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Spatio-temporal distribution of the infestations of *Coelaenomenodera lameensis* Berti and Mariau (*Coleoptera, Chrysomelidae*) an oil palm tree (*Elaeis guineensis* Jacq.) pest in Toumanguié (Côte d'Ivoire)

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Abstract

Spatio-temporal distribution of *Coelaenomenodera lameensis* Berti and Mariau, 1999, pest of palm oil tree (*Elaeis guineensis* Jacquin, 1963) was carried out on 1226 ha of an industrial plantation at Toumanguié (south-east of Côte d'Ivoire). Temporal distribution of population established the existence, according to the years, of favorable periods of *Coelaenomenodera lameensis* infestations. Eight peaks of infestation were observed during 24 months. Infestation cycles proceeds each 90 days. Spatial distribution of the infestations revealed experimental plots having recorded between 0 and 8 months of infestation during the 2 years of investigation. This distribution proved to be independent of the age of the plots. Infestations were also independent of abiotic factors (rainfall, temperature and relative humidity). Larvae at stages 1, 2, 3 and 4 are mostly responsible of the damages observed in the fields.

Key words: *Coelaenomenodera lameensis; Elaeis guineensis*; spatio-temporal distribution; Côte d'Ivoire

Résumé

Répartition Spatio-temporelle des infestations de Coelaenomenodera lameensis *Berti et Mariau (*Coleoptera, Chrysomelidae*), ravageur du palmier à huile (*Elaeis guineensis *Jacq.) à Toumanguié (Côte-d'Ivoire)*

L'étude de la répartition spatio-temporelle de Coelaenomenodera lameensis *Berti et Mariau, 1999 (*Coleoptera, Chrysomelidae*), ravageur du palmier à huile (*Elaeis guineensis *Jacquin, 1963) a été réalisée sur 1226 ha d'une plantation industrielle à Toumanguié, au sud-est de la Côte d'Ivoire. La répartition temporelle a établi qu'il existe, en fonction des années, des périodes favorables aux pullulations du ravageur. Huit pics d'infestation ont été observés en 24 mois, dégageant des cycles d'infestation de 90 jours. La répartition spatiale des infestations a fait apparaître des parcelles ayant enregistré entre 0 et 8 mois de pullulation en 2 ans. Cette répartition s'est avérée indépendante de l'âge des parcelles et des facteurs abiotiques que sont la pluviométrie, la température et l'humidité relative. Les larves aux stades 1, 2, 3 et 4 sont en grande partie responsables des dégâts observés dans les plantations.*

Mots clés : *Coelaenomenodera lameensis ; Elaeis guineensis ;* répartition spatio-temporelle ; Côte d'Ivoire.

1. Introduction

Oil palm tree is an important source of plant oil. It is the oleiferous plant, producing the most oil, with 4.5 to 9 tons per hectare and a year. This production is 5 to 10 times more important than groundnut and soybean oil (Jacquemard, 1995).

The palm tree plantations in Côte d'Ivoire cover more than 215.500 hectares, mainly distributed between village plantations (145 498 ha) and industrial plantations reaching 70 073 ha (Naï-naï *et al.,* 2000). Côte d'Ivoire, seventh world producer of oil palm after Malaysia, Indonesia, Nigeria, Thailand, Colombia and Papouasie New-Guinea, proposes to double its annual production estimated at more than 276.000 tons (Anonymous, 2003).

Elaeis guineensis is extremely vulnerable to the insect's devastations. *Coelaenomenodera lameensis* (Berti & Mariau, 1999), Coleoptera Chrysomelidae Hispinae, is the most devastating pest of this plant. The damages caused by this insect induce fast drying of the palms. More than one thousand larvae can be counted by palm during the time of pullulations safe from hundreds galleries. Severe defoliations caused by these devastations can have as consequence, the decreasing of seeds production from 30 to 50 % during 2 to 3 consecutive years (Lecoustre, 1988).

Many tests were realized to control this pest: chemical fight, by terrestrial way, air or systemic, biological control and resistant varieties selection (Mariau *et al*. 1973; 1979; Philippe *et al.,* 1979; 1983; Lecoustre *et al.,* 1980; Koné, 2002; Appiah *et al.,* 2007).

Biology of the *C. lameensis* was studied by several authors. Thus, Morin and Mariau (1970) did the morphological and development description. These authors successively studied the reproduction, the biology of the main parasites of the coleoptera in 1971 and also the natural mortality of the larvae and eggs in 1974. A study carried out by Mariau and Lecoustre (2000) showed the role of ecoclimatic and edaphic factors of *Coelaenomenodera lameensis* fertility in field. The results of the biological studies were interested especially reproductive biology in order to prevent infestations.

Less data are available to understand the spatio-temporal distribution of *C. lameensis*. Indeed, works of Mariau and Morin (1972) and those of Lecoustre (1988) on the distribution of this coleoptera deserve to be supplemented. Knowledge of the spatio- temporal distribution of a pest is highly essential for the conception and the implementation of efficient fight plan strategy.

This work was conducted to follow an industrial plantation infestation by *C. lameensis* in order to establish the infestation cycles, to determine the favorable periods of infestations, to evaluate the share taken by the various developmental stages of the insect in the episodes of infestation and finally, this study also aimed to determine the existing link between *C. lameensis* and some abiotic factors.

2. Materials and methods

2.1. Study sites

This study was conducted during 24 months, from January 2002 to December 2003, on 1226 ha of oil palm plantation at the agro-industrial unit (AIU) of Toumanguie located in the south-east of Côte d'Ivoire (5° 21' N, 3° 23' W). This region have a wet tropical climate with an annual temperature varying from 24 to 28°C, a relative humidity between 79 and 88 per cent and a 12:12 (L:D). Average annual rainfall varies between 1400 and 1800 mm. The area has two annual rainy seasons (from April to mid-July and September to November) and two dry seasons (from mid-July to August and December to March)

The palm trees observed for this study were 17 to 20 years old. The field research account 14 blocks of 100 ha. Each block has been divided into 4 plots of 25 ha each one. The blocks are named by letters, laid out of north towards the south alphabetically. First figure which follows letters indicates the number of the block and is established from west to east, by ascending order. The second, numbers from 1 to 4 the plots in south-north direction.

The geographical informations of the plots were collected using a Global Position System (GPS). The data were treated by GIS (*Geographic Information System*). Geostatistics was used to characterize and map the research area (Fig. 1).

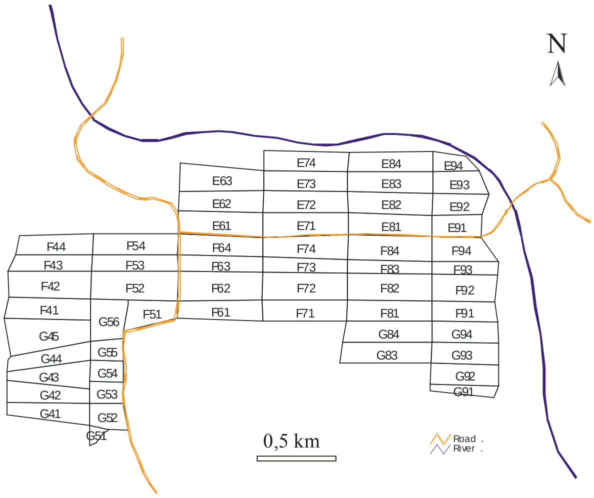

Fig. 1: Experimental plots of V2 section of Toumanguié Agro-Industrial Unity.

2.2. Phytosanitary controls

The sanitary control used is Irho-Cirad's method. Ordinary and special controls were used.

2.2.1. Ordinary control

Ordinary control is realized every two months. One tree per hectare has been identified for sampling. Observation relates to a palm of one tree, a line on five alternatively in the northern and southern half of the experimental plot. The number of adult insects alive on the lower face of the palm is counted; then, the number of larval galleries on the upper face of the palm is recorded. The galleries are thereafter open to count the small ones (larval stages 1 and 2) and the big larvae (larval stages 3 and 4), the nymphs and the internal adults.

As long as the mean of larvae per palm is lower than 10 on an experimental plot, or that the mean of adults per palm is lower than 2 insects, the same frequency of control is preserved. For mean of larvae per palm ranked between 10 and 40 or mean of adults per palm between 2 and 5 insects, controls become monthly.

2.2.2. Special control

A twice-monthly special control is carried out for a mean of larval per palm higher than 40 or mean of adult more than 5 per palm.

2.3. Infestation cycle study methods

Phytosanitary surveys were carried out over 24 months (January 2002 to December 2003). Total average density of insects (all stages) per palm per month and per experimental plot ($d_{i,j}$) was calculated by using the following formula:

$$\bar{d}_{i,j} = \frac{\sum_{k=1}^{n_{i,j,k}} d_{i,j,k}}{n_{i,j,k}}$$

Where $n_{i\,j,\,k}$ indicating the number of samples of the experimental plot i at the month j and $d_{i,\,j,\,k,}$ the number of insect per sample of the plot i.

2.4. Implications of the developmental stages of *C. lameensis* in the infestations

The average numbers of total insects, adults then the youthful ones (larvae and nymphs) per palm per month was calculated using requests in R software (Anonymous, 2004).

The graphs of mean numbers of insects per stages and per palm according to the month were traced and showed the implication of the stages in infestations.

2.5. Impact of some abiotic factors on insect infestation evolution

The effect of rainfall, relative humidity and the temperature were followed. In each case, Pearson's correlation coefficient (r) permitted to evaluate linear relationship between the abiotic factor and the rate of infestation.

2.6. *C. lameensis* infestation: spatial distribution

2.6.1. Global approach

The mean rate of the experimental plot infestation per month and year were calculated using requests made on R software. The cartography of the levels of infestation is thus worked out.

2.6.2. Infestation according to the experimental plot age

The experimental study plots were planted during the years 1983, 1984, 1985 and 1986. The planted palm trees each year correspond to a well defined geographical area.

Effect of the plot age on its sensitivity to be infested was evaluated as follows:

For each year of the experimental plot creation, the number of infested plot and the duration of infestation were recorded. A table of contingency indicating the numbers of plot of the year *x* which was infested *n* time during the follow-up was elaborated.

3. Results

3.1. Establishment of infestation cycles

3.1.1. Temporal evolution of C. lameensis infestations

Eight peaks of unequal intensities were observed in the graphs A, B and C that shows respectively, the mean number of insects (all stages) per palm, average number of adult insects per palm and the mean number of youthful insects (larvae and nymphs) per palm according to the months (Fig. 2). Peaks were particularly marked in February and August of the year 2002 (≈ 45-50 insects per palm) and in September and December of the year 2003 (≈ 80-110 insects per palm), for the mean number of insects (all stages) and youthful insect per palm. The peaks were observed once every three months.

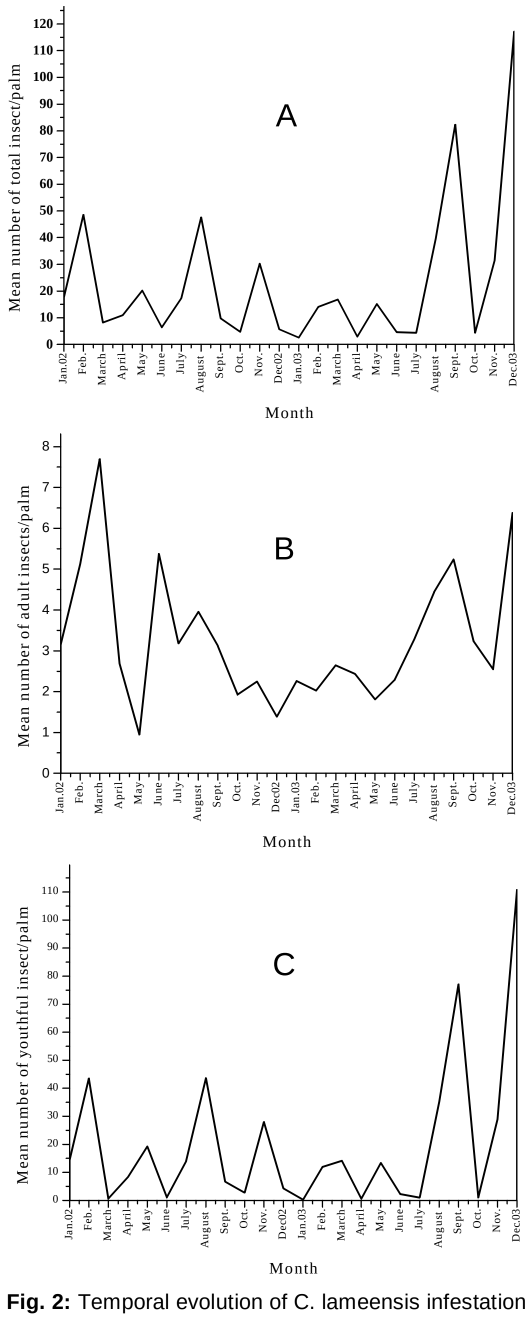

Fig. 2: Temporal evolution of C. lameensis infestation

***A**: Global Infestation (larva, nymphs, adults); **B**: Adults infestation; **C**: Youthful infestation*

Mean number of adults take alone was relatively low. They were upper the critical point of 5 insects by palm in March and June 2002 and in mid-August and December of the year 2003.

Eighteen out of 56 plots observed were not infested, corresponding to 32.14%. At least one month of infestation was observed for the 38 others plots (64.28%). Eight of the 56 plots recorded 5 to 8 months of infestation during 24 months (Table 1).

Table 1: Number of infested plots and duration (months) of infestation

Duration of infestation (lad>40 or ad>5)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**8**
Number of plots concerned	18	10	5	9	6	4	2	2

lad>40 : larval density higher than 40 insects per palm
ad>5 : adult density higher than 5 insects per palm

3.1.2. Influence of abiotic factors on the infestation cycles

The three abiotic factors (rainfall, relative humidity and temperature), with respectively r=0.0316 (probability: p= 0.87) for rainfall, r=0.1378 (p= 0.51) for relative humidity and r=0.0894 (p= 0.67) for the temperature presented low correlation with the infestation of *C. lameensis*. The temporal evolution of *C. lameensis* infestation is not related to the one of these factors in this section, (Fig. 3 & 4).

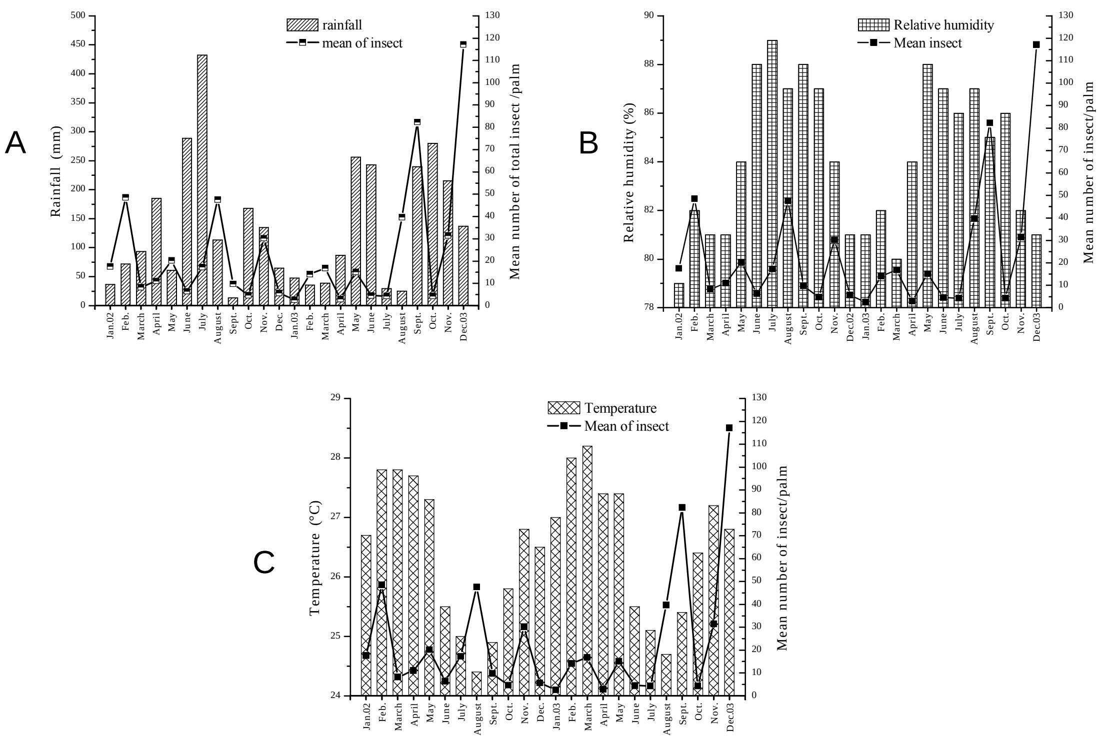

Fig. 3: Influence of rainfall, relative humidity and temperature on temporal evolution of the infestations of *C. lameensis* (***A***: *rainfaill ;* ***B*** *: relative humidity and* ***C*** *: temperature)*

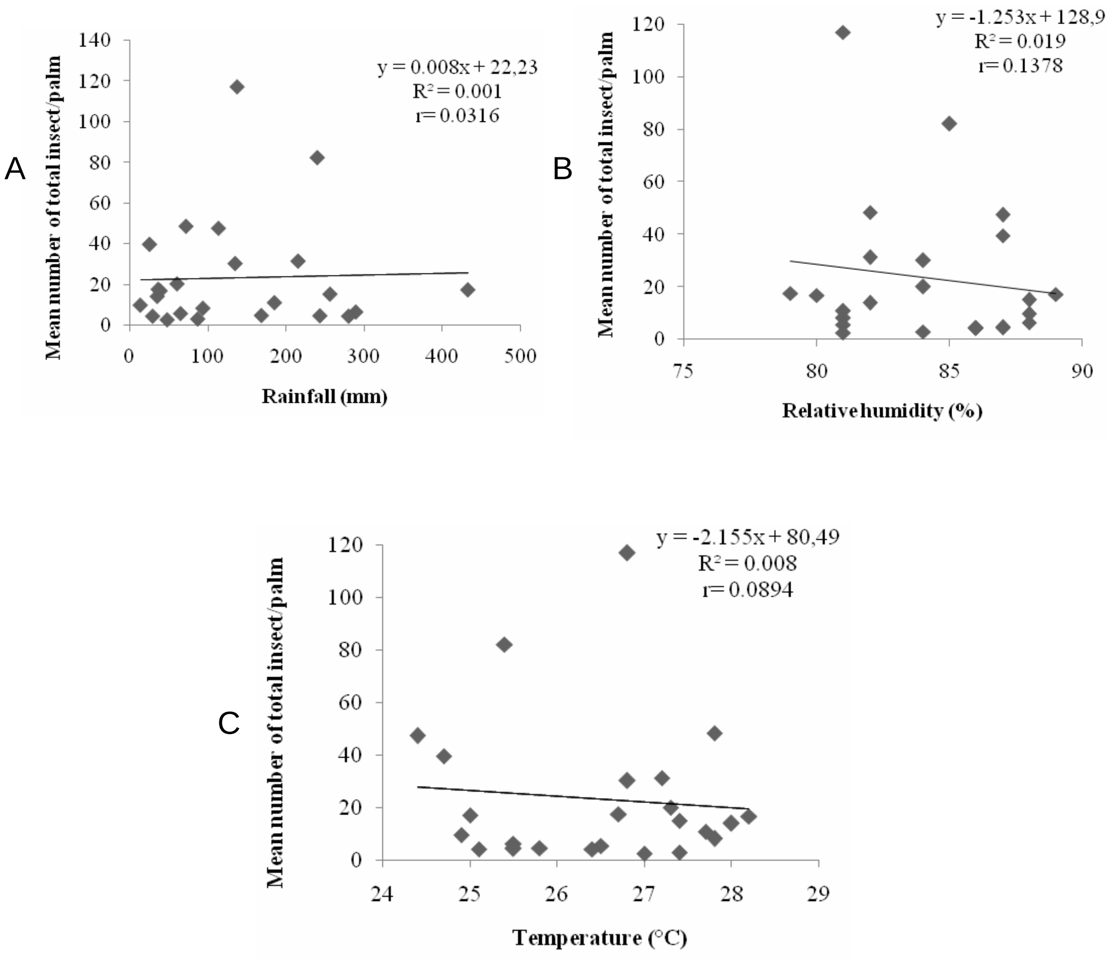

Fig. 4: Correlation between abiotics factors and *C. lameensis* infestation

***A**: Rainfall **B**: Relative humidity **C**: Temperature*

3.2. Spatial distributions of the infestations of *C. lameensis*

3.2.1. Global approach

The number of insects (all stages) counted during the phytosanitary controls by plot shows that the levels of infestations vary from one experimental plot to another. The high infestations of *C. lameensis* mainly concentrated on center and especially south-east zones (Fig. 5). Some plots more than of others presented frequent infestations (Table 1).

3.2.2. Infestation according to the age of the pieces

Nine of the eighteen experimental plots planting in 1983 (50%) did not know any month of infestation. Other half recorded at least 1 month of infestation.

All the plots planting in 1984 knew at least one month of infestation. Fifteen plots (83.33%) out of the 18 recorded more than 2 months of infestation. Two experimental plots reached more than 8 months of infestation on 24 months (Table 2).

Three of the 8 plots planted in 1985, (37.50%) did not know any month of infestation from 2002 to 2003 and 5 plots (62%) underwent from 1 to 5 months of infestation.

Lastly, 6 of the 12 plot planted in 1986 (50%) did not present any month of infestation. The 6 other plots recorded 1 to 4 months of infestation.

The experimental plots planted in 1984 thus were infested and almost totality of palm tree (94.44%) knew periods of infestation higher or equal to 2 months (Table 2) and all the plots knew at least a month of infestation (Table 3).

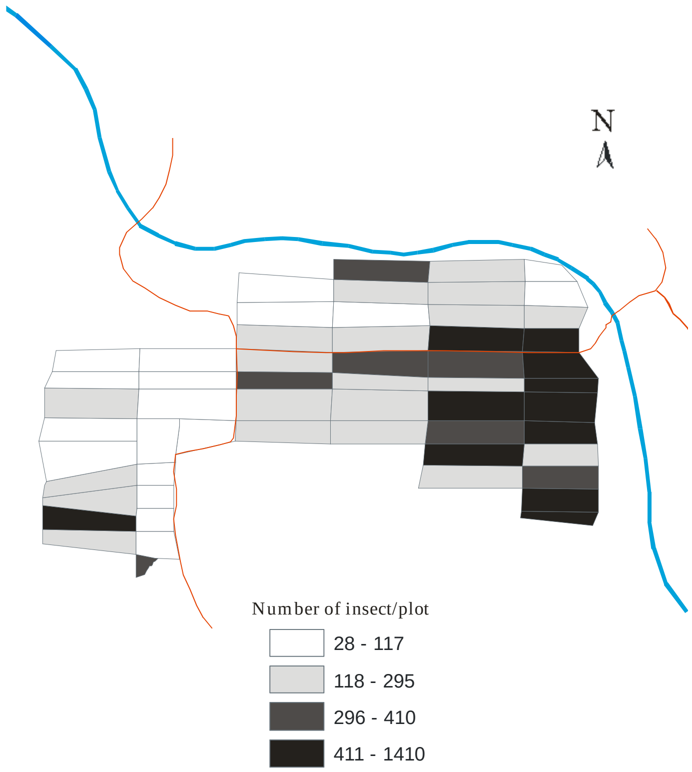

Fig. 5: Cartography of total number of insects in each plot during 24 months

Table 2: Number and duration of infested plots according to the year of setting in culture

	Month number of infestation							
	0	1	2	3	4	5	6	8
1983	9(50)	6(33.33)	1(5.55)	1(5.55)	0	1(5.55)	0	0
1984	0	1(5.55)	2(11.11)	6(33.33)	3(16.66)	2(11.11)	2(11.11)	2(11.11)
1985	3(37.50)	1(12.5)	1(12.5)	1(12.5)	1(12.5)	1(12.5)	0	0
1986	6(50)	2(16.66)	1(8.33)	1(8.33)	2(16.66)	0	0	0

The values in brackets represent the rate of infested plots

Table 3: Rate of plot infested according to the year of culture

Year of plantation	Number of plot without any month of infestation	Number of plot with at least a month of infestation	Percentage of infested plots
1983	9	9	50
1984	0	18	100
1985	3	5	62,5
1986	6	6	50

4. Discussion

The study of the temporal distribution of the infestations established that there are periods of the year presenting marked peaks. Indeed, during the years 2002 and 2003, February (with respectively a mean of 48.56 insects and 14 per palm), May (20.21 and 15.18), August (with 47.57 and 39.67 per palm) and November (30.26 and 31.41) showed high levels of infestation. During the year 2003, December and September presented extremely important peaks with respectively an average of 82.34 and 117.17 insect per palm. It thus arises that certain periods of the year, are more favorable to the infestation of *C. lameensis* than others. Numerous factors can explain variation of insect population including:

- favorable periods to the increase of fertility of *C. lameensis;*
- agro-climatic conditions favorable to the development of the insect;
- decrease of natural mortality;
- Inefficiency or low stability of the plant sanitary treatments.

Mariau and Lecoustre (2004) showed that the fertility of *C. lameensis* increases in the humid zone. In comparison with the temporal evolution of the infestations, our results revealed that the levels of infestation are high as well for the dry periods as for the wet periods. The increase of fertility and the agro-climatic conditions thus do not appear sufficient to explain the variations of the insect population observed.

The natural mortality of *C. lameensis* is low (Mariau, 2001) and cannot be the explanation of the temporal variations of insect population's observed. As for the inefficiency of the phytosanitary treatments, our results showed that the infestations took place every 3 months, establishing a cycle of 90 days infestation. We indeed, observed 8 peaks in 24 months. In spite of the plant sanitary management (insecticidal controls and treatments), this cycle is perfectly repetitive and corresponds to the duration of the development cycle of *C. lameensis* which is of approximately 3 months (Ruer, 1964; Blum, 1965; Morin and Mariau, 1970). The plant sanitary treatments do not represented a limiting factor to the infestations of the pest and can be suspected. Tuo (2004) showed that the choice of sanitary treatments on the UAI of Toumanguié was especially guided by the cost of insecticides.

The incidence of the different developmental stages of *C. lameensis* in the establishment of the infestations peaks showed that the youthful ones (larvae especially) are as a majority responsible for the episodes of infestation. Indeed, the larvae are leaf miners. The young larva begins to dig its gallery. Larva penetrates into the limb without leaving outside. The larvae then feed remaining in the vicinity of the upper leaf epidermis, which dries gradually as the galleries lengthen. Lecoustre (1988) and Mariau (2001) showed that the larval stages are almost exclusively responsible of infestations and damages caused to the oil palm tree by *C. lameensis*. Damages caused by adults are generally not very important, except in case of extreme infestations. It is thus necessary, by effective cures, to stop the cycle of the insect before the appearance of youthful in great quantity.

Results also showed the existence of spatial distribution of the infestations on the UAI of Toumanguié. Indeed, during the 24 months of investigation, some plots did not shown any month of infestation whereas certain experimental plots presented up to 8 months. Because of their geographical position, plots are ready to be infested by *C. lameensis*. According to Mariau and Lecoustre (2004)**,** the genesis of the hearths of pullulation is induced by the combined action of a low parasitism and a high fertility which is the prerogative of the humid zones. The whole study section has presented rates of higher relative humidity ($\geq$ to 79%), this approach does not appear sufficient to explain the spatial distribution of the infestations. We thus sought to know if the infestation were influenced by the abiotic factors which are rainfall, relative humidity and temperature. The results indicated that none of these factors is linearly correlated with the infestations *C. lameensis* (Pearson's coefficient of correlation (r) no significant). Explanation was that, important variations were not observed on the level of the temperature and the relative humidity. Moral-Garcia, (2006) made an analysis of the spatio-temporal distribution of *Helicoverpa armigera (Lepidoptera: Noctuidae)* in tomato fields. It showed that when the temperature and humidity were almost constant, they did not have an influence on the insect's populations.

The study of the evolution of the infestations according to the age of the plot established that the rate of infestation does not depend on the age of the experimental plots. Indeed, the palm trees planted in1984 presented 100% of infested plot. We recorded over the two years of investigation, 62.5% of plots infested on those planted in 1985; 50% on the plots planted in 1986 and 1983. The palm trees in production are likely to be attacked at any age by *C. lameensis*. However, knowing that the date of plantation corresponds to a quite precise zone, it appeared interesting to determine if the geographical position of the plantation could be related to the degree of infestation. With this assumption, several factors could be responsible for the infestation:

- Topographic characteristic. But, in the lack of topographic data, this aspect could not be tested
- Proximity of the «hearths refuges» of *C. lameensis*. The most infested zones (plots planted in 1984 and 1985) are indeed very close to imperfectly maintained village plantations.

The assumption, according to which the degree of infestation of *C. lameensis* would be dependant to spatial dimension, is thus strongly possible.

5. Conclusion

Spatio-temporal distribution of *C. lameensis* infestation showed the constant presence of this pest. In spite of plant sanitary management realized (controls and treatments), it is arisen, on the whole of this section, infestation cycles are observed every 3 months. Plant sanitary management currently used does not disturb the cycle of the pest which remains stable and is repeated every 90 days. The sanitary management of the plantations is to be managing as well as on the level of controls and on the products used for the treatments.

The distribution of infestation zones (spatial distribution) is heterogeneous on the AIU of Toumanguié. All the extent of this section must be the subject of constant monitoring.

Periods of the year presented peaks of infestation must be submitted to particular monitoring. It arises that neither rainfall, neither the temperature and nor humidity are correlated on the level of infestation. These factors indeed, showed minor variations that do not modify the level of infestation.

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