Trends in Entomology
Vol. 7, 2011

Review

Review of the economic importance and sustainable management of the oil palm leaf miner *Coelaenomenodera lameensis* Berti and Mariau (Coleoptera: Chrysomelidae)

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ABSTRACT

In most African and tropical countries, oil palm is one of the most economically important crops. There are constraints in its production and cultivation, among which are insect infestations, of which both adults and larvae of the oil palm leaf miner *Coelaenomenodera lameensis* Berti and Mariau formerly called *C. minuta* are the most serious and disastrous pests in West and Central Africa. Because of the great value and high economic importance of oil palm, several control measures are being taken to ensure high and quality yield during harvesting. The following control measures are being used; cultural, phytosanitary monitoring, chemical, biological, host plant resistance and integrated pest management. Chemical control is the most widely and commonly used control measure in plantations. Biological and host plant resistance have not been investigated and exploited much. These need more attention for healthy life, environmental safety and sustainable agriculture.

KEYWORDS: *Coelaenomenodera lameensis*, oil palm, control measures, economic importance of oil palm, *C. lameensis*

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INTRODUCTION

Oil palm *Elaeis guineensis* Jacq which was named the ‘bread tree’ of West Africa by [15], originated from the tropical rain forest region in West Africa [16, 17]. The African oil palm, is native to West Africa where the processing of oil palm fruits for edible oil has been practiced for thousands of years. There are 3 oil palm varieties making up *E. guineensis*: *Dura*, *Tenera* and *Pisifera* with *Tenera* being mainly selected for economic production. The palm oil is concentrated in the fruit bunches, composed of a fresh fruit pulp, and in the fruit kernels [50]. A palm can live up to sixty-five years and reach a height of 20 meters [19]. In Ghana, it begins to fruit in the fourth year of growth, though genetic manipulation has reduced this in plantation areas [8]. Oil palm is now the most important source of vegetable oil in the world, [50]. There has also been an increase in the demand for palm wine for the distillation of local alcohol (akpeteshi), and distillation of palm wine necessitates felling of the tree, these factors lead to a decrease in the number of harvestable palms [8].

In most African and tropical countries, oil palm is one of the most economically important crops (shown in Figure 1) and contributes enormously to reduce poverty in rural areas. In Ghana, oil palm is one of the most valuable economic crops, which is next to cocoa and provides a major source of

Figure 1. Oil palm plantation with cover crop beneath.

employment. [13] stated that oil palm allows many small householders and land owners in the rural areas to participate in the processing activities in the industry which generates income, since it is essentially rural-based and has positive impact on the standard of living of the people.

Oil palm production in Ghana is constrained by insect pests of which *Coelaenomenodera lameensisis* formerly called *C. minuta* is a key pest. In Benso and Twifo Oil Palm Plantations in Ghana, trained people have been employed and the plantations have invested in the safety and application equipment necessary. They have been able to 'hot fog' with Evisect S (*thiocyclam hydrogen oxalate*) for control of *C. lameesis*. But this insecticide is impossible to obtain at short notice in sufficient volume to manage a significant outbreak of the pest, and is also very expensive. There is, of course, also the possibility that the pest will develop resistance to the chemical. There is no efficacious alternative available and it is very essential to exploit the use of botanicals and biological control for health, environmental safety and sustainable agriculture.

Distribution of oil palm

Oil palm exists in the wild, semi-wild and cultivated state in the three land areas of the equatorial tropics: Africa, South-East Asia and South America [19]. It is also found in the main belt in Africa that runs through the southern latitudes of Cameroon, Cote d'Ivoire, Ghana, Togo, Liberia, Nigeria, Sierra Leone and into Angola and Congo [42].

Oil palm requires a well-distributed rainfall of at least 1,500mm per annum, high relative humidity and monthly temperatures not below 20ºC [49]. In Ghana, oil palm is found in six regions, as follows: Western, Eastern, Central, Volta, Ashanti and Brong-Ahafo regions, [39].

Economic importance of oil palm

Due to the high value placed on oil palm it has led to substantial increase in oil palm plantations in most of the tropical countries to generate more income for both the government and individual farmers. Oil palm produces two types of unique oils, which are obtained from its fruits (displayed in Figure 2) used in the food, cosmetics, detergent and in the oleo-chemical industries. These oils are

Figure 2. Oil palm tree bearing fruits.

the palm oil and palm kernel oils which are used in products all around the world [14]. These are common cooking ingredients in countries where they are produced. Oil palm production is 5 to 10 times more important than groundnut and soybean oil [20].

Palm oil has so many important uses both domestically and commercially, such as in the commercial food industry, manufacture of margarine and chocolate to cream cheese and oven chips, as well as in cosmetics, and increasingly, for use in bio-diesel [13]. As the highest yielding of all oil crops, it is by far the most widely-produced tropical oil. [50] stated that the oil content in the fruit pulp is about 50-60% or 20-22% of bunch weight; oil content in the fruit kernels is 48-52% or 2-3% of bunch weight. Fresh fruit bunches once harvested must be treated in an oil mill within 24 hours to avoid oil quality decrease [50].

Insect pest of oil palm

The increasing number of oil palm plantations has provided more suitable ecology and environment for some insects and pests. This has therefore led to an increase in the pest and disease population. Insect pests are one of the major constraints in oil palm production [53]. Not all of these insects are of economic importance. Some are beneficial. Among the insect pests of oil palm in Africa, the oil palm leaf miner *Coelaenomenodera lameensis* Berti and Mariau are the most serious and disastrous pests in West and Central Africa [40, 19].

Leaf miners are so named because of their habit of mining between the upper and lower surfaces of leaves. They are one of the most serious pests of commercial flower crops, especially chrysanthemums, as well as bedding plants. The larvae of C. *lameensis* are the main cause of foliar damage due to their mining behaviour, although the adults can also cause severe damage to the oil palm [9, 35].

Ecology of the oil palm leaf miner (*Coelaenomenodera lameensis*)

The yield of plantations is often compromised, by both abiotic and biotic factors which determine the distribution, abundance and occurrence of insect pests. These factors are the presence and absence of natural enemies, indiscriminate use of insecticide, climatic factors such as temperature, rainfall, relative humidity and sunshine which play very important role in the development and mortality of *C. lameensis* [9, 34, 53, 25]. [28] stated that the insect's fecundity is higher during the rainy season. In Ghana, [9] observed that during the major rainy season between the month of October and November, there is drowning of the pest larvae in the mines, thus tremendously reducing their population.

Description and biology of *C. lameensis*

The life cycle for insect varies based on the climatic conditions and available food material. [9] reported that the leaf miner takes between 91 to 98 days to complete their life cycle; while [35] however stated an average life cycle of 96 days and four generations of the pest per year. [11] reported a total life cycle of 99 days for *C. lameensis* in Ghana.

Egg

The females oviposit on the lower surfaces of the frond leaflets and cover them with masses of fibrous debris. They have high fecundity and lay between 350 - 400 eggs per female. The eggs are wet, pale yellow, about 0.8mm long and 0.28mm wide [35, 1]. The eggs take 20-21 days to hatch.

Larva

There are four developmental larval stages with a total of 44 days before it pupate [9]. Larvae are dorsoventrally flattened and of uniform yellow colour as seen in Figure 3. It measures 0.8mm for the first instar to 6.5 for the fourth instar, which is very big with visible digestive canal that is green [41].

Pupa

The pupa is orange-red and naked [38] as shown in Figure 4. Pupa takes about 11-13 days for maturity [35].

Adult

According to [34], the adults are small orange-yellowish beetles about 4.5-6mm in length and about 1.5-2mm wide (displayed in Figure 5). The adult females are slightly bigger than the males; females are 5.6mm long without the antennae and the males are 5.2mm long. Internal adults are usually pale yellow and measure about 5mm long, take about 3 days before emergence and the external adults take about 17 days before maturity [19]. Adults live for about three to four months [1].

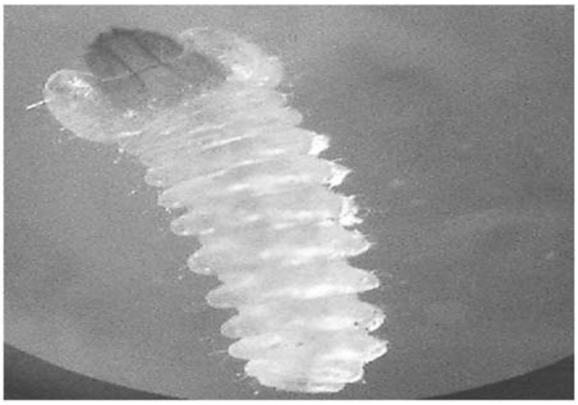

Figure 3. Larva of *C. lameensis*.

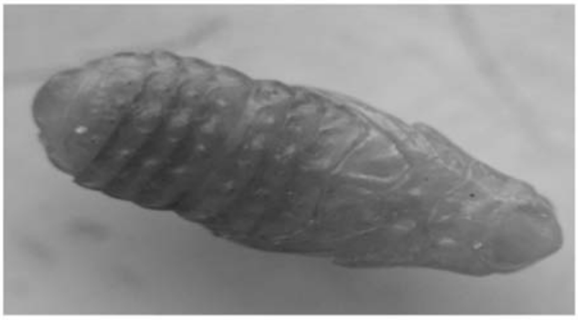

Figure 4. Pupa of *C. lameensis*.

Figure 5. Adult of *C. lameensis.*

Damages caused by *C. lameensis*

The larvae are the main stage that causes most of the damages due to their mining behaviour, which lasts for about 44 days. The adult also causes serious damages and also the incidence of reappearing of the pest occurs every three or four months in some cases on oil palms [19]. The larvae live and develop within the frond leaflets and mine the upper epidermis of the palm leaflets while feeding [9]. Due to the feeding habit of the larvae, the fronds are defoliated and deprived from enough palm surfaces for maximum photosynthesis to occur. Each one attacks approximately 3 to 4 cm of leaflet, destroying the leaflet directly, or causing its fast drying. Larvae produce mine of about 20cm in length and 1-2 cm wide. At pullulating period, more than one thousand larvae can be counted per palm, setting hundreds of safe galleries and damaging the totality of the leaf area as shown in Figure 6.

According to [38], the adults while swarming cause serious damage to the fronds by feeding on the underside of the leaves, scooping out grooves parallel to the veins which lead to partial dying of the fronds. Their damages may lead to the introduction of secondary infestation. [53] noted that damages caused by *C. lameensis* can lead to inflorescences abortion, bunch failure and considerable economic loss. *C. lameensis* outbreak varies in extent and can spread over hundreds of hectares.

Economic importance of *C. lameensis*

Leaf miner outbreaks are sporadic and difficult to predict (Figure 7). Control with pesticides has proven costly and beyond the means of small-scale oil palm producers [13]. Heavy infestations of *C. lameensis* can cause 90% defoliation which can subsequently lead to a 50% reduction in fresh fruit bunches over the following two years [40] (Figure 8). [38] also reported that during heavy infestations only the central spear remains uninfested and the leaflets appear desiccated thus reducing photosynthetic activity of the leaves (Figure 8). Severe defoliations can lead to a yield decrease ranging from 30 to 50%, during 2 to 3 consecutive years, wrecking production [52, 5, 7]. It is difficult to control *C. lameensis* using insecticide due to their mining behaviour [31].

Figure 6. Typical damage caused by *C. lameensis* larva.

Figure 7. Typical outbreak situation of *C. lameensis.*

[47] reported the first outbreak of *C. lameensis* in Lobe, Cameroon in 1972, and by 1991 over $200,000 had been spent on insecticides on annual basis to eradicate the pest. In Nigeria the first outbreak took place in 1966 at Nigeria oil palm belt, followed by another in 1967 in the field of Cowan Pamol Oil Palm Estate [2, 3]. [35] reported an outbreak in Ivory Coast.

In Ghana, outbreaks have been observed in all of the large oil palm plantations; in 1985 Jukwa farms of the State Oil Palm Plantation (SOPP) had an outbreak of *C. lameensis* and low yields resulted in the felling of the palm trees [5]. Between 1986-1987 a total of 2000 hectares out of 4200 hectares in Ghana Oil Palm Development Corporation (GOPDC) at Kwae suffered from serious outbreak of *C. lameensis*, which led to a revenue loss of about $13506.49 [5]. Twifo Oil Palm Plantation (TOPP) and Benso Oil Palm plantation (BOPP) have also suffered from recurring outbreak of the pest leading to severe defoliation of the oil palm trees [7].

Figure 8. Heavy infestations with only the central spear remaining uninfested and the leaflets appearing desiccated.

Management of *C. lameensis*

The biology, behaviour, population changes of the pest as well as the effect of the environmental factors on the development cycle are important components for effective management of the pest and reduction of yield loss [41]. Basically four control measures are being used; phytosanitary monitoring, selective use of insecticide, cultural or agronomic practices, biological methods, and a combination of all four in an integrated pest management [2, 3, 40].

Effective Integrated Pest Management includes knowledge of the biology and ecology of the pest and beneficial, the economic thresholds, monitoring of the pest and beneficial, physical, cultural, biological and precise targeting of pesticides [43].

Phytosanitary monitoring

The management of *C. lameensis* cannot be effective without efficient phytosanitary monitoring and surveillance that identify and focus on small infestation of the pest as early as possible thus delimiting the area for appropriate control measures in order to avoid outbreaks which are expensive to manage. In older palms it is impossible to observe the pest infestations in the crowns since they are taller. Therefore some of the lower fronds are cut for examination, and must be done early in the morning as most of the external adults are active late in the morning and fly away [54].

Traps baited with a pheromone insect attractants can also be used as they have been used for citrus leaf miner and are useful tool for determining when moth are flying and depositing eggs [18]. [18] also said that the pheromone traps help one to determine when male flights are occurring, which helps correct timing of insecticide applications if they are needed. Ovicides such as oil or diflubenzuron (Micromite) should be applied during peak flights of moths. [22] clearly pointed out the constant presence of the pest, based on their result from the phytosanitary monitoring carried out on the spatio-temporal distribution of *C. lameensis* infestation.

[29] showed that the fertility of *C. lameensis* increases in the humid zone, and in a comparison with the temporal evolution of the infestations, their results revealed that the levels of infestation are high in dry periods as well as in the wet periods. They observed that increase of fertility and the agro-climatic conditions do not appear sufficient to explain the variations of the insect population observed, since the natural mortality of

C. lameensis was low [27] and cannot be the explanation of the temporal variations of insect populations. Plant sanitary management currently used had no effect on the cycle of the pest, which remains stable and is repeated every 90 days. It was realised that neither rainfall, temperature nor humidity are correlated on the level of infestation, although these factors showed minor variations that do not modify the level of infestation.

[37] stated that there are two methods that are usually used to carry out the sanitary control supervision of *C. lameensis* attacks in two levels in the agro-industrial unit of toumanguié (côte d'ivoire). These are irho-cirad and priou methods. Irho-cirad method was the first to be established by the Oil-plants Research Institute. It provides a better anticipation of probable damage before it occurs and allows better observation of the evolution of the movement of *C. lameensis* [37]. Priou method circumscribed a larger total surface of infested zones and is considered to be better than the first one by few operators, which has been established in some palm plantations, but requires more time and labour. Priou method examines twice more trees and 4 times more palms than the irho-cirad's. Still 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 [37]. On the whole, for economic reasons and sensitivity in the detection of infested zones, the irho-cirad method is preferred; the priou's is more accurate for special control before treatment, to guarantee the complete handling of treated surfaces [37].

Cultural control

Cultural control as an integrated approach to dipterous leaf miner control is essential, because when ornamental crops are not present in fields, leaf miner populations are found on broadleaf weeds [6]. Cultural control includes various agronomic practices which are; early pruning of the fronds to reduce larval population, collection and destruction of rotten bunches logs and other decomposing matter, planting of leguminous cover crops which impede the flight of low flying insect pests setting of nursery far from adult source of pest, collection and destruction of pupae, caterpillars and attacked plants. Removal or destruction of pruned fronds immediately after plant removal helps reduce the leaf miner population. Burning crop residues is very effective in preventing emergence of any living larvae and pupae in leaves, destruction of weed hosts near nursery areas at least four weeks before placing plant containers in blocks eliminate potential pests or delay their appearance if they must migrate from distant areas, [46, 41]. [2, 3] in a pilot scale trial in Nigeria revealed a 99% post pruning reduction of *C. lameensis*.

Citrus leaf miner moths are attracted to new flush of citrus trees. Once leaves are hardened, the pests are unable to carry out their usual mining activities. Thus, pruning of branches more than once a year must be avoided, in order for the cycles of flushing to be uniform and short. Do not prune off leaves damaged by citrus leaf miner because undamaged areas of the leaves continue to produce food for the tree. Nitrogen fertilizer must not be applied at times of the year when leaf miner populations are high, as flush growth will be severely damaged. Where citrus leaf miner is a problem, water sprouts and suckers that might act as a site for the moths to lay eggs are removed because they originate from the rootstock and do not produce desirable fruit [18].

Host plant resistances to *C. lameensis*

[48] defined host plant resistance as a genetically based property that enables it to avoid, tolerate or recover from the injurious effects of insect feeding and oviposition.

According to [12], there were no significant differences existing in the susceptibility levels of five oil palm progenies investigated. Progeny D supported the lowest population of the leaf miner (45.9%) and consequently suffered slight damage (25%), followed by C. Progeny E, which supported the highest population of *C. lameensis* (54.9%) and also suffered highest average damage (37.4%), followed by progeny A. Progeny B supported the third highest population of the test insect but suffered the slightest damage [12].

The slight variations observed on the various progenies may be an indication of differential degree of antixenosis for feeding or antibiosis for development or tolerance, or a combination of these [12]. This calls for advance investigation on the molecular genetics of the plant.

Chemical method

Severe outbreaks of *C. lameensis* over the years had great impacts on industries growing oil palm. This had put the use of chemical pesticides under close scrutiny and a drive towards more environmentally sound and sustainable plantations. Several factors such as the area infested the type of plantation, weather, time of application, terrain, and the equipment available affect the choice of a particular method.

[44] stated that dosages for aerial treatment are 250 g a.i./ha for the first application and 200g a.i/ha for the second application, and also that aerial spraying is indispensible to stem outbreaks in areas of 500 ha or more using helicopter. Ground spraying can be facilitated using a tractor-drawn Tecnoma Twin Cannon Fluidair sprayer and Evisect S [thiocyclam], in areas of up to 500 ha so long as the ground is flat or almost flat but this has an immediate toxicity effect and is very effective against adults and has satisfactory systemic effect against larvae, but had no permanent adverse effects on the activity of the egg and larval parasitoids [44]. Observation made from plantations revealed that trunk injection with a systemic insecticide is well suited for smallholdings especially for areas that are inaccessible for tractor-drawn sprayers and gives very good results, whereas root absorption is a slow and tricky method that is applied on small foci if no other methods are possible. Hot fogging is attractive and good but is used only when there is a total lack of wind, and over medium-sized areas.

[54] reported that Evisect S at the dose rate of 450g/ha was effective against *C. lameensis* adult and caused a decline in their population within two weeks after application, but had adverse effect on other insect species; 47.69% of the Dipterans among the insect collections on the plantation were affected followed by the Hymenopterans with 20.80%. The Neuroptera were the least affected, while for the Coleopterans only *C. lameensis* were affected.

Pruning of infested fronds may be successful in limiting spread during early stages of outbreak. However, once an outbreak is established, smallholder farmers (who are the main growers of oil palm in West Africa) cannot control the pest. Larger plantations which, employ trained people who have knowledge in the safety and application equipment necessary for hot fogging, use Evisect S (thiocyclam hydrogen oxalate) for successful control of the pest [6]. It is advisable to use chemicals judiciously under supervision and at specific time. Knowledge of the sanitary situation of the plantations is highly essential [26].

[22] observed during the experiment carried out on the temporal distribution of the infestations of *C. lameensis* that there are peak periods of infestation in the year. [22] made the following observations; during the years 2002 and 2003, for the following months with respect to mean of pest; February (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) which showed high levels of infestation. [22] also stated that in 2003, December and September presented extremely important peaks, respectively, with an average of 82.34 and 117.17 *C. lameensis* per oil palm frond. These show that certain periods of the year are more favourable to the infestation of *C. lameensis* than others.

Biological method

Hymenoptera species such as *Oecophylla longinoda* Latreille, *Crematogaster gabonesis* Mayr and *Tetramorium aculeatum* Emery had been used before to control *C. lameensis* [48, 10]. Some leaf miner parasitoids belonging to the hymenopterans have also been obtained from stages of leaf miner larvae. [30] stated that about 90% of larval galleries of *C. lameensis* were attacked by predatory ants mostly *Crematogaster* spp.

[47] also reported the effective use of *Crematogaster* spp. as biocontrol agent in Cameroon, where the ants open the larval galleries and predispose them to parasites, predators, high temperature and the vagaries of the weather. [54] stated that mortality was 1.89% due to Evisect S application. Effect of the chemical on the insect may not be significant. Exotic leaf miners are usually quickly adopted by native parasitoids that may provide substantial control. The ambermarked birch leaf miner, *Profenusa thomsoni* Konow, a sawfly of European origin, was successfully controlled in North America by a native ichneumonid parasitoid,

Lathrolestes luteolator Gravenhorst [23]. Natural enemies of leaf miners include several species of parasitic wasps which attack and destroy the larvae in the mines.

[55] identified some parasitoid species in Ghana for the control of *C. lameensis*. These include *Phymasticus* spp., *Neochrysocharis* spp., *Pleurotroppopsis* spp., *Apleurotropis* spp., and *Cirrospilus* spp. [24] stated that *Neochrysocharis* spp. had been used before in a trial to control the pest in Ivory Coast. These parasitoids have been used successfully to control other leaf miners. According to [51, 21, 36] there are other parasitoids that have been used to control *C. lameensis*. They are as follows; *Achrysocharia leptocerus* (egg parasitoid); *Sympiesis aburianus*, *Pediobius steigenus* and *Closterocerus africanus* (larval parasitoid); *Oligosita longiclauvata* (egg parasitoid) and *Perislitus persimillis* (adult parasitoid).

Integrated Pest Management (IPM) of *C. lameensis*

The Integrated Pest Management approach requires a good knowledge of the biology of the pest and its environment including the effect of the host plant on the development of the pest. [9] reported duration of 91 to 98 days for the complete life cycle of *C. lameensis* while [30] reported an average of 96 days. Both authors reported that the life cycle is dependent on the prevailing environmental condition and the quality of the oil palm. Pesticide resistance and health issues due to over use of chemicals have highlighted the need for increased knowledge of the leaf miner and its dynamics and thus a move towards more environmentally sustainable integrated pest management methods.

(IPM) is the best method as it includes all the other control measures. It reduces pollution, harmful effect on humans and reduces the application of pesticides. It encourages the build up of natural enemies and reduces cost in the control of the pest. It was successfully used to control the outbreak of *C. lameensis* during 1975-1977 in Nigeria, when it effectively reduces the population of the pest during the dry season after a month by 81.3% - 98.4% [2, 3].

Conclusion and key research areas needed to be considered

In order to bring down the pest populations to a tolerable level, chemical and integrated pest management methods should be applied [32, 33, 45, 24]. Developing effective good practices for leaf miner management is a priority.

According to [47, 36], insecticide application also harms natural enemies of *C. lameensis*, which are very important for regulating the pest population. Thus their destruction can lead to outbreak of the pest.

Various research works had been carried out to stem out the outbreak of the oil palm leaf miner *C. lameensis*. So far the most widely used and successful one is chemical application which has adverse effect on the environment, human and animal health. It is therefore essential to research into areas which have safe application, inexpensive, sustainable and easy to adopt and apply.

There has already been some research on leaf miner, but further research is urgently needed in the following two areas:

1. Evaluation of methods to boost bio-control via encouraging natural enemies and enhancing the bio-efficacies of the identified natural enemies, as well as identification and evaluation of entomopathogens associated with various life stages of the pest.
2. Evaluation of bio-pesticides as a management option.

Natural enemies, botanicals, bio-pesticides and host plant resistance have not been extensively researched and effectively used for control of *C. lameensis*. Some research work is on-going at the CSIR-Oil Palm Research Institute, Kusi, Ghana on some botanicals, natural enemies (including parasitoids), and entomopathogens. More research however needs to be encouraged in these areas. Although host plant resistance against *C. lameensis* and differences in the susceptibility of palms to the leaf miner, *C. lameensis* had been observed in Ivory Coast [4], there is still need for further research for proper clarification and assurance.

The use of pheromone against *C. lameensis* is an area which has not been investigated at all. This area needs funding and equipment for successful investigation and will also complement in monitoring and efficient control of *C. lameensis.*

ACKNOWLEDGEMENT

This review forms part of the first author's project for the successful completion of her Masters of Philosophy in Entomology Degree. The authors would like to acknowledge the German Academic Exchange Service (DAAD) for their sponsorship, and all staff at the African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana. Special appreciation goes to the Acting Director and staff of CSIR-Oil Palm Research Institute, Kusi, Ghana for their tremendous support and finally to Miss Margaret George and Mr. Raymond Johnson for their tremendous support. The pictures are original ones taken with the permission and assistance of management of CSIR-OPRI, Kusi, Ghana.

REFERENCES

1. Afreh-Nuamah, K. 1999, Insect pests of tree crops in Ghana: Identification, damage and control measures. Buck Press Inc, 65.
2. Agwu, S. I., Appiah, F. O., and Aisagbonchi, C. I. 1986, A paper presented at the International Conference on Oil Palm, 5th-19th November, 1986, Port Harcourt, Nigeria.
3. Agwu, S. I., Appiah, F. O., and Aisagbonchi, C. I. 1988, Paper presented at the Entomological Society Conference. Held on 9th-14th at Okigwe Imo State University, Nigeria.
4. Anonymous, 1971-1973, I. R. H. O. report d'activite's 1971, 1972 and 1973 cited in Philippe (1977).
5. Anonymous, 1993, Oil Palm Research Institute Kusi, Kade, Ghana, 100.
6. Anonymous, 2011, Florida Insect Management Guide, University of Florida.
7. Appiah, S. O. and Yawson, G. K. 2003, Oil Palm Research Institute Technical Report, Kade, Ghana, 1-9.
8. Bergert, D. L. 2000, Management Strategies of Elaeis guineensis (Oil Palm), in Response to Localized Markets in South Eastern Ghana, West Africa. MSC., Michigan Technological University.
9. Cotterell, G. S. 1925, J. On the Gold Coast. Bull. of Ent. Res. XVI, 77-83.
10. Dejean, A., Djieto- Lordon, C., and Durand, J. L. 1997, J. Entomological Society of America 1908 v 90 (5), 1092-1096.
11. Dimpka, S. O. N. 2004, Susceptibility of some oil palm progenies to the oil palm leaf miner Coelaenomenodera lameensis Berti and Mariau (Coleoptera, Chrysomelidae, Hispinae). M. Phil Thesis, University of Ghana, Legon, Accra.
12. Dimkpa, S. O. N., Appiah, S. O., Afreh-Nuamah, K., and Yawson, G. K. 2010, Current Research Journal of Biological Sciences, 2(3), 168-172.
13. Djeddour, D. 2011, J. CAB International, U. K.
14. Duke, J. A. 1983, Handbook of Energy Crops, Unpublished.
15. Essiamah, S. K. 1985, Institute for Scientific Co-opreation, Tubingen, Vol. 21, 44-58.
16. Food and Agricultural Organisation (FAO) of the United Nations, 1961, Agricultural and Horticultural Seeds, 285.
17. Food and Agricultural Organisation (FAO) of the United Nations, 2002, Agricultural Services Bulletin Series, 148, 56.
18. Grafton-Cardwell, E. E. 2011, Citrus Leafminer (Phyllocnistis citrella) UC IPM , Pest Management Guidelines: Citrus. UC ANR Publication, 3441.
19. Hartley, C. W. S. 1988, The oil palm Elaeis guineensis Jacq. Longman Scientific and Technical, New York. Third Edition, 761.
20. Jacquemard, J. C. 1995, Le palmier à huile. Le technicien d'Agriculture tropicale. Ed. Maisonneuve et Larose, Paris, 205.
21. Kerrich, G. J. 1970, Bull. Ent. Res., 60, 327-331.
22. Koua, H. K., Mathieu, J., Seri-Kouassi, P. B., Tano, Y. and Mora, P. 2010, Sciences & Nature, 7, No.1, 1-10.
23. Langor, D. W., Digweed, S. C., and Spence, J. R. 2002, Fenusa pusilla Lepeletier, birch leafminer, and Profenusa thomsoni Konow, ambermarked berch leaf miner (Hymenoptera: Tenthredinidae). Biological control programmes against insects and mites, weeds and pathogens in Canada, 1981-2000 (Ed. By Mason, P. and Huber, J.), 123-126 CABI, U. K.
24. Lecoustre, R., Mariau, D., Phillipe, R., and Desmier de Chenon, R. 1980, Oleagineux, 35(40), 177-186.

25. Mariau, D. 1976, Insect Pests in West Africa. In: Corley, R. H. V., Hardon, J. J., and Wood, B. J. (Eds.), Oil Palm Research, Developments in Crop Science, 1.
26. Mariau, D. 1994, Oléagineux, 49, 249-257.
27. Mariau, D. 2001, Gestion des populations de Coelaenomenodera lameensis Berti et Mariau (Coleoptera : Chrysomelidae) en vue de la mise au point d’une stratégie de lutte raisonnée. Thèse de doctorat de l’ENSA de Montpellier, 198.
28. Mariau, D. and Lecoustre, R. 2000, Insect Science and its Application, 20, 1, 7-21.
29. Mariau, D. and Lecoustre, R. 2004, International Journal of Tropical Insect Science, 24(2), 159-169.
30. Morin, J. P. and Mariau, D. 1974, Oléagineux, 29(5), 233-238.
31. Mariau, D. and Philippe, R. 1983, Oleagineux, 38(6), 365-370.
32. Mariau, D., Besombes, J. P., and Morin, J. P. 1973, Oléagineux, 28, 167-174.
33. Mariau, D., Philippe, R., and Morin, J. P. 1979, Oléagineux, 34, 51-58.
34. Maulik, S. 1920, The Gold Coast. Bull. Ent. Res. X, 171-174.
35. Morin, J. P. and Mariau, D. 1970, Oleagineux, 25, 11-16.
36. Morin, J. P. and Mariau, D. 1971, Oleagineux, 26, 373-378.
37. Nahounou, S. C., Koua, H. K., Aboua, L. R. N., Agnakpa, G. J., and Séri-Kouassi, B. P. 2010, African Journal of Agricultural Research, 5(2), 114-120.
38. National Resources Institute (NRI), 1996, Chatham, UK, 253.
39. Nuertey, B. N. 1999, Studies on oil palm based cropping systems in Ghana. PhD. Thesis, University of Ghana, Legon, Accra, 169.
40. Obeng –Ofori, D. 1998, Pest of field, plantation and vegetable crops. Their biology, damage and control. Dept. of Crop Science, University of Ghana, Legon, 151.
41. Obeng-Ofori, D., Afreh-Nuamah, K., Owusu, E. O., Owusu-Appiah, S., and Yawson, G. K. 2007, Major Pests of Food and Selected Fruit and Industrial Crops in West Africa, 1-192.
42. Opeke, L. K. 1982, Tropical tree crops. Chichester, New York, Brisbane, Toronto, Singapore: John Wiley and Sons.
43. Page, W. W. 2010, Integrated Pest Management Strategies Used By The Oil Palm Industry of Papua New Guinea. PNG Oil Palm Research Association, Papua New Guinea, Scribed Inc.
44. Philippe, R. 1990, Oléagineux Paris, 45, No. 4, 143-156.
45. Philippe, R. and Diarrassouba, S. 1979, Oleagineux, 34(5), 229-233.
46. Reur, P. 1964, Oleagineux, 19(6), 387-390.
47. Timti, I. N. 1991, Tropical Pest Management, 37(4), 403-408.
48. Van loon, J. J. A. 2003, Insect plant relationships and host plant resistance. International course on integrated pest management. Dep. of Entomology, WAU, 26.
49. Vander Vossen, H. A. M. 1969, Ghana J. Agric. Sci., 2, 113.
50. Verheye, W. 2010, Growth and Production of Oil Palm. In: Verheye, W. (Ed.), Land Use, Land Cover and Soil Sciences. Encyclopedia of Life Support Systems (EOLSS), UNESCO-EOLSS Publishers, Oxford, UK.
51. Waterston, J. 1925, Bull. Ent. Res., 15, 385-395.
52. Wood B. J., Corley R. H. V., and Goh K. H. 1973, (As cited in Wood 1976). Studies on the effect of pest damage on oil palm yield. In Wastie R. L. and Earp, D. A. (Eds.), Advances in oil palm cultivation, Incorporated society of Planters, Kuala Lumpur, 360-379.
53. Wood, B. J. 1976, Insect pest of South East Asia, In Oil Palm Research (Ed. Corley). Development in Crop Sciences. I, Elsevier Science Publication Company, Amsterdam, 532.
54. Yawson, G. K. 2007, Studies on Some Major Pest of Coconut (Cocos nucifera L) and oil palm (Elaeis guineensis Jacq.) and their management in Ghana. The United Graduate School of Agriculture Sciences, Ehime, Kagawa and Kochi Universities, Ph.D Thesis.
55. Yawson, G. K., Shin ichi, T., Chul-Sa, K., Davis, H. E., and Owusu, E. O. 2009, African Journal of Science and Technology, 10, No. 1, 24 -31.