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Diversity and damages of termites on papaya trees (*Carica papaya*) in M'brimbo (south of Côte d'ivoire)

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Abstract
The general objective of this study is to know the diversity of termites in papaya plantations in southern Côte d'Ivoire and the damages caused by those termites. A papaya plantation was sampled using the standardized method for the rapid estimation of termite biodiversity. Two transects were plotted on diagonals 111 m long, 2 m wide and divided into 10 sections each. A last transect 100 m long and 2 m wide was drawn vertically in the middle of the farm and divided into 5 sections. A total of 25 sections have been delineated and searched. The results obtained show that five species are present in this papaya plantation. The species *Pseudacanthotermes spiniger*, *Ancistrotermes crucifer*, with respectively 70.05% and 12.79% of occurrence are the most abundant in the medium. *Macrotermes bellicosus* records the lowest occurrence at 1.08%. The fungus-growers make up the majority of termites harvested on the plot. And out of 68% of the attacked papaya trees, 38% has recorded structural damages, and 05% of the plants/trees would have been died because of termites, have been noticed.
This work is a preliminary study that shows the impact of the papaya crop on termite biodiversity. However, the variation of termite communities according to the age of the plantation deserves to be studied.

Keywords: papaya, termites, fungus-growers, damage, attacks

1. Introduction
Termites are one of the major components of tropical ecosystems [1, 2, 3, 4]. They account for nearly 65% of the biomass of soil fauna [5]. Many studies have shown their ecological importance in these tropical ecosystems [6]. However, in several African countries, food and cash crops are regularly attacked and destroyed by termites. According to [7], nearly 10% of termite species described nowadays, are known to be harmful to living plants and buildings. In Côte d'Ivoire, studies on termite damage have focused particularly on infestation in palm oil [8], rice and maize [9, 10, 11, 12], rubber trees [13], cocoa trees [14] and mango trees [15]. Whereas, work on the distribution of termites, their diversity, their abundance, the nature of the damages caused on papaya plantations and their control remain very little documented. The cultivation of papaya (*Carica papaya*) is in full swing in Ivory Coast. Between 1994 and 2002, the number of commercial plantations increased from three to eighty [16]. Papaya has become Côte d'Ivoire's third largest export fruit. Second largest African papaya producer, after Ghana, the country exports annually 1163 tonnes to the European Union [17]. But in recent years, the sector has some problems with the advent of Virose due to the Papaya Ringspot Virus (PRSV), in the traditional area of cultivation (Azaguié, Abidjan), forcing producers to settle in new areas of culture [17]. However, even in this new production area some problems persist. Indeed, it was first described in June 2007 in Toumodi, in the new production area, severe root rot and / or papaya root rot caused by *Pythium aphanidermatum* [18]. Several methods of fighting have been put in place against these pests [17]. However, despite all these efforts, production remains below the expected tonnages in Côte d'Ivoire.
The objective of this study is to know the diversity of termites in papaya plantations, while evaluating the attacks and the damage that could cause those termites.

2. Material and Methods
2.1 Study site
This study was carried out in the region of Agneby-Tiassa, in the department of Tiassalé.
Enjoying a warm and rainy equatorial climate, the study site is 41 km north of Tiassale and 135 km from Abidjan. The average temperature is around 28 ° C and the daytime differences are 5 to 13 ° C. The minimum humidity is around 60% in this region. The soils, ferralitic, are strongly denatured. They are generally characterized by a fine sandy-clay texture; furniture and deep brown red color.
The sampled plot is a papaya plantation (*Carica papaya*) of the Bandama Agricultural Company (SAB). The plants are in production and are two (2) years old (Fig 1). On an area of 2 hectares of papaya that SAB exploits, half a hectare (100 m x 50 m) was used for this study. The plants are equidistant from 2m.

2.2 Sampling of Termites

Termite sampling was conducted using the standardized method for rapid estimation (RAP) of termite biodiversity. This method has been slightly modified and adapted to our study. Three (3) transects have been set up for termite sampling. Two of the three transects were delineated on the diagonals of the study plot. These two transects each measured 110 m long and 2 m wide. Each transect has been subdivided into 10 sections. The last transect was made vertically through the center of the plot. This transect was 100 m long and 2 m wide and was divided into 5 sections of 20 m x 2 m. A total of 25 sections have been delineated. The search was done in successive sections in three stages [19].

The first step was to collect in the litter, the termites observed. Veneers and fragments of branches or trees on the ground are lifted, broken and examined carefully. The galleries covering the ground, are observed. Epigeic nests on the soil surface are destroyed and termites collected.

Fig 1: Papaya parcel (*Carica papaya*) two years old

The second step is to search the aerial part of the plants up to 1.5 m height. Veneers along the trees are recorded. The termites present are also harvested, The third stage is a general search and is up to 5 m on both sides of the different transects. It consists of looking for termites in all micro-habitats, buildings, nests on the ground and in the canopy. This step completes the list of species in the environment.

All termites harvested in one section are kept in the same container containing 70% alcohol and labeled.

2.3 Identification of recovered termites

The identification of termites was done in the laboratory under a binocular loupe. It is based on the caste of the soldiers using the identification keys of: [20, 21, 22, 23] and [24, 25]. The termites without soldiers, the workers were analyzed using the key of [26].

2.4 Evaluation of damages

A hundred (100) feet of papaya were randomly selected from the plot Attendance and observed damage are recorded. The rating scale of [27] was used to rank the different levels of attacks. The modalities of the rating scale are contained in Table I.

2.5 Statistical treatment

Ecological indices were chosen to describe the stands. The species richness (S) which is the total number of species sampled was calculated. Then with the software R version 2.2.1, the Shannon index (H '), equitability (E') and Simpson's index (IS) were calculated. The relative abundance (N) of termites in the transect is the average number of encounters (occurrences) of a species i harvested in a transect [28]. It is based on the incidence (presence = 1 and absence = 0) of the species considered.

Table 1: Rating scale for termite damage on a tree

Rating	Definitions of ratings
E0	No gallery, no earthy veneer, no presence of termites on the tree
E1	Presence of termite galleries and earthy veneer on the bark of the tree
E2	Presence of termites on and in the bark of the tree
E3	Presence of termites in the wood of the tree
E4	Wood eaten by termites and replaced or not by soil of a length greater than 50 cm
E5	Wood eaten by termites and replaced or not by soil of a length greater than 50 cm with death of the tree

3. Results

3.1 Specific Richness of Termites

A total of 5 termite species were harvested from the study plot. These species are grouped into 5 genera, one family and one subfamily. All collected species belong to the Termitidae family and the fungus-growers group. *Pseudacanthotermes spiniger* and *Ancistrotermes crucifer* with respectively 70% and 13% of occurrence, are the most represented species in the medium. The least represented species with 1% of occurrence is *Macrotermes bellicosus* (Fig 2).

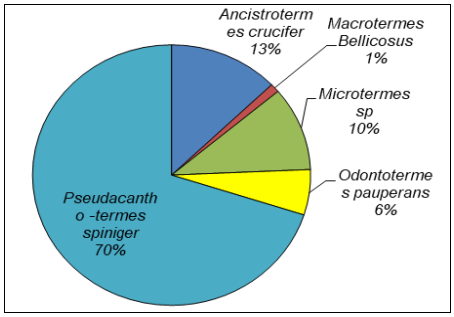

Fig 2: Distribution of different genera of termites in the plot

3.2 Diversity of present termite species

The Shannon H 'index on the study plot is 0.95. As for equitability, it is 0.59 and Simpson's index is less than 0.5.

3.3 Attacks and termite damages on papaya trees

Attacks and damages by termites are observed on different parts of papaya plants. The plot studied has a relatively high attack rate. Out of 100 trees sampled, 68% show termite attacks and damage. Only 32% of the trees sampled are healthy.

Of the 68% of papaya attacked, 38% recorded structural damage and 5% died from termites. Several soil jams were observed in dead papaya trees.

4. Discussion

Termite sampling in that studied plot/area has yielded five (05) species. The diversity indices recorded in this plantation are also low. The results recorded in this study are much lower than those obtained by [29] who harvested 25 species in the cocoa plantations in Oumé. There are several possible reasons for the low number of species harvested. First, the sampling method, because unlike the work of these authors who sampled in a natural forest, this study only concerned papaya plantations. This result could also be explained by the agricultural practices used in the plantations. Indeed, to facilitate the maintenance of the plantations, farmers use herbicides and tillage. These practices could contribute to a significant reduction in specific wealth in these plantations. Several studies have shown that some chemical inputs could prevent termites from colonizing the environment [30-33]. also showed that in plantations, termite stands remain smaller than in surrounding environments.

The history of the papaya plantation could have an impact on termite communities in the plantation. In fact, this papaya plantation would be set up after the destruction of two hectares of virgin forest. This method of exploitation is said to be at the root of the absence of woodborers and humivores, as several authors have shown [13, 11, 34].

The termite species harvested belong mainly to the fungus growers group. That group of termites has always predominated in exploited environments because most of them are termite pest species that attack plants [35]. Termites in this group are considered to be the first crop destroyers in Africa [36, 8].

The ability of this group to live in exploited environments is believed to be due to their remarkable adaptation, fostered by their symbiotic relationship with a fungus of the genus Termitomyces [37]. That fungus degrades wood fragments that become easily digested by termites [38].

The study of the attacks has shown that out of the 100 feet of the selected papaya trees, the attack rates reach 68%. And out of 68% of the attacked papaya trees, 38% has recorded structural damages, and 05% of the plants would have been died because of termites. These results are consistent with the N'Diaye study (1998) [38], which states that termites influence and cause damage to fruit trees and can reach up to 80% depending on the fruit tree. The attack (68%) and damage (38%) rates are lower than those obtained on mango (80%), lemon (58%) and apple cinnamon (11.11%). This low rate of attack on papaya may be due to the insecticidal effect of this plant on termites [40].

Termite attacks are characterized by galleries and veneers observed on the surface of the bark, destruction of roots and bark. These types of damage observed in this study are similar to those observed and described by [27]. The presence of earthy veneers on the trunk of trees reduces the photosynthetic capacity of the trees. According to Logan and El Bakri (1990) [41], these veneers also cause stress to trees and are a source of future termite attack.

5-Conclusion

This study, conducted in a papaya orchard in the central region of Côte d'Ivoire, made it possible to inventory 5 species (*Ancistrotermes crucifer*, *Macrotermes bellicosus*, *Microtermes sp*, *Odontotermes pauperans*, *Pseudacanthotermes spiniger*) of termites belonging to a family, a single subfamily and a single trophic group. These results show that fungus growers are primarily responsible for attacks and damage on papaya seedlings. These attacks range from a simple plating to the death of the tree.

This study is worth pursuing in order to better understand termite damage in relation to the age of the plant and to study the correlation between the nature of the soil and the abundance of termites.

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