp*, also caused major damage, with 15.47% ± 16.06% and 10.47% ± 8.41% of attacks respectively. *A. guineensis* with 4.04% ± 6.41% of attacks were responsible for minor, major damage. Analysis of variance showed that the major damage caused by these termite species was significantly different ($P < 0.01$) (Figure 4).

In plantation P2, *A. crucifer* was the most damaging species, with a major damage rate on "Mercedes" cocoa trees of 43.05% ± 35.12%. It is followed by *C. sjostedti* and *P. militaris* with respectively 23.61% ± 20.01% and 25% ± 24.72% of major damage. *A. guineensis* with 4.16% ± 10.20% is the species responsible for

the lowest rate of major damage. Statistical analysis showed that major damage caused by these termite species was significantly different ($P < 0.05$) (Figure 5).

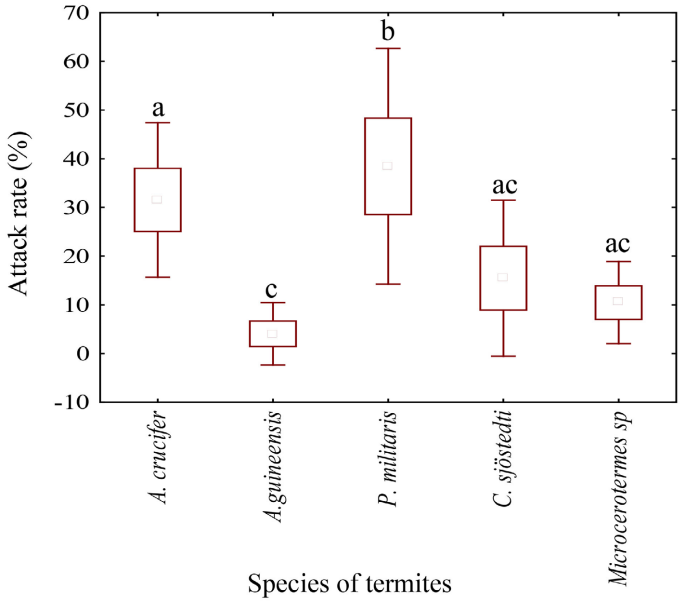


Figure 4. Distribution of termite species responsible for major damage in plantation P1. Means followed by the same letter are not significantly different ($P < 0.05$).

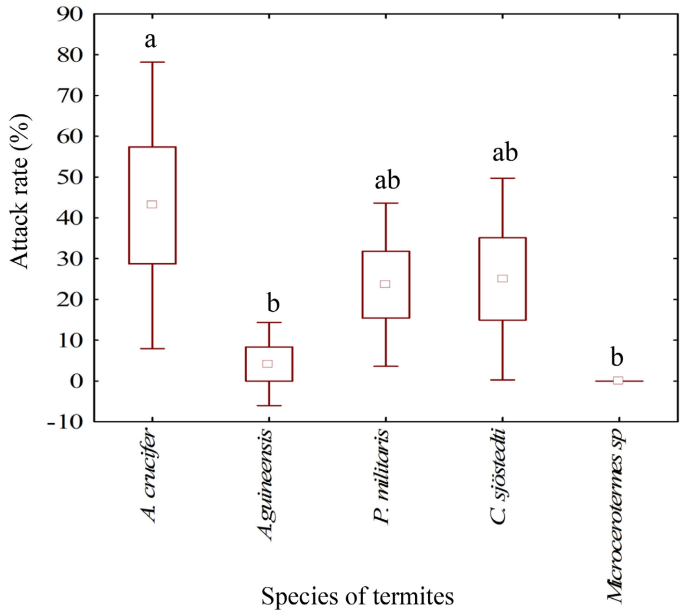


Figure 5. Distribution of termite species responsible for major damage in plantation P2 Means followed by the same letter are not significantly different ($P < 0.05$).

In plantation P3, *A. crucifer*, *P. militaris* and *C. sjostedti*, with 34.68% ± 10.56%, 29.68% ± 17.02% and 23.06% ± 16.08% respectively, caused most of the major damage to the "Tout-venant" cocoa trees. *Microcerotermes sp* (7.40% ± 8.36%)

and *A. guineensis* (5.15% ± 8.02%) also damaged cocoa plants. Analysis of variance indicates that the major damage caused by these species is statistically very different (P < 0.001) (Figure 6).

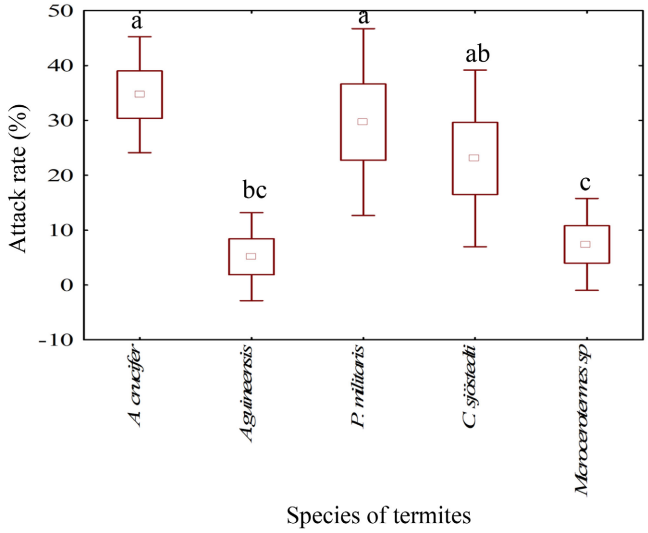


Figure 6. Distribution of termite species responsible for major damage in plantation P3. Means followed by the same letter are not significantly different (P < 0.05).

In all, *A. crucifer*, *P. militaris* and *C. sjostedti* caused most of the major damage to cocoa trees in the study area, with 33.61% ± 1.27%, 30.92% ± 3.69% and 21.75% ± 6.42% respectively. *Microcerotermes sp* with 6.67% ± 6.29% and *A. guineensis* with 5.18% ± 0.32% also damaged cocoa plants in the study area. Statistical analysis showed a highly significant difference between the major damage caused by the different species (P < 0.001) between plantation P1 and the other 2 plantations (P2 and P3) (Figure 7).

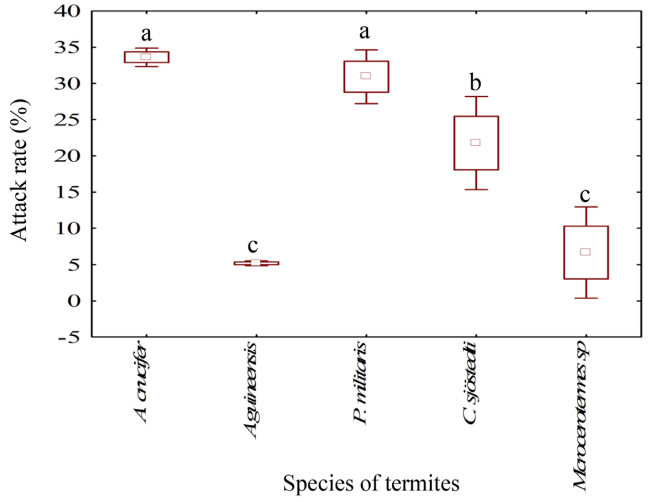


Figure 7. Distribution of termite species responsible for major damage in all plantations. Means followed by the same letter are not significantly different (P < 0.05).

In plantations P2 with "Mercedes" cocoa trees and P3 with "Tout-venant" cocoa trees, both 8 years old, termite attacks responsible for major damage were not significantly different ($P > 0.05$).

## 4. Discussion

Only eight (8) termite species were collected from cocoa plants (*Theobroma cacao L.*). The termite species collected belong to the trophic groups of mushroom feeders and xylophagous termites. The presence of these two groups could be due to their essentially cellulose-based diet. For [30], termites attack trees, given their mainly cellulose-based diet and their need for water. Anani *et al.* [31] showed that the termite species responsible for the damage caused to trees on the University of Lomé campus belong to the xylophagous and mushroom-feeding groups. Coulibaly *et al.* [11] have also shown that termite attacks on mango seedlings are essentially due to the mushroom and wood-boring groups. These groups predominate in growing environments in Côte d'Ivoire [5] [10].

The eight (8) species harvested infested cocoa trees in particular, with attack rates varying from one plantation to another. The low use of insecticides against termites and the low number of annual weeding operations in the various plantations sampled certainly influenced the attack rate of termite populations in the orchards. Similarly, repeated ploughing around the trees helps prevent termites from establishing themselves around the trees [32]. The highest attack rate in plantation P1 can be explained by the low level of maintenance, characterized by a single insecticide treatment (Neonicotinoid + Pyrethroid) and a single annual weeding operation. The two insecticide applications and annual weeding carried out on P2 and P3 plantations seem to have played a role in reducing termite attacks. The age of the cocoa trees in these two plantations could also have an effect on the resistance of the cocoa trees in plantations P2 and P3.

The termite attack rate in plantation P3 with "Tout-venant" cocoa trees showed no significant difference from plantation P2 with "Mercedes" cocoa trees. This suggests that "Mercedes" and "Tout-venant" cocoa trees are equally susceptible to termite pests. This fact is comparable to that of [23] who showed, in the Abengourou locality, that termite attacks on 2-year-old "Mercedes" and "Tout-venant" cocoa trees were not significantly different.

The study of termite species attack rates in the plantations studied showed the predominance of P. *militaris*. In the Oumé region (Côte d'Ivoire), this species is constant in the surveys carried out by [33] in an age gradient of pod mulch. The impact of human activity can lead to the disappearance of certain species and encourage the development of others [34]. Thus, due to human action, a significant development of *P. militaris* in cocoa plantations has been noted. Akpesse *et al.* [35], who studied the corrosol plantations at M'Brimbo, in the south of Côte d'Ivoire, recorded the species *A. crucifer*, *A. guineensis*, *C. sjostedti* and *P. militaris*, among others, in our surveys. These species, harvested in this forest area, therefore have the ecological potential to adapt to different environments.

The damage caused by termites ranged from the simple covering of galleries-tunnels or veneers (minor damage), to the total death of the cocoa tree (major damage), including the consumption of roots, bark and wood. These infestations were mainly characterized by the presence of gallery-tunnels or veneers on the trunk (D1 infestation). These observations were also noted by [30] on four forest species in Togo.

Of the 8 species inventoried, 5 were noted as being responsible for major damage to cocoa trees. These species were cited by [5] [11] and [36], as responsible for major damage to crops and trees. Among these species, *Microcerotermes sp*, *C. sjostedti*, *A. crucifer* and *P. militaris* were the most formidable on cocoa trees in our study locality. *C. sjostedti* is formidable on old cocoa trees [37]. The genus *Microcerotermes* can proliferate rapidly in old plantations, building numerous harvest galleries and arboreal nests [38] [39]. A comparison of the attack rate of the species responsible for major damage in "Mercedes" and "Tout-venant" cocoa trees of the same age, *i.e.,* 8 years, shows that the attack rate of each species on these two varieties does not vary significantly. This seems to indicate that the wood of these trees has the same resistance to termite mandibles. Ano *et al.* [23] made contrary observations on younger cocoa trees and showed that *A. guineensis* is more aggressive on 2-year-old "Mercedes" cocoa trees, while *Microtermes sp1* is more aggressive on 2-year-old "Tout-venant" cocoa trees.

## 5. Conclusion

The average attack rate of termite species harvested in the three (3) plantations P1, P2 and P3 in Daloa was 45.78% ± 11.32%. Plantation P1, with its 15-year-old "Tout-venant" cocoa trees, was the most infested, followed by plantations P3 and P2, respectively. Of the 8 species harvested, *Pseudacanthotermes militaris*, *Ancistrotermes crucifer*, *Coptotermes sjostedti* and *Ancistrotermes guineensis* were responsible for the most damage. The three species *P. militaris*, *A. crucifer* and *C. sjostedti* are the most aggressive and damaging to cocoa trees. Their rate of attack on "Mercedes" and "Tout-venant" cocoa trees of the same age is no different. The action of termites could affect the long-term development and production of old cocoa trees in this locality.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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