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Socio-entomological characterisation of cocoa orchards in the haut-Sassandra region (Côte d'Ivoire)

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Abstract
Cocoa alone accounts for more than 46% of export earnings and employs more than two-thirds of the working population. Despite this social importance, the sustainability of the cocoa orchards in Côte d'Ivoire is compromised by several biotic constraints. The objective of this study is to determine the main pests of the plantations in the area of study, to examine the perception of farmers on the importance of these pests and to assess their knowledge in managing the threat. To this end, a survey was conducted among 360 cocoa farmers in the Haut-Sassandra region of Côte d'Ivoire. The study revealed that 96.67% of the farmers were men. The plantations are family farms with an average size of about 3.24 ha and cocoa farms established on five main types of previous crops, with a preponderance of "forest" previous crops. Three types of insects are of greater concern. These are mirids, stem borers and green bugs. The distribution of insects according to the age gradient shows an abundance of stem borers on the plots.

Keywords: Cocoa, orchard sustainability, pests

1. Introduction
Cocoa is one of the most profitable crops in the world [1]. More than 50 million people live from cocoa incomes in the world. In Africa, 70% of raw cocoa beans production market is owned by Côte d'Ivoire, Ghana, Nigeria and Cameroon. With a production of 2.225 million tons of raw cocoa beans for the 2020-2021 period, this commodity is the economic mainstay of Côte d'Ivoire current world leading production [2]. Indeed, cocoa represents more than 46% of export incomes and employs more than two-thirds of the working population [3, 4]. To produce such a large amount of beans, farmers exploit vast plots of cocoa farms in the southern half of the country. In this area, the movement of pioneer fronts still called "cocoa loop" took place from the Southeast to the Southwest through the Center. Apart from the large production areas, some southern regions of the country whose production varies from 3 to 7%, help to complete the national production [5]. Despite this important performance in cocoa production, the sustainability of the Ivorian orchards is threatened by many constraints, namely diseases, pest attacks, rodents and parasitic plants [6]. Generally, the main constraints to cocoa production in Côte d'Ivoire can be classified into two categories according to their origin. These are abiotic constraints characterized by fluctuations in market prices and the scarcity of available land, and biotic constraints marked by the action of diseases and insect pests of the cocoa tree [7]. Among these diseases, brown pod rot is the main disease affecting cocoa in Côte d'Ivoire [8]. There is also the swollen shoot virus (Badnavirus) and pathogenic fungi [9]. Swollen shoot is one of the most economically damaging viral diseases of cocoa with 30 to 40% of post-harvest losses [10]. Cocoa trees are also attacked by certain insects such as Hemiptera, Lepidoptera and Isoptera which cause production losses [11, 12, 13].
The Haut-Sassandra region, one of the main cocoa production areas in Côte d'Ivoire, is no exception to that key issue. Previous studies by N'Guessan *et al*. (2014) [14]; Kouamé *et al*. (2015) [15] and Siapo *et al*. (2018) [16] have reported the importance of pests in this region. In such a context, understanding the perception and knowledge that local farmers have of the various threats and the practices implemented to address them. The objective is to study the typology of producers, to determine the main insect pests of plantations in the study area and

to examine the perception that farmers have of the importance of these pests in order to formulate a good management strategy.

2. Methods

2.1. Study sites

This study was conducted in the Haut-Sassandra region, in the west-central part of Côte d'Ivoire, in the departments of Daloa, Vavoua, Issia and Zoukougbeu (fig. 1). This region covers an area of 15,200 km². Climate is humid tropical type characterized by a long rainy season from mid-March to mid-July, a short rainy season from September to November. They alternate with a long dry season from December to mid-March and a short dry season from mid-July to August. Average annual precipitation is between 1200 mm and 1600 mm [17, 18, 19, 20]. The average annual temperature is 26 °C (SODEXAM)

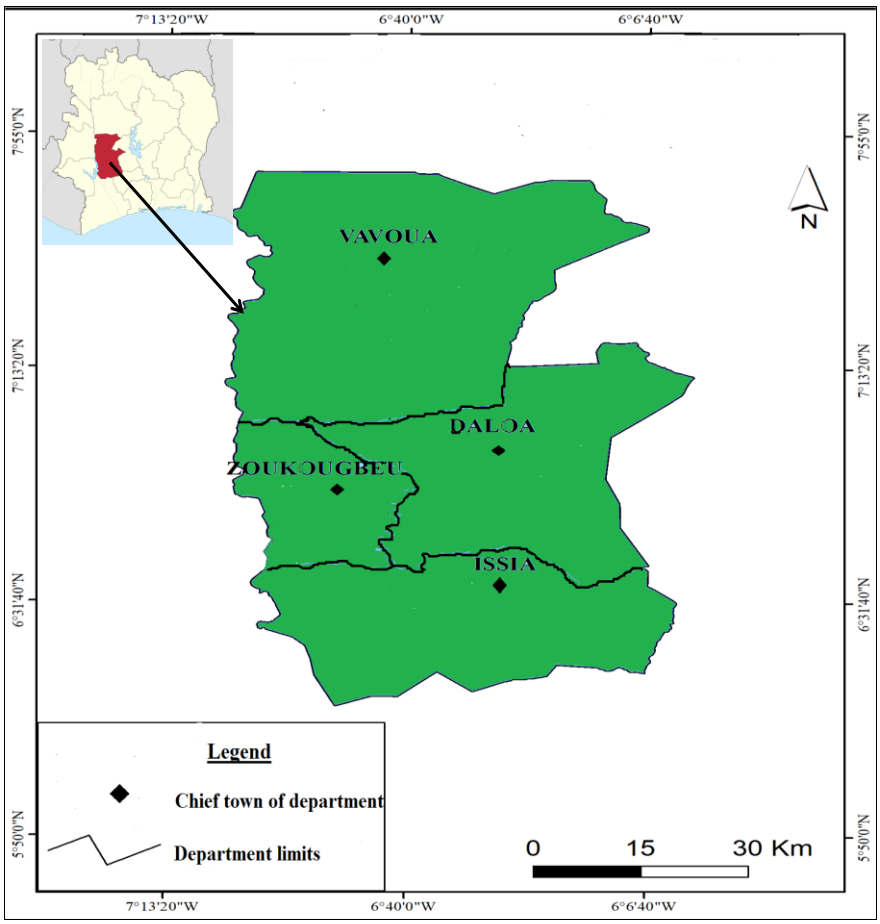

Fig 1: Study area

2.2 Sampling method

The survey was conducted from November 2020 to January 2021. A semi-structured questionnaire was used to interview cocoa farmers in the 4 departments [21]. The farmers were interviewed individually on their cocoa plantations. The questionnaire was addressed to cocoa farmers and aimed collecting information on producer's typology and cocoa farming in these areas. Questionnaire was divided into three main parts. The first part is based on the identification of cocoa farmers, i.e. their typology. The second deals with the previous crop, the age of the plots, the area and the plant material planted. As for the last part, it deals with the impact of pests and threat management, the level of maintenance of cocoa plantations, weeding, pesticide treatments and fertilization. Information was also collected on some pests, their damage and the means of control used. Based on the list of producers of the ECOOKIM Company, the sampling of cocoa farmers who were surveyed was carried out selectively. The survey was carried out considering a gradient of cocoa farm age (0-10 years, 11-20 years and more than 20 years) in each department.

2.3 Statistical analysis

All collected data was entered on the EXCEL spreadsheet. The data were then subjected to an analysis of variance using Statistica version 7.1 software in order to compare the average area of cocoa plantations per producer and also the distribution of insects according to age classes. The separation of the means was carried out by the Student-Newman-Keuls test at the 5% threshold. The distribution of cocoa plantations according to crop precedents was also calculated and represented graphically in order to determine the abundance of these.

3. Results

3.1 Producer's typology

A total of 360 cocoa farmers (90 farmers per department) were surveyed. The results show that 96.67% of the producers surveyed are men while women represent only 3.33%. We interviewed 89 men and 1 woman in each of the departments of Zoukougbeu and Issia, respectively (Table 1). In the department of Daloa, 83 men and 7 women were interviewed. As for the department of Vavoua, 87 men and 3 women were sampled. The 360 planters surveyed had about 1166.65 ha of cocoa trees.

Table 1: Distribution by production area of producers and areas surveyed according to departments and sites

Production area	Department	Number of farmers		Total area (ha) of plots surveyed
		Men	Women	
Haut Sassandra	Daloa	83	7	242,3
	Issia	89	1	323,1
	Zoukougbeu	89	1	298,75
	Vavoua	87	3	302,5
Total		348	12	1166,65

3.2. Origin of cocoa plantations and orchard size

Cocoa farms are established on five main types of habitats (Fig. 2). Among these habitats, the previous "forest" crop represents 49.17% of the orchard. On the other hand, previous croplands such as former cocoa and coffee plantations, food crop fields and fallow land represent respectively 23.61%, 15.28%, 2.22% and 9.72%. The survey reveals that the total sizes of the plantations are comprised between 0.5 and 12 ha. The average sizes per producer are not significantly different between departments (Anova, p = 0.43) (Fig. 3). As all plantations are family-type farms, most cocoa farms covered an average of 3.24 ha per producer for the entire orchard.

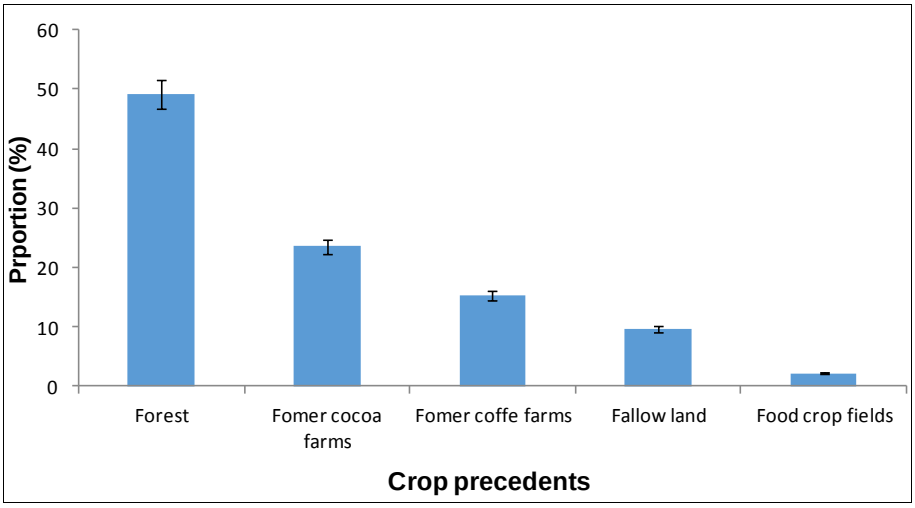

Fig 2: Distribution of cocoa plantations according to crop precedents

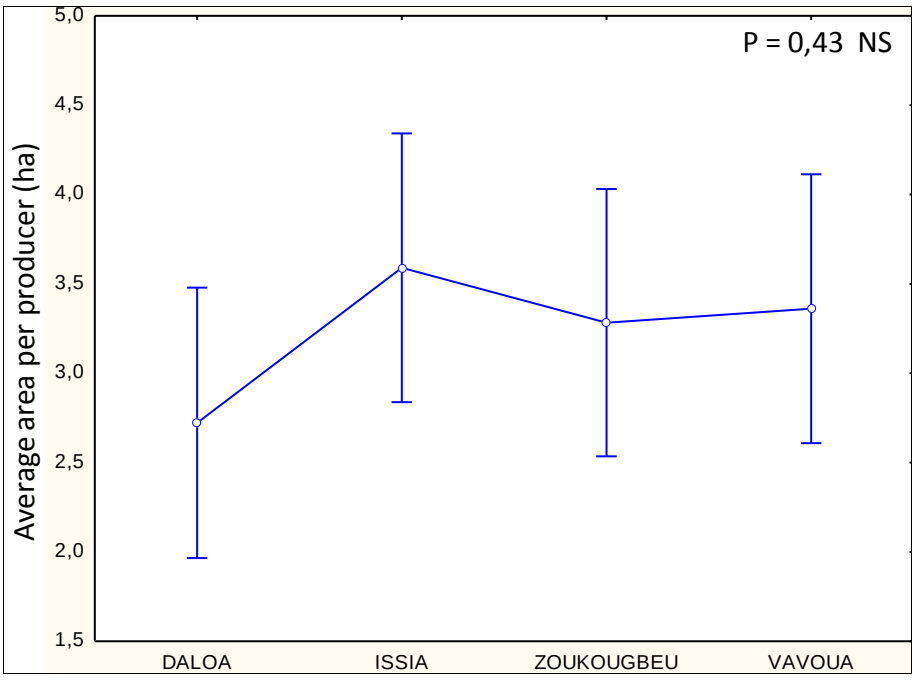

Fig 3: Average area of cocoa plantations per producer

3.3 Biological farm pests

In addition to swollen shoot disease and brown rot, farmers mentioned six main pests responsible for the major damage to their plantations (Fig. 4). Three types of insects were cited as the most concerning. These are the mirids (88.41% of famers interviewed) that attack the fruits and twigs of the cocoa trees; stem borers (61.5% of farmers interviewed) digging deep galleries in the trunk and branches of the cocoa trees and the green bug (77% of farmers interviewed) that attacks the fruit of the cocoa trees. Termites, caterpillars and mealybugs are

responsible for some damage. The latter are considered to be of less concern by farmers in view of the damages they caused in comparison to those mentioned above (less than 25% of farmers surveyed).

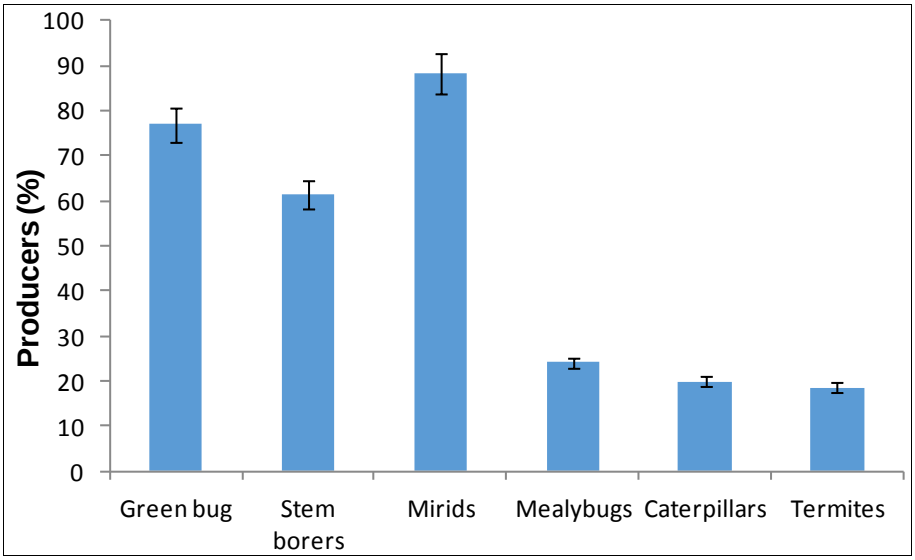

Fig 4: Abundance of the main plantation pests according to producers

3.4 Distribution of insects according to age gradient

The distribution of insects according to age classes shows a significant difference in insect abundance following age of cocoa ochards (Fig. 5). Abundance of stem borers and green bugs is higher for plots aged to 0 and 10 years in comparison to abundance of termites, caterpillars, mealybugs and mirids which are less represented (Anova, p = 0.0005) with compared to. Similarly, the same trend was observed for insect abundances in orchards aged from 11 to 20 years (Anova, p = 0.0157) and more than 20 years (Anova, p < 0.0001). The abundance of stem borers is higher in these plots followed by that of green bug plots. The lowest values of insect abundance were observed with termites, caterpillars, mealybugs and mirids.

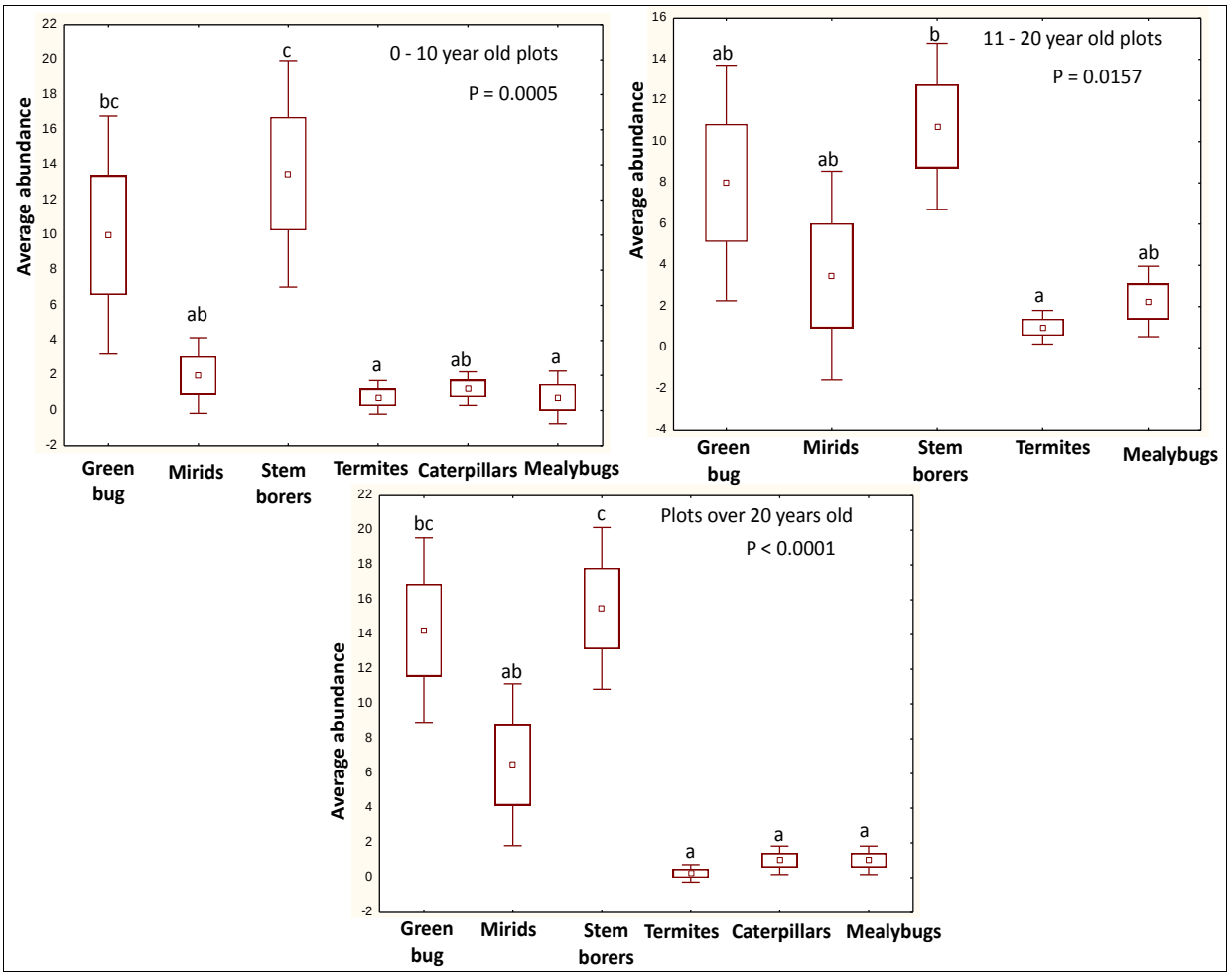

Fig 5: Distribution of insects according to age classes

(The average abundances with the same letters are not significantly different according to Newman-Keuls test)

4. Discussion

Globally, 96.67% of the farmers surveyed are men while women represent only 3.33%. This high rate of men compared to women could be due to that in most cases, the creation of perennial crop plantations in Ivory Coast is reserved for men who are supported by their wifes after the establishment of the plantation. Women plantation owners usually inherited from a relative deceased. Some of this minority of women who owns cocoa plantations, have taken the initiative to create their own. Cocoa farms are established on five main types of crop precedents with a preponderance of "forest" precedent. These plantations are mainly installed on crop precedents by direct sowing at high density, using unimproved plant material. All plantations are family-type farms with a size comprised between 0.5 and 12 ha and an average size of 3.24 ha per farmer for the entire orchard in the study area. The results also confirm that in Côte d'Ivoire, cocoa farming remains an activity dominated by smallholders (Boni, 1985). Indeed, 80% of farmers own small farms of less than 10 ha. According to Assiri *et al.* (2009) [22], the average size of cocoa orchards per producer ranges from 3.5 ha in the 1970s to 6.3 ha in 2003. However, these sizes tend to decrease due to the abandonment and conversion of some old cocoa farms into plantations of other perennial crops such as oil palm, rubber, etc. [23]. The decrease in the size of orchards could be also explained by the slowing down of the dynamics of cocoa extension due to the depletion of the forest reserves [24, 25]. Apart from a handful of farmers growing the improved variety of the CNRA (Mercedes), most producers use the plant material "all coming". The abundance of the unimproved variety on farms highlights a low uptake by producers of the selected plant material. This low level of innovation adoption may be related in part to the low income level of producers, as well as the lack of information [22]. Siapo *et al*. (2018) [16] argued that the cost of seeds in the department of Daloa is 17 USD / ha for "*Mercedes cocoa*" while the producer pays nothing for the "all coming". The free "all coming" plant material would therefore be an important factor in the choice of plant material in the area of study. Some groups of insects have been cited as the most concerned with damage. These are mirids, stem borers and green bugs that attack the cocoa tree as well as the fruit. In addition, termites, caterpillars and mealybugs are also pointed out to cause important damages to cocoa orchards. This observation of the extent of pest damage on cocoa is confirmed by diagnoses made by several authors such as Pohe *et al*. (2013) [26]; N'Guessan *et al*. (2014) [14]; Tra Bi *et al*. (2010) [27]; Sib *et al*. (2020) [13] and Kissi *et al*. (2022) [28]. Indeed, stem drillers perforate the stems of the cocoa tree causing nearly 25.8% losses in Côte d'Ivoire [14]. The fungus of the genus *Phytophthora* attacks the pods of the cocoa tree causing attack rates of more than 40% in the absence of treatment in village plantations [27]. In Côte d'Ivoire, termites also attack cocoa trees and can cause plant death [13, 29]. Analysis of the distribution of insects according to age gradients shows a significant difference in insect abundance in all cocoa age classes. This difference in insect abundance could be related to the prevalence of some insects over others in the cocoa fields. Indeed, mirids, green bugs and stem borers are the most important in the three age classes. According to Kouamé *et al*. (2015) [15], mirids remain the main insect pests of cocoa in Côte d'Ivoire and are a major concern for farmers. In addition, the cocoa tree supports a wide range of insect pests at all stages of its development. These include defoliating insects, stem and twig borers, sucking biters and root rodents [29, 30].

5. Conclusion

This study shows that cocoa production in the Haut Sassandra region is mainly carried out by men. The plantations are small family farms with an average size of about 3.24 ha and cocoa farms established on five main types of previous crops with a preponderance of the "forest" previous crop. Three types of insects are of greater concern. These are mirids, stem borers and green bugs. The distribution of insects according to the age gradient shows a higher abundance of stem borers on the plots.

6. Acknowledgements

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Annex: survey sheet

Department ……	
1. Village name:…….	
2. Cultivated varieties:…….	
3. Age of the plot:…….	
4. Plot area:……	
5. Number of feet per surface …….	
I. Origin of plants	
○ Structure	○ Individual
II. State of plot	
……	
III. Species present in the undergrowth	
……	
IV. Cultural background	
…….	
V. Method of treatment	
○ Chemical	○ Organic
6. …….	
7. VI. Plot cleaning frequency	
8. ……	

9. VII. Educational level of the product user	
……	
VIII. Part of the tree treated	
○ Trunk	○ Foliage
IX. Planting problems	
…….	
X. what type of plot do we meet them? young, middle or old?	
…….	
XI. When do we meet them?	
…….	