International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 16, 2019, pp.-8902-8907.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

ATTACKS MODALITIES AND BIOGENICS STRUCTURES OF TERMITES (INSECTA: ISOPTERA) COCOA PESTS (*THEOBROMA CACAO* L.) (OUME: CÔTE D'IVOIRE)

TRA BI CROLAUD SYLVAIN[1]*, BLEI SIKA HORTENSE[2], COULIBALY TENON[3], SORO SENAN[1] AND TANO YAO[4]
[1]Laboratory of Zoology and Animal Biology, UFR Agroforestry, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire
[2]Laboratory of Biochemistry and Microbiology, UFR Agroforestry, University Jean Lorougnon Guédé, Côte d'Ivoire
[3]Department of Zoology and Animal Biology, UFR Biological Sciences, University Pelefero Gon Coulibaly, Côte d'Ivoire
[4]Department of Zoology and Animal Biology, UFR Biosciences, University Felix-Houphouët Boigny, Côte d'Ivoire
*Corresponding Author: Email - trolaud@yahool.fr

Received: July 18, 2019; Revised: August 26, 2019; Accepted: August 27, 2019; Published: August 30, 2019

Abstract: The study on termite attack patterns and biogenic structures produced in cocoa farms of different ages was conducted in the Oumé region (former cocoa loop). Thus, eight kinds of termites belonging to two trophic groups (Fungus-grow and xylophagous) are particularly harmful on the cocoa tree: *Ancistrotermes, Coptotermes, Microtermes, Microcerotermes, Nasutitermes, Neotermes* and *Schedorhinotermes*. Fungus-grow termites insert clay soil under the bark, which causes it to be stripped in the presence of the sun. On the other hand, xylophagous establish crop tunnels in the plant made of chewed sawdust of different hues according to the genera. In this group, only Neotermes does not construct veneers of external crops. It has direct access to the plant by undoubtedly perforating the secondary roots and invading the whole plant. Their presence is characterized by the walls of galleries in "necrotic" form.

Keywords: *Termites, Foraging galleries, Xylophageous, Fungus-grower, Cocoa plantation, Pest*

Citation: TRA Bi Crolaud Sylvain, *et al*., (2019) Attacks Modalities and Biogenics Structures of Termites (Insecta: Isoptera) Cocoa Pests (*Theobroma cacao* L.) (Oume: Côte D'Ivoire). International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 16, pp.- 8902-8907.

Academic Editor / Reviewer: Vinod S Kukanur, Seyyed Fazel Fazeli Kakhki

Introduction

Termites have particularity building nests to colony and to cope with the many physiological and biological needs [1]. In addition, they fear excessive temperatures and high hygrometry [2]. They build several types of structures: termite mounds, crop galleries and *Anoplotermes pseudocies* [3,4]. Singular architecture of biogenic structures constitutes a distinctive element of identification (taxonomy). In addition, studies carried out by some authors in Ivory Coast on biogenic structures have been devoted in most cases to the description of nests and their physicochemical compositions [4,5,6]. Akpesse, *et al*., (2008) [7] showed termite attacks food crops (rice and maize) in Côte d'Ivoire. This study has highlighted four types of termites: *Amitermes; Ancistrotermes, Microtermes* and *Pseudacanthotermes*. However, very little work has been done on the traces and modalities of termite attack. Cocoa production value represents 10% of GDP in Ivorian economy, is also not immune to termite attacks [8,9]. So, in order to effectively fight against these pests, a study on the description and recognition of the different biogenic structures resulting from the termite attack on cocoa is necessary to alert the scientific community and cocoa industry leaders.

Materials and Methods

Study site

Study was carried out in the cocoa farms of Oumé (6°31 North latitude and 5°30 West longitude), in Central West of Côte d'Ivoire. The region of Oume has an equatorial climate. Rainfall observed amounts to 1 698 mm of rain compared to 1 614 mm. Average temperature vary from 24.6°C to 29°C. The soil is ferralitic [10].

Methodology

Effect of termite attacks according to cocoa plantation age

Termites attacks on cacao were studied in plots less than one year old and older (5, 8, 20, 25 and 30 years old) to determine the effect of age on termite attack. This involved looking for and describing the density of the veneers and the types of attacks. Termite progression in anatomical plant structures (bark, sapwood and heartwood) has been essential in the description of the attack patterns.

Statistics

The search for similarity between attack modalities and biogenic structures made it possible to identify four variables related to the attack modalities and nine variables that characterize the biogenic structures resulting from these attacks [Table-1]. Factorial Correspondence Analysis (AFC) is used to determine the relationships between attack patterns and biogenic structures produced by termites.

Table-1 *Variables used to analysis the relation between different termites genus*

A. Biogenic Structure			
1. Soil			
1.1	BPG	Total stuffing of galleries	Yes= 1 or No= 0
1.2	BICO	Incomplete stuffing of galleries	Yes= 1 or No= 0
1.3	GCO	Big oval cavity makes of contain soil	Yes= 1 or No= 0
1.4	G	Foraging gallery in form of tunnel	Yes= 1 or No= 0
2. Sawdust			
2.1	FS	Biogenic structure makes of sawdust of brown tint dark	Yes= 1 or No= 0
2.2	FB	Biogenic structure makes of sawdust of with-milky tint	Yes= 1 or No= 0
2.3	NSF	Biogenic structure not containing a ground nor sawdust	Yes= 1 or No= 0
3. Foraging galleries			
3.1	VGTX	Composed essentially of plant fragments	Yes= 1 or No= 0
3.2	SOL	Composed essentially of soil	Yes= 1 or No= 0
B. Attacks modalities			
1	PEA	Bark Perforation level air parts	Yes= 1 or No= 0
2	PER	Bark Perforation at root level	Yes= 1 or No= 0
3	COL	Bark Perforation at collet level	Yes= 1 or No= 0
4	PAR	Bark Perforation at arian and root level	Yes= 1 or No= 0

Also, dendrogram of similarity has made possible to observe the link between different genera of pest basis of attacks modalities and biogenics structures. BPG: Total stuffing of galleries; BICO :incomplete stuffing of galleries; GCO: Big oval cavity makes of contain soil; G: Foraging gallery in form of tunnel; FS: Biogenic structure makes of sawdust of brown tint dark; FB: Biogenic structure makes of sawdust of white-milky tint; NSF: Biogenic structure not containing a ground nor sawdust; VGTX: Composed essentially of plant fragments; SOL: Composed essentially of soil; PEA: Bark Perforation level air parts; PER: Bark perforation at root level; COL: Bark perforation at collet level; PAR: Bark perforation at arian and root level

Results

Attacks modalities and biogenics structures

In total, eight (8) genera of termites attack cocoa. These termites can be classified into two major groups according to their diet: Fungus-growers composed of Ancistrotermes, Microtermes, Pseudacanthotermes and xylophageous composed of Nasutitermes, Coptotermes, Schedorhinotermes, Microcerotermes and Neotermes.

Fungus-growers attacks modalities

Ancistrotermes

Ancistrotermes begin with the construction of crop galleries that start from the hypogenous nest and usually reach the cocoa tree trunk. At the base of the foot, in general, there are many ramifications of the crop galleries. It does not attack the root as in corn plots [7]. They pass the bark through small perforations. Once settled under the bark, the Ancistrotermes accumulate large quantities of clay soil. This accumulation leads to the cracking and stripping of the bark under the effect of swelling clays in the presence of sun [Fig-1A, 1B]. The stuffing of the stem by the clay soil continues as they move towards the heartwood [Fig-1C]. Once in the heartwood, very weak plant dies in the short term. Sometimes suffocates the stipe of the flowers by the veneer of soil which can lead to premature death of this one [(Fig-1D].

Fig-1 Attacks modalities and biogenic structures of Ancistrotermes.
A: foraging gallery (Scale: 1/20), B: overview of the cacao tree attacked (Scale: 1/20), C: sight brought closer to the attack with stuffing the bark with soil and crack of this one (Scale: 1/10); D: flowers suffocation by foraging gallery (Scale: 1/4)

Microtermes

The genus Microtermes primarily attack cocoa trees less than one year old (seedling) [Fig-2A]. The first contact with the plant is established by the harvest veneer made of clay soil on the stem at the base of the collar. The termite with a hypogeal nest comes out of the ground and cut the seedling by the collar [Fig-2B and 2C]. It does not attack the root of the plant [Fig-2D]. The thin bark is quickly eaten away and the parenchyma is reached. The parenchyma is gradually replaced by clay soil. It establishes a harvest gallery between the seedling's internal structures and the hypogenous nest [Fig-2E]. However, in aged cacao trees, Microtermes build harvest veneers that do not exceed 1.5 m in height. Their presence on aged cacao does not affect the "health" of the plant.

Fig-2 Attacks modalities and biogenic structures of Microtermes
A: healthy young tree (Scale: 1/8); B: young tree drilled in collet (Scale: 1/6); C: fall young tree drilled in collet (Scale: 1/6); D: healthy roots of young tree (Scale): (1/11); E: progression way of termites in plant structure (Scale: 1/5).

Pseudacanthotermes

Pseudacanthotermes, as Microtermes access the plant by building veneers of crops on the soil and on the plant. This genus preferentially attacks aged feet whose diameter varies between 20-30 cm and 30-40 cm. These veneers are true protection shields against the sun's rays and especially attacks of ants [Fig-3A]. Perforation of the bark is carried out for most cases from 1 to 1.5 m in height. Once the bark is perforated, termites run under the bark. At this stage, there are two possibilities depending on the thickness or structure of bark:

1. when the bark is thin, termite consumes all the structures of it by leaving thin outer bark concealing their presence [Fig-3B].
2. In the presence of a thick bark, Pseudacanthotermes perforates and empties these underlying structures and such as liber and cambium. Once these structures are removed, termite digs oval cavities in the superficial portion of sapwood [Fig-3C and 3D]. They stay there for a longer or shorter time and go through the sapwood. Harvest tunnels are established in the clay soil between the hypogenous nest and the attacked trunk. External harvest veneers also act as a link between the hypogenous nest and the plant. This genus attacks the plant from the outside inwards and establishes tunnels with the hypogenous nest. At this stage, outer veneers begin to be less and less frequented by the termite. Which leads to their partial or total disintegration. Thus, we sometimes observe apparently healthy plants but completely emptied of their internal structures.

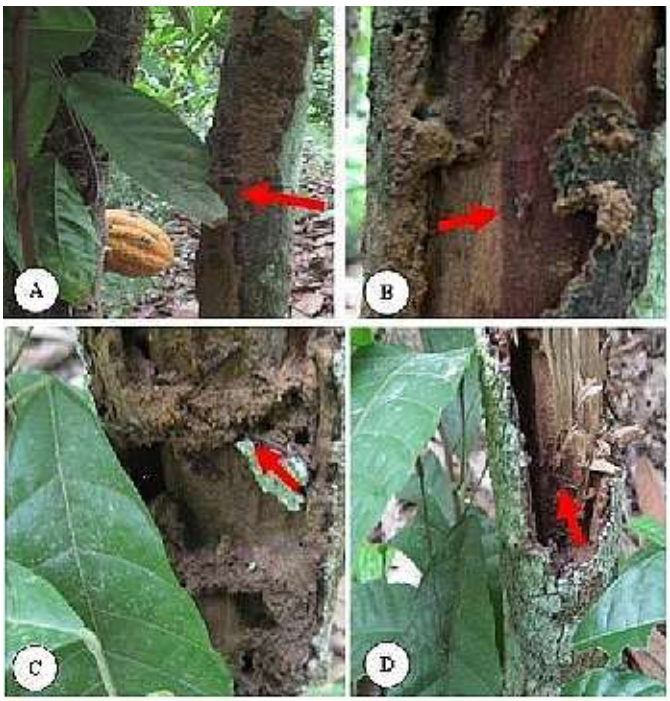

Fig-3 Attacks modalities and biogenic structures of Pseudacanthotermes
A: external view of cacao plantation with presence of foraging galleries (Scale : 1/6), B: same trunk after retreat of foraging galleries and revealing fine bark hollowed by termites workers whose individual is present; C:view of oval cavities on thick barks (Scale:1/4); D: view of rectangular cavities on thick barks (Scale:1/7).

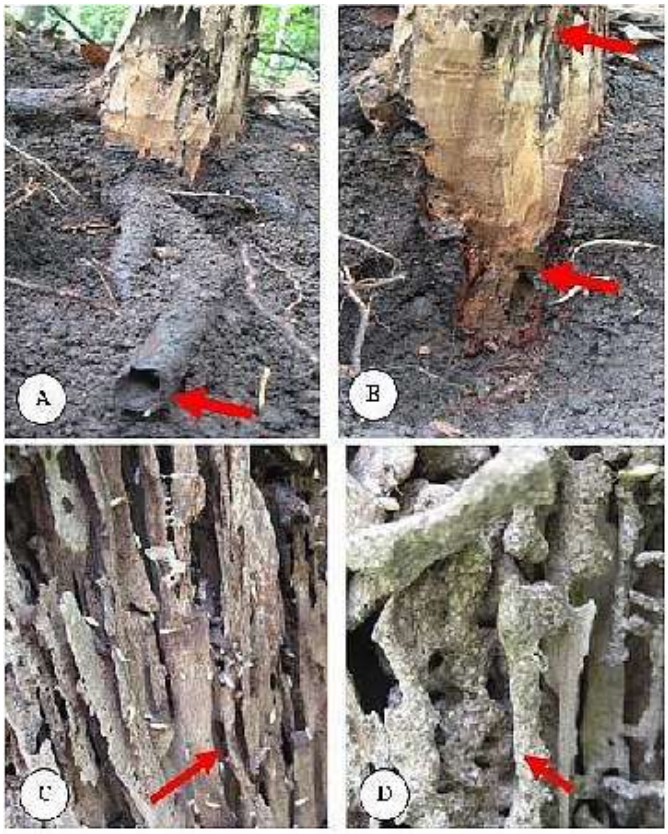

Fig-4 Coptotermes attacks modalities and biogenics structures
A: attacked and perforated root (Scale:1/3), B:cut secondary root showing most of ramifications of foraging galleries at collet level (Scale:1/6);C: internal of destroyed structures with presence of very dense foraging galleries (Scale:1/8);B: brought closer view of sawdusts built by workers (Scale:1/3).

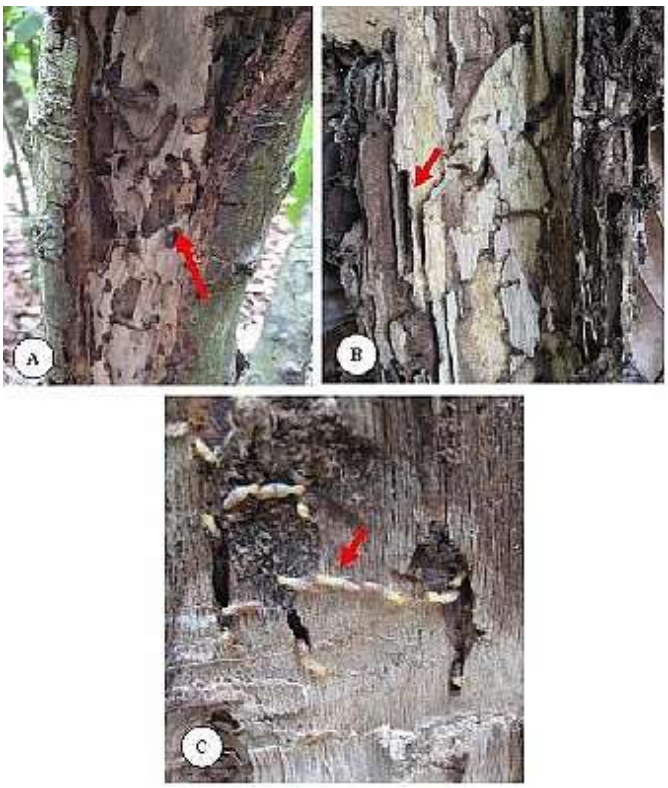

Fig-5 Microcerotermes attacks modalities and biogenics structures
A:bark and sapwood perforation (Scale:1/3), B:galleries in lamellate form (Scale:1/2); C:proliferation of Microcerotermes workers in foraging galleries (Scale:1/3)

Fig-6 Attacks modalities and biogenic structures of Nasutitermes
A:distant(Scale:1/4), B: brought closer view of foraging gallery after stripping showing barks perforations and termites entries (Scale:1/3). C:biogenic structure resulting from attack (Scale:1/3).

Xylophageous attacks modalities

Coptotermes

Coptotermes is the most harmful of the cocoa pest. It attacks preferentially older cocoa trees of large diameters 20-40cm and weakened. Termite sometimes conceals these pathways. Termites perforate the secondary root [Fig-4A], destroy internal structures of secondary root and reach neck [Fig-4B]. At this level, they propagate under the bark and perforate the sapwood and migrate upwards by establishing galleries of very dense crops until they reach the heartwood. The death of the orchard occurs during the following months. In addition, the Coptotermes build harvest veneers on the outer parts of the plant (trunk and branches). With regard to biogenic structures, this genus establishes very dense galleries in the internal structures (sapwood and heartwood) that communicate with hypogenous nest [Fig-4C]. Sawdust or feces derived from wood consumption are produced by workers and stored in drifts [Fig-4D].

Microcerotermes

Microcerotermes build many veneers of crops to access food sources. Harvest veneers start from the base of the trunk to the top of the plant. This termite attacks preferentially already weakened (eroded) areas such as slits, cut trunks and cut stumps [Fig-5A]. But, in the absence of these structures, they attack the healthy parts of the cocoa tree. The bark is perforated in various places all along the gallery. The workers dig numerous galleries in the sapwood. This takes on the appearance of sheets stacked in lamellar form [Fig-5B]. These structures, very hard and dark brown are invaded by a large number of individuals [Fig-5C].

Nasutitermes

Nasutitermes was mostly observed on aged cocoa trees between 20 and 30 years old. Termite comes into contact with the cocoa tree through harvest veneers that they establish on the bark of plant [Fig-6A]. The workers perforate the bark and settle under it [Fig-6B]. They reach the sapwood through small galleries. In this structure, the workers progress towards two directions: one centripetal (towards the heartwood) and the other upward to reach branches. After crossing all the internal layers, termites settles definitively in the plant until the death of this one. As with Coptotermes, Nasutitermes produce dark-brown biogenic structures that sometimes fade to black. These structures are made from sawdust from excreta [Fig-6C].

Neotermes

Neotermes has been observed only on cocoa trees aged 30 and 20 years. It does not build a harvest veneer, unlike other xylophages. Our attention was very often attracted by small cracks, small holes and cracks on the bark at the level of the trunk [Fig-7A]. Termites establishes a network of very dense crop galleries in sapwood and heartwood. At the base of trunk, precisely at the collar, there is a high density of larvae. On the other hand, soldiers and workers are clearly abundant beyond the base of the trunk [Fig-7B]. The openings of the galleries are, in general, very black in color, similar to a necrotic structure or similar to the traces of burns left by a metal heated in dry wood [Fig-7C].

Schedorhinotermes

Schedorhinotermes are less present on the cocoa tree. They also attack fresh and fragile adult cocoa trees. They are present on the trunk and branches of cocoa trees. They come into contact with the orchard through harvest veneers [Fig-8A]. In this structure built by the workers, they attack the bark, perforate it in various places [Fig-8B] and access the bark-sapwood interface. At this stage of the attack, the external signs of their presence are represented by the detachment of bark (cracks and fissures). Termite continues its progression towards the internal structures of the plant. Biogenic structure produced is made of droppings made of white-milky sawdust [Fig-8C]. In this genus, our investigations could not highlight galleries linking internal structures of plant to endogenous nest.

Fig-7 Attacks modalities and biogenic structures of Neotermes
A:general view of a foot attacked with presence of hole (Scale:1/12);B:workers and soldiers in foraging galleries (Scale:1/2);C:galleries with "necrosed" walls (Scale:1/2).

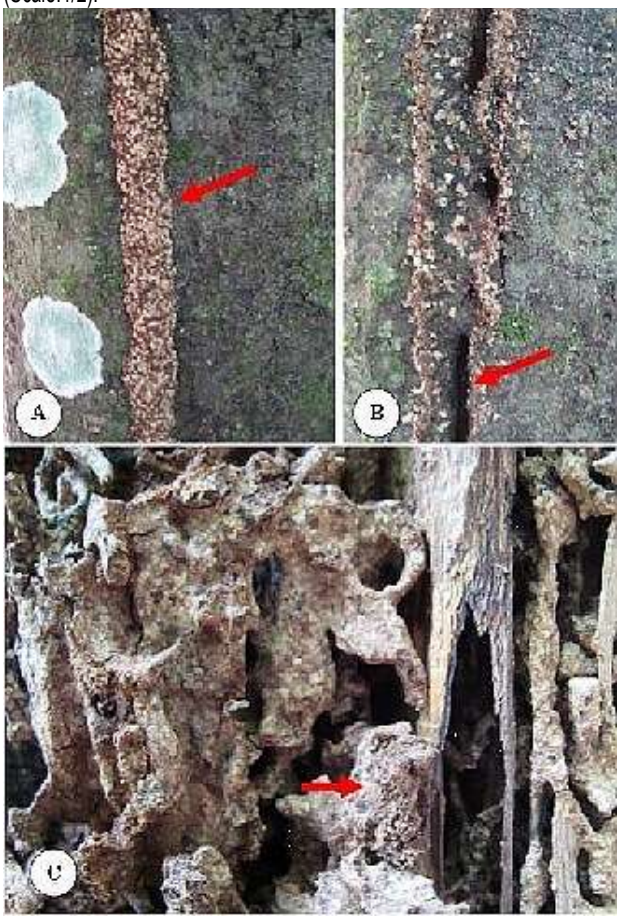

Fig-8 Attacks modalities and biogenic structures of Schedorhinotermes
A:distant(Scale:1/4), B: brought closer view of foraging gallery after stripping showing barks perforations and termites entries (Scale:1/3). C:biogenic structure resulting from attack (Scale:1/3).

Distribution of termites according to biogenics structures

Factorial analysis of correspondence (AFC) (F was performed based on attacks modalities and biogenics structures in relationships to relative abundance of termites genera [Fig-6]. The ordination in the factorial plane described by the axes F1 and F2 explains 51.40% of total variance.

The first axis 1 explain 29.00% of total inertia and second axis 2 explain 22.40% of inertia). Negative part of Axis 1 is characterized by tunneling tunnels (G), biogenic structures containing no soil or faeces (NSF), harvest veneers made from plant debris (VGTX), perforation of bark on aerial parts (PEA), and bark at the level of collar (PER), biogenic structure similar of white feces (FB). In the positive part of this axis, only the soil-based harvest veneers (SOL) characterize it.

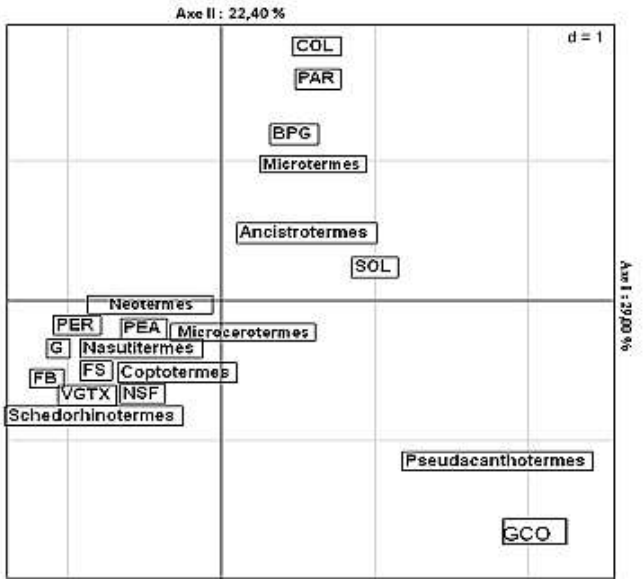

Fig-9 Relation between termites attacks modalities and biogenic structures

BPG: Total stuffing of galleries; BICO :incomplete stuffing of galleries; GCO: Big oval cavity makes of contain soil; G: Foraging gallery in form of tunnel; FS: Biogenic structure makes of sawdust of brown tint dark; FB: Biogenic structure makes of sawdust of white-milky tint; NSF: Biogenic structure not containing a ground nor sawdust; VGTX: Composed essentially of plant fragments; SOL: Composed essentially of soil; PEA: Bark Perforation level air parts; PER: Bark perforation at root level; COL: Bark perforation at collet level; PAR: Bark perforation at arian and root level

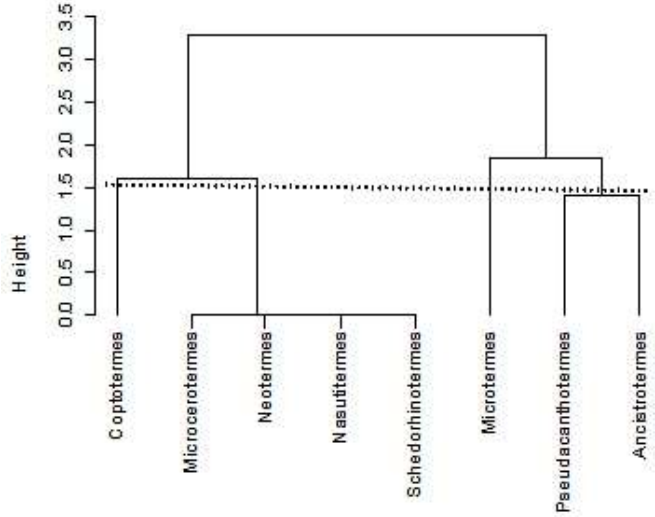

Fig-10 Dendrogram of similarity between different genus of termites based on the values of attacks modalities and biogenics structures

Axis 2 is characterized in its positive part by the different modalities of attacks such as perforation the bark at root level (PAR) and total tamping of galleries in soil (BPG). Projection the genus on these two first axes, shows that on the Axis 1 characterized on negative side by the genera: Coptotermes, Microcerotermes, Schedorhinotermes and Neotermes. Axis 2 is characterized on the positive side by Ancistrotermes and Microtermes. This group of genera oppose Pseudacanthotermes on Axis 2 on the negative side.

Hierarchical classification (dendrogram) based of genus relative abundance by attacks patterns and biogenics structures allowed termites to be grouped in two according to the first level of association [Fig-9]. Two groups are distinct according trophic composition. Thus, the first group consists only xylophageous and second group of fungus-growers. But, detailed analysis of these two major groups leads to four subgroups according to second level of association. The first subgroup contains Coptotermes, the second subgroup contains Microcerotermes, Neotermes, Nasutitermes and Schedorhinotermes genus. The third subgroup includes Microtermes and finally Pseudacanthotermes and Ancistrotermes genus constitute elements of fourth subgroup.

Key of attacks modalities and biogenics structures

[1] Foraging galleries built essentially of clay soil [FUNGUS-GROWERS]
-Perforing the bark and stuffing this one by the clay soil [2]
[2] Stuffing the bark with clay soil [3]
[3] Presence in clay soils with holes of small sizes of foraging [4]
[4] Split young tree in tree collet [Microtermes]
-Do not split young tree in the collet [5]
[5] Stuffing bark with some clay containing galleries relatively big sizes [6]
[6] Presence of oval or rectangular cavities under the bark [Pseudacanthotermes]
Absence of oval or rectangular cavities under the bark [Ancistrotermes]
[7] Absence of foraging galleries but if it presence, it make essentially of sawdust of chewed wood [XYLOPHAGEOUS]
Absence of external foraging galleries but presence of internal foraging galleries whose edges look like performing dry wood by heated metal [Neotermes]
[8] Presence of foraging galleries make essentially of sawdust of chewed [9]
[9] bark perforation various spots under foraging galleries [10]
[10] Perforation of the bark of secondary root with presence of sawdusts of chewed color milky with granules chestnut lights in the principal trunk [Coptotermes]
No perforation of the bark of secondary root [11]
[11] Foraging galleries under the bark of aspect lamellate and very rigid [Microcerotermes]
Foraging galleries under the bark made of anastomosed partitions with presence of sawdusts chewed of dark color gray [Nasutitermes]
[12] Presence of sawdusts chewed of color milky with maroon and presence of granules lights [Schedorhinotermes]

Discussion

Coptotermes genera acts perniciously. The veneers of harvest are very often absent on the trunk of the cocoa tree although the infestations are advanced. This shows that these attacks occur at the root level [11]. Once the termite inside the plant, the veneers located outside, being no longer regularly exploited by the harvesting colony dislocate and detach from the trunk. Thus, the workers establish tunnels between the internal structures of the plant and the underground colony. This attitude is observed in xylophageous such as Nasutitermes and Schedorhinotermes, with the exception of Microcerotermes for which harvest veneers have been observed continuously. This genus stands out clearly from other xylophageous constructors of harvest veneers by the size and especially the density of these [12]. Root and crown attacks were not observed on the cocoa tree. On the other hand, on the mango tree in Senegal, [11] observed attacks of this termite on these organs. In short, the terms of attack of termites seem to vary according to plant species, environment and climate. Fungus-growers, on the whole, attack the cocoa tree under cover of veneers, under the bark, causing cuts in the bark and progress in the internal structures of the plant [11]. Their common point is the presence of soil in the structures of the plant.

Correspondence factorial analysis (AFC) and the dendrogram that identify the similarities of attacks and the biogenics structures derived from them, reveal that taxa belonging to the same trophic group are very close, considering the attacks modalities. It is the same for biogenic structures. Microtermes attack the seedlings by covering the clay stem [13]. Koudou [14] and [15] observed the attack of this genus on the rubber and mango grafts respectively. Coptotermes and Nasutitermes genus attack wood in forests [16, 17]. Nasutitermes perforate the plant to the sapwood producing biogenic structures of blackish color [18]. Many galleries are observed during Microcerotermes attack. These results are similar to those of [18]. Also, these authors have observed that Microtermes essentially attacks the roots [14]. In sum, xylophagous termites cause a great deal of damage to perennial crops in Côte d'Ivoire [19].

Conclusion

According to plant age and the environment termites adopt different types of attacks. These can be more or less grouped according to trophic groups. They produce various genera of biogenic structures during harvesting activities on the cocoa tree. Unlike attack modalities, biogenics structures have great differences from each other. Recognition of these structures could be a determining factor in the control of this pest.

Application of research: This study highlights the difficulties of termite management in cocoa trees. This is because of their modalities of attacks contrary to other cacao insects. Attacks under the bark and progression in internal structures of the plant limit the use recommended contact insecticides. Only systemic insecticides could effectively control these pests. Thus, particular attention must be paid by agricultural institutes and policymakers to deal with this new agricultural

Research Category: Pest managment

Acknowledgement / Funding: Authors are thankful to Laboratory of Zoology and Animal Biology, UFR Agroforestry, University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire. This work was carried out as part of the CSM-BGBD project (N°: IMIS: GFL / 2328-2715-4923; PMS: GF / 1030-06-01.

***Principal Investigator or Chairperson of research: TRA Bi Crolaud Sylvain**
University: University Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire
Research project name or number: CSM-BGBD project (N°: IMIS: GFL / 2328-2715-4923; PMS: GF / 1030-06-01

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Central West of Côte d'Ivoire

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Dosso K., Kone F., Kra K.D. and Konate S. (2017*) Journal of Animal & Plant Sciences*, 33(3), 5320-5331.
[2] Josens G. (1972) *Thèse de Doctorat d'Etat, Université Libre de Bruxelles*, 262 p.
[3] Grasse P.P. (1986) *Foundation Singer-Polignac, Masson, Paris*, 715 p.
[4] Tano Y. (1993) *Thèse d'Etat ès Sciences, Université Nationale de Côte d'Ivoire*, 250 p.
[5] Konate S. (1998) *Thèse de Doctorat, Université Paris VI*, 252 p.
[6] Boga J.P. (2007) *Thèse de Doctorat, Université de Cocody-Abidjan*, 231 p.
[7] Akpesse A.A.M., Kouassi K.P., Tano Y. and Lepage M. (2008) *Sciences et nature*, 5 (2), 121-131.
[8] Anonyme (2005) *Missions économiques. MINEFI-DGTPE*, 4 p.
[9] Tra Bi C.S. (2013) *Thèse de Doctorat, Université Félix Houphouët Boigny de Cocody-Abidjan*, 252 p.
[10] Angui P.K.T., Tie-bi T., Tamia J.A., Assie K.H., Danho D.M. (2005) *Mid-terme report. CSM-BGBD Project phase I*, 21 p.
[11] N'diaye A.B. (1998) *Thèse de Doctorat de 3ième Cycle, Université Cheick Anta DIOP*, 101 p.
[12] Leponce M. (1996) *Thèse de Doctorat, Université libre de Bruxelles*, 152 p.
[13] Tahiri A. and Mangue J.J. (2007) *Sciences et Nature*, 4(1), 45–55.
[14] Koudou G B. (2000) *Diplôme d'Etude Approfondie (DEA), Université de Cocody (Abidjan)*, 79 p.
[15] Coulibaly T., Akpesse A.A.M., Yapi A., Zirihi G.N. and Kouassi K.P. (2014) *Journal of Animal & Plant Science*, 22(3), 3455-3468
[16] Kirton L.G., Brown V.K. and Azmi M. (1999) *Journal of Tropical Forest Science*, 11(1), 218-239.
[17] Martin J.M. (2014) *Thèse de Doctorat, Université des Antilles et de la Guyane*, 155 p.
[18] Gbenyedji J.N.B.K., Kasseney B.D and Sanbena S.W.N.B.B. (2016) *European Scientific Journal*, 12(9), 1857-7431.
[19] Han S.H., Tokro G.P., Tano, Y and Lepage M. (1998) *Plantation, Recherche, Development*, 5(2), 119-123.