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Full Length Research Paper

Comparison of two sanitary control methods of *Coelaenomenodera lameensis* Berti. and Mariau (Coleoptera, Chrysomelidae: Hispinae), an oil palm (*Elaeis guineensis* Jacq.) leaf miner in West Africa

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***Coelaenomenodera lameensis* (Coleoptera, Chrysomelidae: Hispinae) is a dangerous pest of oil palm (*Elaeis guineensis*, Jacquin 1963). Two sanitary control methods (IRHO/CIRAD method) were compared for the first time on the agro-industrial unit of Toumanguié (Côte d'Ivoire). PRIOU method examines twice more trees and 4 times more palms than the IRHO-CIRAD's. Yet the latter presented a rate of sampling of leaflets 10 times superior to the first method and was more economic and sensitive in the detection of the infestation zone (23 against 15). However the PRIOU method detected, a larger total infestation zone (150 ha against 94). IRHO/CIRAD method provides a better anticipation of probable damage before it occurs. The PRIOU method circumscribed a larger total surface of infested zones. These results are essential in the sanitary management of palm plantations.**

Key words: Côte d'Ivoire, *Coelaenomenodera lameensis, Elaeis guineensis*, infestation zone, IRHO-CIRAD method, PRIOU method.

INTRODUCTION

The oil palm (*Elaeis guineensis*) is an important source of edible oil. It is the most productive oleiferous plant with 4.5 to 9 tons per hectare and per year. These tonnages represent 5 to 10 times more oil than groundnut and soya (Jacquemard, 1995). In Côte d'Ivoire, oil palm tree plantations cover currently more than 215,500 ha, distributed mainly between the traditional plantations (145, 498 ha) and the industrial plantations (70, 073 ha) (Naï-naï et al., 2000). The culture of oil palm faces many plant health problems which alter its development out of its natural ecosystem. This culture is vulnerable to the devastations of insects, mainly belonging to the orders of Coleoptera and Lepidoptera (Lepesme, 1947). *Coelaenomenodera lameensis* (Coleoptera Chrysomelidae: Hispinae), is currently considered as the most threatening pest of this culture in West Africa (Mariau, 2001).

The damage caused by this leaf miner to the oil palm plantation, is especially due to the larvae. Each one attacks approximately 3 to 4 cm of leaflet, destroying the palm directly, or causing its fast drying. Indeed, at pullulating period, more than one thousand larvae can be counted per palm, setting hundreds of safe galleries, damaging the totality of the leaf area. Strong defoliations can lead to a yield decrease ranging from 30 to 50%, during 2 to 3 consecutive years, wrecking production (Wood et al., 1973; Anonymous, 1993; Appiah and Yawson, 2003).

To bring back the pest populations to a tolerable level, chemical and integrated pest management methods have been applied (Mariau et al., 1973; 1979; Philippe et al., 1979, Lecoustre et al., 1980). It is however advisable to use these methods judiciously under supervision and at specific time. Knowledge of the sanitary situation of the plantations is highly essential (Mariau, 1994). Sanitary control takes place at two levels. A routine control warning

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Table 1. Comparison of the characteristics of the two methods.

Characteristics of the two methods	IRHO/CIRAD method	PRIOU method
Prospection team	1 controller and 1 assistance	1 controller and 2 assistants
Daily contract	50 to 75 ha (two sections)	35 to 40 ha (a parcel and half)
Frequency of control	Bi-monthly or monthly	monthly
Course	1 /5 line, 1 tree by line	1 ligne/5 2 trees per line
Choice of the trees	Alternatively in the northern and southern half of the parcel	Fixed definitively
Unit of observation	Whole palm	16 leaflets (8 leaflets per sheet)
Level of observation	F25 or F17	F25 and F17
Calculated variables	Index larva (Il) and adult index (IA) (they are the average indices of infestation of the parcel)	none
Critical levels	Il = 40 larvae Ia = 5 adults Indices to start semi-monthly special control	Larvae: 8 Adults: 2 Levels relate to each tree
Other observations	The small larval galleries are mentioned in control	The small larval galleries are not mentioned in control

ha: hectare; F17 and F25 indicate the foliar rows of the palm tree.

that occurs over the entire plantation and a special control, more detailed, limited in time and space when damages are reported, to evaluate the conditions of intervention. Two methods are usually used to carry out the sanitary supervision of *C. lameensis* attacks: IRHO-CIRAD and PRIOU methods. IRHO-CIRAD method was the first to be established by Oils and oil-plants research institute (IRHO) - Agricultural Research for developing countries to make the monitoring of palm oil plantations. PRIOU method considered to be better than the first one by a few operators, has been established in some palm plantations.

This study presents these two methods in order to establish a comparison to select the most accurate, sensitive and economical sampling method related to the level of infestation of *C. lameensis.*

MATERIAL AND METHODS

The study site

Investigations were carried out on the agro-industrial unit of Toumanguie located in the south-east of Côte d'Ivoire (Latitude: 05-15N, longitude: 003-56W, altitude 7m). This region have a wet tropical climate with an annual temperature varying from 24 to 28°C, a relative humidity between 79 and 90% 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 agro-industrial unit of Toumanguie is subdivided into 3 sections (S). Each section includes several blocks of 100 ha. A block is divided into 4 parcels of land of 20 to 25 ha depending on the topography. A parcel of land is composed of 127 lines of palm trees. Each line contains 27 trees. The investigations were carried out on the sections S1 (962 ha) and S2 (1226 ha).

Presentation of the two methods

The characteristics of the methods IRHO/CIRAD and PRIOU, allow to follow through the evolution of the pest populations and to circumscribe the infestation zones. Each method presents several components summarized in Table 1.

Sampling rate for each method

The sampled parcel of land had an average density of 135 palm trees/ha, 33 palms per tree and 300 leaflets per palm.

For the IRHO/CIRAD method, the controller observes one palm tree per hectare. On each tree, the palm on rows 25 or 17 was cut down and all the leaflets were inspected. The inspection consists in opening galleries on palms to extract larvae and nymph of *C. lameensis* for their counts. The number of adult forms located on the lower surface of leaflets was also noted.

For the PRIOU method, the controller observes 2 trees per hectare. On each tree, 16 leaflets were taken. The observation is done on 8 leaflets of a row 25 palm and 8 from a row 17 palm. The leaflets are cut in the median part of the palm on both sides of the rachis.

The sampling rate for each method was calculated according to 3 indices: τ; τ'; τ'':

$$\tau' = \frac{\text{number of palm observed per hectare}}{\text{number of palm per hectare}} X\,100$$

$$\tau = \frac{\text{number of palm trees observed per hectare}}{\text{number of palm trees per hectare}} X\,100$$

$$\tau'' = \frac{\text{number of leaflets observed per hectare}}{\text{number of leaflets per hectare}} X\,100$$

Comparative study of the infestation on 16 leaflets and on entire palm

The observations were carried out on 6 parcels of land (3 at S1 and 3 at S2) at the beginning of *C. lameensis* infestation. During inspection, the recording of *C. lameensis* (larvae and adults) is done first on 16 leaflets (8 leaflets on row 17 palm and 8 leaflets on row 25 palm), and consist of cutting along the median part of each of the two palms on both sides of the rachis. At the same time, the number of insects observed of all stages in the entire palm was noted for the two palms concerned with the first sample. Thus, fifty observations were made according to the row of the palm.

Precision and the delimitation of infestation zones

A preliminary study was undertaken, for one month, out of 30 parcels of land of S2 section. Thereafter, 13 of the 30 parcels of land, having revealed the effective presence of *C. lameensis*, were inspected for the evaluation. The two sanitary control methods were applied to the 13 parcels of land. On the same parcel, the control methods were carried out the same day. The number of detected infestation zone, their delimitation and their surface were recorded.

Statistical approach

For the comparison of the infestation on 16 leaflets and on entire palm, simple linear regression model was done. In this model, the independent variables (x) are referred to as regressors or predictor variables. The dependent variable (y) is also referred to as the response. The sampling permitted to plot, for the larvae and the adults of *C. lameensis*, the curves of correlation for the various rows of palms (17; 25), between the values on entire palm (y) and on 16 leaflets (x). This same correlation was evaluated on the two foliar rows taken together. Pearson's correlation coefficient (r) permitted to evaluate linear relationship between the larvae or adults of *C. lameensis* on entire palm and on 16 leaflets.

RESULTS

Sampling rates defined for each method

The rates (τ; τ'; τ'') permitted to assess the level of sampling of each parcel of land based on the 2 methods. These rates are generally low. PRIOU method examines twice more trees and four times more palms than IRHO-CIRAD's. However, IRHO-CIRAD method has a sampling rate of the leaflets ten times superior to the first method (Table 2).

Comparison of the infestation on 16 leaflets and on entire palm

The regression lines obtained (Figures 1 to 6), shows Pearson's correlation coefficient (r) higher than 0.60 ($R^2 > 0.60$) and give an account of relationship between the number of adult insects and larvae, on entire palms and 16 median leaflets taken from rows 17 and 25. There thus exists a moderate linear correlation between the parameters measured. In the various cases, the lines obtained have all the following equation form:

Table 2. Sampling rate for the 2 sampling procedures.

Parameters	IRHO /CIRAD method	PRIOU method
τ	0.74	1.48
τ'	0.02	0.09
τ''	0.02	0.002

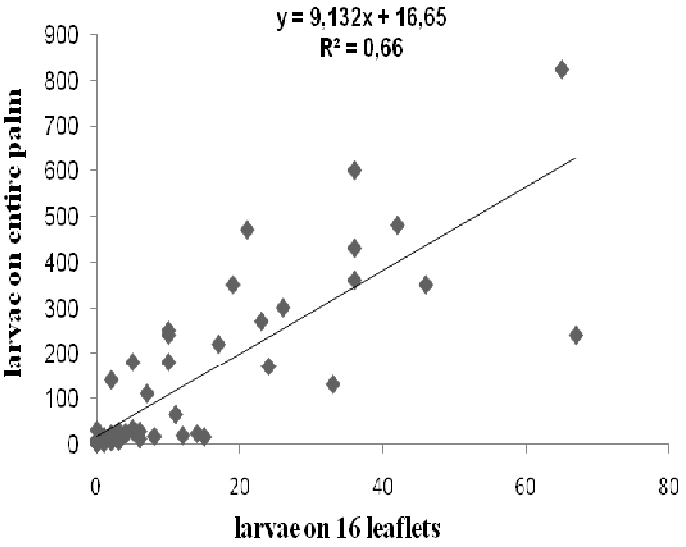

Figure 1. Correlation between the numbers of larvae observed on entire palm and 16 leaflets of row 17.

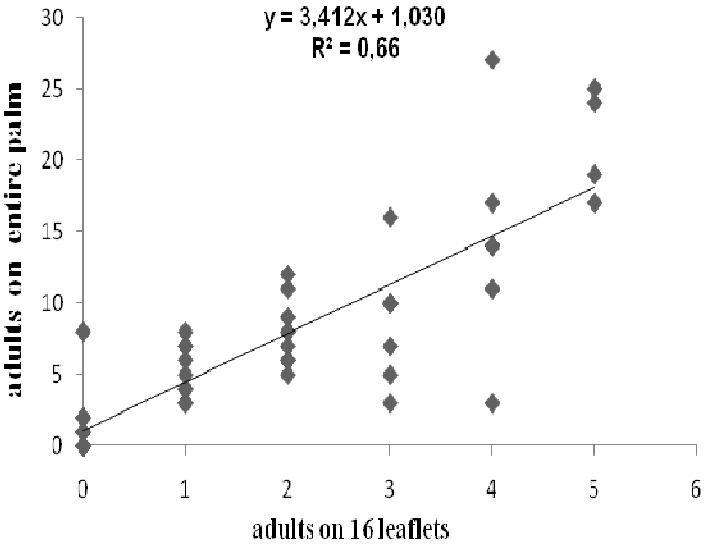

Figure 2. Correlation between the numbers of adults observed on the whole palm and on 16 leaflets on palms of row 17

EP=a (16L) + be

EP = insects observed on entire palm (row 17 or 25),

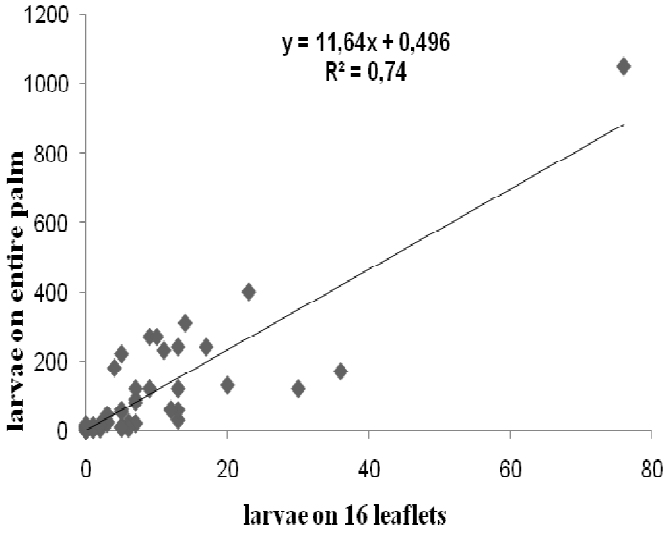

Figure 3. Correlation between the numbers of larvae observed on entire palms and 16 leaflets on row 25.

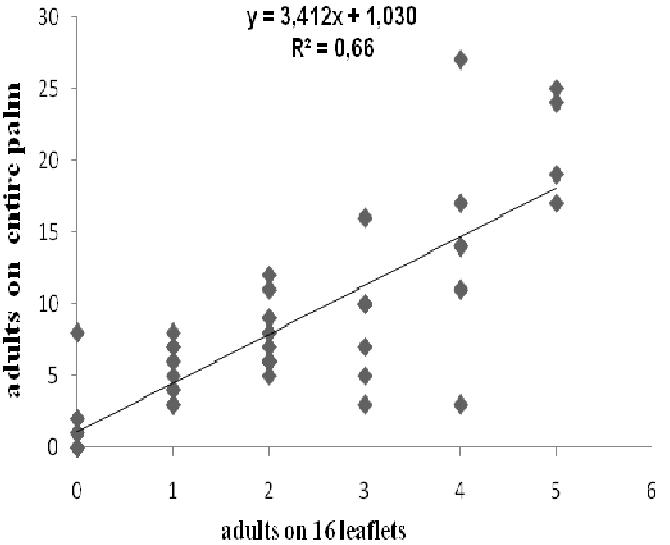

Figure 4. Correlation between the number of adults observed on whole palm and 16 leaflets of row 25.

16L = insects observed on 16 leaflets,
a = directing coefficient of the line;
b = height at the origin

The critical points of infestation fixed for the IRHO-CIRAD method which analyzes the entire palm are of 5 adults or 40 larvae per palm (Table 1). These levels for the PRIOU method, which observes 16 leaflets, are 2 and 8 for adults and the larvae respectively. By replacing EP or 16L in the various equations by these fixed critical levels, the predictable values obtained in the case of this study were established (Table 3).

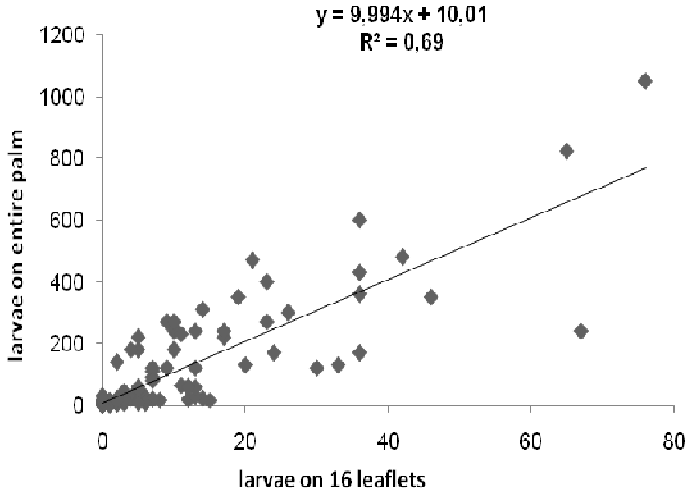

Figure 5. Correlation between the number of larvae observed on whole palm and 16 leaflets of rows 17 and 25.

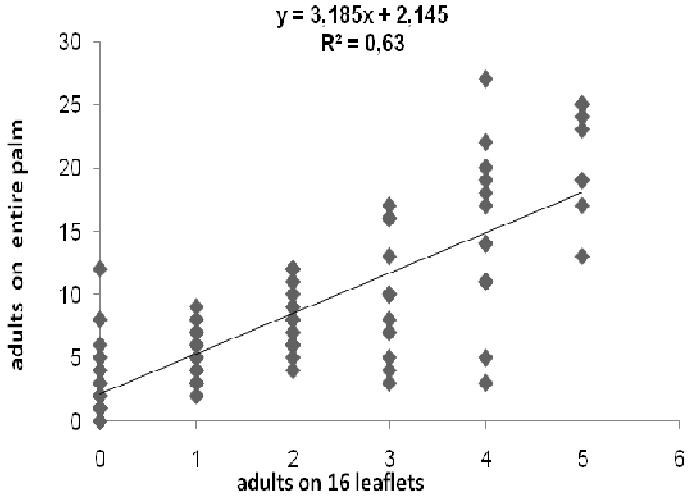

Figure 6. Correlation between the number of adults observed on whole palm and 16 leaflets of rows 17 and 25.

The correlations of the number of larvae observed on F17, F25, F17 and F25, reveal that the values estimated on the entire palm, ranging between 90 and 94 larvae, are much higher than the critical level fixed by the IRHO-CIRAD method which is of 40 larvae. The correlations of the number of adults observed (8 to 9 adults) show values estimated of adults on entire palm also higher than the fixed level, by this same method, which is of 5 adult insects.

For the PRIOU method, the considered value, calculated according to the correlations for the larvae, is 3. This value is lower than the fixed critical point which is of 8 larvae. For the adults, this same method gave an estimated value (1) which is half of the fixed breaking value which is of 2.

Table 3. Estimated values of the levels of infestation obtained starting from the correlations.

		F17	16F17	F25	16F25	F17 and F25	16F17 and 25
Larvae	Fixed threshold	40	8	40	8	40	8
	Estimated value	90	3	94	3	90	3
Adults	Fixed threshold	5	2	5	2	5	2
	estimated value	9	1	8	1	9	1

F17: entire palm of row 17; F25: entire palm of row 25; F17 and F25: entire palm of rows 17 and 25; 16F17: 16 leaflets on palm of row 17; 16F25: 16 leaflets on palm of row 25; 16F17 and 25: 16 leaflets on palm of row 25.

Precision of the delimitation of infested zones

It is difficult to estimate the importance and the extension of the infestations of *C. lameensis* in plantation, because of its low mobility. We assumed that, the most suitable method is the one which allows a broader delimitation of the infestation zones. Thus, 13 of the 30 parcels of land chosen for the experiment revealed the presence of an effective or an incipient infestation zone (Table 4).

The parcels of land where the PRIOU method detected the existence of infestation zone, the IRHO-CIRAD method showed similar results. The IRHO-CIRAD method, however, detected more infestation zones (23) than the PRIOU method (15). On the other hand, this last method detected a larger total surface of infestation zone (150.5 ha) than circumscribed by the method IRHO-CIRAD (94 ha). For example for parcel of land 5 (P5), the PRIOU method detected only an infested zone (the whole parcel) whereas the IRHO-CIRAD detected 3 adjacent zones of infestations (L13 to L58, L68 to L103, L113 to L123).

DISCUSSION

Characteristics of sampling methods

The choice of the palm trees, which is variable in the IRHO-CIRAD method, allows a better observation of the movement evolution of *C. lameensis*. This method uses, moreover, less labor (1 controller and 1 assistant).

The selection of the trees to be examined recommended by the PRIOU method, enables an easier work of the controllers. Moreover this method has the advantage of recommending an accurate surveillance with a monthly ordinary control. It covers, one and half section a day, whereas the IRHO-CIRAD ensures the inspection of two parcels of land per day. The small larval galleries, responsible of the infestation (Mariau and Morin, 1972) are not mentioned in the PRIOU method and remove the possibility of tracing the development cycle of *C. lameensis* which is of approximately 90 days (Ruer, 1964; Blum, 1965; Morin and Mariau, 1970, Appiah et al., 2007, Koua, 2008).

Sampling rate

The sampling rate of the two methods revealed that the IRHO-CIRAD method gives more precise results on the state of the palm whereas the PRIOU method allows only one global view based on a sampling. However, this last method has the advantage of making the sampling on two foliar levels (F17 and F25). The low level of sampling of the two methods is compensated by the course of the inspections which allow the coverage of the whole sections.

Often, trees with low level of infestation are beside too much infested trees: This phenomenon called “nugget effect” (Lecoustre, 1988) is not always taken into account by the current inspections. It seems vital to increase sampling rates and vary the course of inspection to expect better results. Lecoustre (1988) proposed to increase the sampling rate of the IRHO-CIRAD method to 5%. Such rate would give further information 3 times better than current sampling but would require more labor and a longer working time as well as increasing defoliation of palm trees.

Correlations values

The correlations provide higher larvae and adults on entire palm estimates, than the critical point fixed by the IRHO-CIRAD method. The detection of sections with incipient infestations, the critical points, fixed by this method has a perfectly acceptable sensitivity to initiate the fight against *C. lameensis*. For the PRIOU method, the critical points are 8 and 2, respectively for the larvae and the adults. Results estimated, on the same sections previously mentioned, were of 3 for the larvae and 1 for the adults. The critical points fixed by the PRIOU method thus seem high. In fact, where the IRHO-CIRAD method would have reached an alarm threshold, the PRIOU method, for the same pieces, would have been short of its critical points. This wide variation of sensitivity could have an explanation. Indeed**,** Lecoustre (1988) noted that approximately 60% of the attacks are concentrated on the 100 median leaflets. This observation, which justifies

Table 4. Number, delimitation and surface of infestation zones.

Parcel of land (P)	Method	Number of hearths	Delimitation of the hearth	Surface (ha)	Total surface area (ha)
P1	IRHO-CIRAD	1	L3 to L13	2	2
	PRIOU	1	L36 to L66	2.5	2.5
P2	IRHO-CIRAD	2	L28 to L38	2	5
			L48 to L63	3	
	PRIOU	2	L16 to L56	10	14
			L86 to L106	4	
P3	IRHO-CIRAD	3	L23 to L48	5	9
			L53 to L63	2	
			L73 to L83	2	
	PRIOU	1	Whole	20	20
P4	IRHO-CIRAD	1	L1 to L32	6.4	6.4
	PRIOU	1	L1 to L36	7	7
P5	IRHO-CIRAD	3	L13 to L58	10	18
			L68 to L103	6	
			L113 to L123	2	
	PRIOU	1	Whole	24	24
P6	IRHO-CIRAD	2	L53 to L63	2	6
			L103 to 123	4	
	PRIOU	1	L41 to L116	15	15
P7	IRHO-CIRAD	1	L18 to L43	5	5
	PRIOU	1	L21 to L66	9	9
P8	IRHO-CIRAD	2	L13 to L27	3	6
			L62 to L77	3	
	PRIOU	2	L17 to L37	4	7
			L51 to L66	3	
P9	IRHO-CIRAD	1	L98 to L128	6	6
	PRIOU	1	L91 to L126	7	7
P10	IRHO-CIRAD	2	L48 to L63	3	8
			L103 to L127	5	
	PRIOU	1	L91 to L126	7	7
P11	IRHO-CIRAD	1	L43 to L68	5	5
	PRIOU	1	L41 to L86	9	9
P12	IRHO-CIRAD	1	L58 to L98	8	8
	PRIOU	1	L51 to L96	9	9
P13	IRHO-CIRAD	3	L8 to L18	2	9.8
			L28 to L48	4	
			L83 to L101	3.8	
	PRIOU	1	L1 to L101	20	20
Total	IRHO-CIRAD	23	-----	-----	94.2
	PRIOU	15	----	-----	150.5

ha: hectare; L: line.

that the sampling in the PRIOU method is done in the median part, missed nevertheless 40% of the attacks. The IRHO-CIRAD method which examines the whole palm, integrates the totality of the attacks.

Precision of the delimitation of infestation

The results of this test indicate that the special control, which leads to the decision of plant treatment, would be elicited by the IRHO-CIRAD method first. For the number, the delimitation and the surface of infestation zones, it was noted that on the sections where the IRHO-CIRAD method detected infestation, the PRIOU method did so as well. However, the IRHO-CIRAD method enabled to locate a greater number of infestation zones (23 against 15). On the other hand, the PRIOU method circumscribed a larger total surface of infestation zones than that highlighted by the IRHO-CIRAD's (150.5 ha, against 94). This result could be explained by the sampling rate of the PRIOU method which is higher. It is however important to make a distinction between an infestation zone detected and a zone to be treated. For a safety purpose, the zone to be treated is always larger than the zone infected (Mariau et al., 1973).

Regarding the assumption according to which the most suitable method is the one which allows a broader delimitation of the infestation zones, PRIOU method, is the most suitable to delimit in an efficient way infestation zones.

Conclusion

The study concludes that PRIOU method presents the higher sampling. The fact that the sampled trees are fixed in this method, leads to prefer the IRHO-CIRAD method which allows a better observation of the evolution of the movement of *C. lameensis* throughout the sections. Also, PRIOU method requires more labor and time. This practical and economic dimension should be taken into account. The comparative study of the infestation on 16 leaflets and whole palm, allows knowing that damage prediction is by the IRHO-CIRAD method first. The study of the precision and the delimitation of infestation show that the PRIOU method is more suitable.

On the whole, if for economic reasons and sensitivity in the detection of infested zones, the IRHO-CIRAD method must be preferred, the PRIOU's is more accurate for special control before treatment, to guarantee the complete handling of treated surfaces.

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