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Variation of sex-ratio and identification of natural enemies of *Cœlaenomenodera minuta* uhmann, the main pest of *Elaeis guineensis* Jacq. in the South-west region of Cameroon

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Abstract
The optimal production of oil palm (*Elaeis guineensis* Jacq.) is usually limited by pests and diseases. Severe infestations by the leaflet miner (*Coelaenomenodera minuta)* of this crop can cause about 50% yield loss. Chemical treatment of young and adult palms against the pest is not totally satisfactory, hence the need to develop alternative control methods. This study was carried out on young and mature palms in the perspective of developing integrated control against this pest. Fisher blocks were applied as experimental design and monitoring was done on palm crowns subdivided into 3 levels. The results show that the sex ratio of *C. minuta* is one female to 0.6 male (1:0.6). The study also revealed that natural enemies or predators of *C. minuta* belong to four genera of the order *Araneae* and 6 genera of the order *Hymenoptera*. These results can be exploited in the development of control measures against the pest.

Key words: *Coelaenomenodera minuta*, sex-ratio, *Elaeis guineensis* Jacq., oil palm pest control, natural enemies, Cameroon.

1. Introduction
The oil palm is a perennial oil crop of the *Arecacae* family which is the second largest group of plants after the *Graminae* (Bernal, 1997). It originated from Africa along the Gulf of Guinea. In relation to the equator, this crop extends about 15º latitude North and South (Surre and Ziller, 1963 cit. Pouvreau, 1984). The oil palm was named by the botanist Jacquin as *Elaeis guineensis,* taxonomically indicating the place where it was discovered for the first time – the gulf of Guinea. Evidence in favor of the African origin of the oil palm is based on the descriptions of botanists, travelers and particularly on the discovery of fossil pollen in Nigeria (Zeven, 1965 cit. Cao, 1995). The oil palm (*Elaeis guineensis* Jacq.) commonly called African oil palm is a monoecious tree plant with a single vegetative bud located in the heart of the crown on the stipe (IRHO, 1991; Anonymous, 1995; Jacquemard, 1995). It is part of the group of oleaginous plants which present a significant economic interest for producer countries (IRHO, 1991). Improvement of oil palm production or yield is done genetically. In fact, the hybrid *Tenera* which is the most popularized variety nowadays results from crosses of two other varieties of agronomic interest: *Dura* female and *Pisifera* male (Jacquemard *et al.*, 1997). *Tenera* contributes about 27% of the world's production of vegetable oils (Fold, 2003). Malaysia and Indonesia are currently the best producers of this vegetable oil at the global scale with production estimated at 85.42 per cent in 2001 (Corley, 2003).

When grown industrially as monoculture in ecologically favorable areas, the fruits of *E. Guineensis* produce 5 to 7 times more oil per hectare, or 6 tons of oil per hectare compared to other oilseed crops such as soybeans and groundnuts (IRHO, 1991; Selabie, 1999). Palm oil which is obtained from the mesocarp of the fruit is one of the main sources of dietary fat and vitamins (IRHO, 1991). About 80% of palm oil produced in the world is used for everyday consumption, in the form of margarine or basic vegetable fats (Blaak, 1976). The other 20% are used for the production of soap, paints, manufacture of candles, lubricants, glycerol and fatty acids and other cosmetic products. Palm kernel oil obtained from palm kernel is used in the composition of pharmaceutical products, inks, and pastries (Pantzaris, 1988; Cao, 1995). The fibers and the cake of palm kernels are used as feed for livestock while the hulls of fruits are used in the manufacturing of active charcoal (Pantzaris, 1988).

In Cameroon, oil palm cultivation has been practiced by the agro industries and smallholders over the decades in the administrative regions of the South-west, littoral, the center and south (Fanguin, 1978; Anonymous, 2003). Smallholders occupy about 43,300 ha against 60,785 ha of land by the industrial sector and supply the industrial mills with approximately 50,000 tons of fresh fruit bunches (FFB) per year; or 10 000 tons of crude palm oil (CPO), meanwhile the rest is processed locally (Anonymous, 2003). By 1998, the average annual production of palm oil in Cameroon was estimated at 119,000 tons produced by the agro-industrial companies (CDC, SOCAPALM, SPFS, PAMOL, SAFACAM) on one hand and a few smallholder palm plantations on the other hand (Bernard *et al*., 1998). This annual national production of palm oil remains insufficient because it does not cover the national annual needs valued at about 200 000 tons, needed by the processing industry and for local consumption (Anonymous, 2003). However, the annual production would be significantly greater if oil palm cultivation was not confronted with phytosanitary pressures due primarily to pests and diseases. In Africa, as elsewhere in the world, oil palm groves host a high diversity of insect pests. The economic impact of these pests varies from one region to another and according to the taxa. The major pests belong to the Lepidoptera, *Hemiptera* and *Coleoptera* (IRHO, 1980 & 1981). In tropical America and in South-East Asia, the leaf eating caterpillars of the order *Lepidoptera* are the major insect pests of oil palm. A dozen families are known, but the *Limacodidae* is the most represented (IRHO, 1982). Biological insecticides based on *Bacillus thuringiensis* and chemicals such as the pyrethroids, trichlorfon and carbaryl are used to control these pests (IRHO, 1987). In nature, the regulation of populations of these pests can be of viral or biological origin. Viruses involved in this regulation are the β virus type, *Nudaurelia* found in Indonesia; the Densovirus and Piconavirus types found in Africa and in South America; and the Baculoviruses which are much more cosmopolitan (IRHO, 1987 & 1988).

Coelaenomenodera minuta Uhmann (*Coleoptera: Chrysomelidae*) commonly called *hispine* is the most harmful pest of the oil palm (its primary host) in Africa (Timti, 1991; Dimkpa *et al*., 2010). This invasive pest has been observed on coconut, raffia, certain varieties of ornamental palm trees, borassus and other hosts, including some succulent *Gramineae* such as *Pennisetum purpuerum* (Cotterell, 1925; Cachan, 1957; Mpe *et al*., 2002). *C. minuta* belongs to the Animal Kingdom, Phylum Arthropoda and to the Class Insecta (Crowson, 1955; Delvare and Aberlenc, 1989). The order Coleoptera to which *C. minuta* belongs is the most important of the animal kingdom with more than 300,000 described species and representing 40% of the class of insects (Delvare and Aberlenc, 1989). The genus *Coelaenomenodera* was originally reported in West Africa between the years 1909 and 1910 in Gold Coast, current Ghana. Between 1925 and 1926, attacks of this pest were observed in palm groves in Sierra Leone (Hargreeaves cit. Shearing, 1964). In 1950, *C. minuta* was reported in La-Me in Ivory Coast, and then in Porto Novo and Pobè in Dahomey, current Republic of Benin (Cachan, 1957; Bachy, 1963). In central Africa and Cameroon precisely, the first characteristic symptoms of hispine were observed in the Muyuka area and the severity of infestation was registered in Mpundu in the Southwest region of Cameroon toward the end of the year 1964 (Shearing, 1964). A leaf miner outbreak on oil palms at Lobe (Cameroon) was first recorded in 1972 (Timti, 1991). In those days, the presence of hispine leaf miner did not much exceed the Moungo area but recently, it has been reported in the palm groves of the Southern region of Cameroon (Mpe *et al*., 2002). In addition, no infestation of *C. minuta* has been observed in the smallholder plantations of the littoral and coastal areas (Nyouma cit. Anonymous, 1997).

The damage caused by *C. minuta* is commonly located on the leaflets of the palms. This results partly from larvae drilling galleries on the limbs of leaflets or the activity of imagos stripping the lower side of the leaflets for their food (Shearing, 1964; Lecoustre and Reffye, 1984). Attacks of the adults of *C. minuta* lead to stripping of the epidermis of leaflets. The adult female inserts the eggs laid in the parenchyma. The infestation of the leaflets by the leaf miner results in a deterioration of the mesophyll of leaflets, which is manifested by chlorosis of the part attacked (leaflet) and the drying out of the entire leaf. An epidemic by this pest reduces oil palm yields by as much as 30% (Timti, 1991). For a period of two years at least in the absence of any control, and as a result of a severe infestation, yield losses can reach 50% (Mpe *et al.,* 2002). The critical threshold of damage caused by *C. minuta* is obtained once one or two green palms are damaged (Anonymous, 1997; Mpe, 2002).

Several methods have been employed in the fight against this pest like spraying insecticide on the palm leaflets, systemic insecticide injection in the trunk and biological control using bio-insecticides and ants of genus *Oecophylla* (Philippe, 1990; Aneni *et al*., 2012; Tano *et al*., 2013). However, chemical treatment against *Coelaenomenodera minuta* remains the most used control method in oil palm growing areas though the excess or misuse of pesticides more often leads to undesired effects. In the Ivory Coast, *C. minuta* has presented some resistant strains with respect to some insecticides including the HCH and Parathion (Lecoustre and Reffye, 1984). Similarly the chemical pesticides, with their toxic nature and less specificity, often cause the death of many other untargeted animal species, while exercising a powerful selective effect on these agents that leads to the emergence of resistant generations (Barbault, 1990). The limits shown by the chemical pest control approach reveal the need for the development of sustainable and more environmentally friendly alternative methods in the oil palm production basins. However, the development of these alternative control methods requires a good knowledge of: the agro-ecological characteristics of oil palm cropping areas; the bio-ecology of the major insect pests of oil palm and the natural enemies of potential pests of the host plant (Maho et al., 2013; Aneni *et al*., 2014). In this light, the biomathematical modeling of attacks of the palm tree by *C. minuta* has been the subject of a study in Ivory Coast revealing that the level of infestation is proportional to the surface area of the leaflets (Faure, 1918; Bartlett, 1978). Meanwhile, a study of the spatio-temporal distribution of *C. minuta* has been done in the Southwest region of Cameroon (Mondjeli *et al*., 2013). The present study had the objective of determining the sex ratio and to identify the potential natural enemies of *C. minuta* in the same monomodal rainfall area of the Southwest region of Cameroon in view of developing an integrated pest management (IPM) strategy against the pest.

2. Material and Methods

2.1. Presentation of the experimental site

The experiment was conducted from August 2005 to August 2006, in one of the oil palm cropping zones of Cameroon, the “Benoe Palms Estate” of the Cameroon Development Corporation (CDC). This Estate is located in Tiko Sub-division, 12 km from Buea and 42 km on the highway from Douala town. The climate is of the humid dense forest type with monomodal rainfall regime. Figure 1 shows the variation of rainfall and sunshine registered during the period of the study.

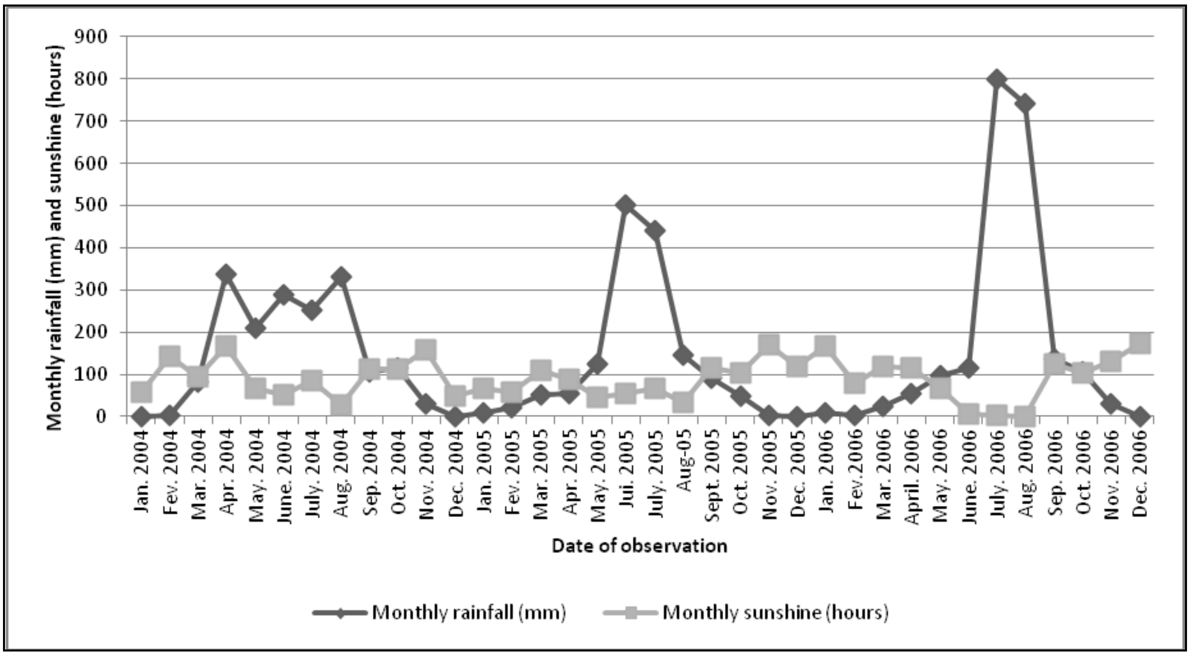

Figure 1. Monthly rainfall and sunshine from 2004 to 2006 in CDC-Tiko area
Source: meteorological data "CDC Group oil palms department, Benoe palms estate"

2.2. Biological Material

The biological material included *Coelaenomenodera minuta* (Fig. 2) and oil palms (*E. Guineensis*) of the *Tenera variety*. The palm plantations surveyed had been established with improved seedlings from the Specialized Center for oil palm Research (CEREPAH) of the Institute of Agricultural Research for Development (IRAD) La-Dibamba, Littoral region of Cameroon.

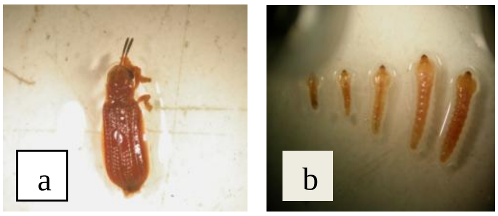

Figure 2. *Coelaenomenodera minuta* a) Adult b) larvae

2.3. Methodology

Two types of palm plantations were subject to observations. The immature, aged one year, which had not yet started production and the mature, aged 9, which had started FFB production. Each palm plot retained for this study covered a surface area of 20 ha. The experimental design adopted was a completely randomized Fisher blocks, with 10 repetitions or blocks. Each palm plot was divided into 10 blocks. In each block, 5 palm trees were chosen at random and labeled. A total of 100 trees were marked; 50 trees in the young palm plot and 50 trees in the old palm plot. Then on each marked palm tree, the crown was subdivided into 3 levels (basal-E1, median-E2 and top-E3) (Figures 3). For each level, a palm was chosen at random on which weekly observations were made. Thus a total of 150 palms marked in the young palm plot and 150 palms marked in the adult plot were subject to observations.

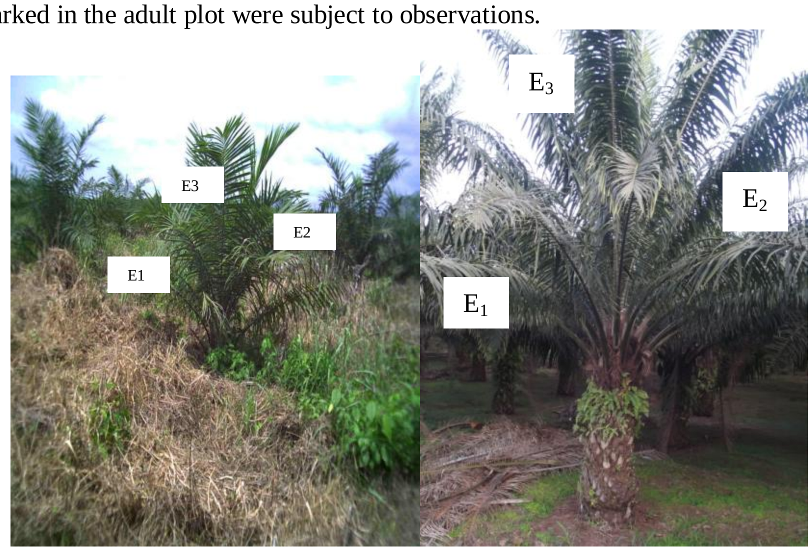

Figure 3: Observation levels a) in young palm plot b) in adult palm plot
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During the period from August 2005 to July 2006 and on each leaflet of the 300 palms, the individual *C. minuta* were caught by hand weekly and inserted into collection tubes containing alcohol (70°) and then taken to the laboratory. Each tube was labeled with information on the crown level of collection, the number of the tree being sampled and the age of the palm tree. In addition, the number of individuals captured per palm was recorded on the data collection sheet. The identified arthropod predators of *C. minuta* were those observed in full predation. Such were captured and introduced into other collection tubes containing alcohol (70°) and transported to the laboratory. Weather information from the study site was also collected during the whole sampling period. The individuals captured and brought to the laboratory were subject to the following observations:

- -Determination of the sex-ratio of *C. minuta* representing the ratio between the number of female adults and the number of adult males. Using boxes, a microscope and entomological clamps, females and males of the pest caught were separated from each other and then counted.
- -Characterization (identification) of the natural enemies of *C. minuta* was done using the dichotomous identification key (Delvare and Aberlenc, 1989; Barry, 1994; Millar *et al.*, 2000; Heinrichs and Barrion, 2004) in the museum of insects of the Central Laboratory of Entomology of the Institute of Agricultural Research for Development (IRAD).

Statistical Analysis

Analysis of variance (ANOVA) and Pearson correlation coefficients were realized on the data obtained for sex ratio. This was processed with the Microsoft Excel software to determine the ratio between male and female of *C. minuta*.

3. Results

3.1. Variation of sex ratio of *C. minuta* adults with respect to the sampling period

The sex ratio of the pest varied on the overall, and was relatively dominated by females (Fig. 4). From 20th August 2005 to September 24, 2005, the number of individuals observed was slightly dominated by males. From October 2005 until the end of March 2006, the results revealed that the adult population was highly dominated by the female sex of the pest. During the month of April 2006, the sex ratio observed was once more with a high dominance of the male insects. From the month of May 2006 until the end of the period of observations, the number of adult females of *C. minuta* was higher than that of males.

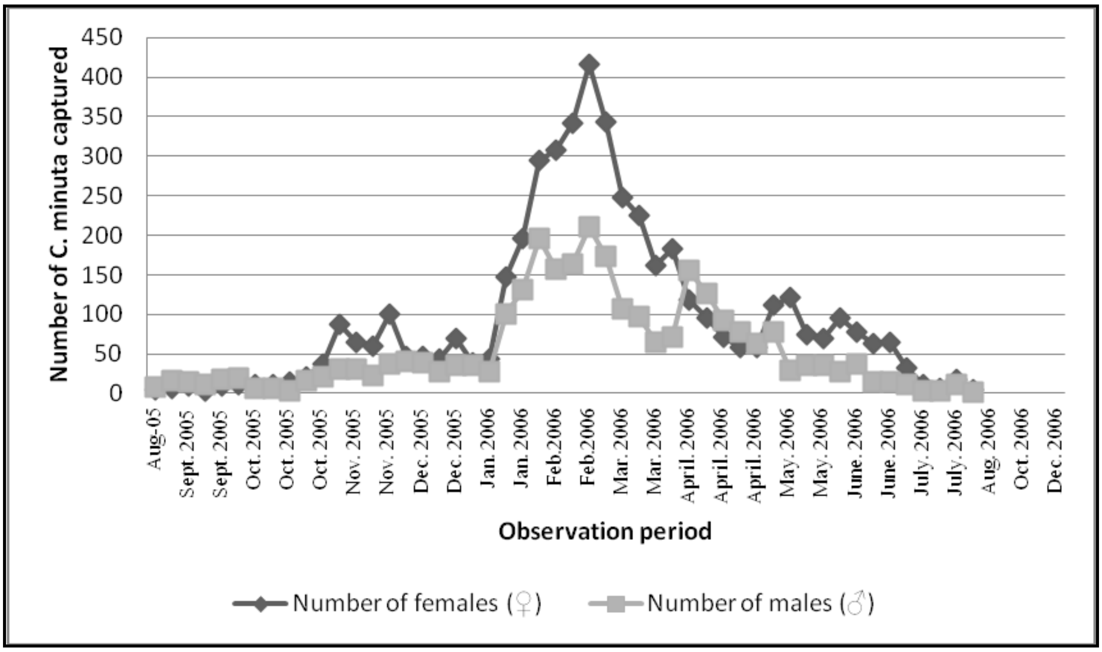

Figure 4. Sex-ratio (number of females versus males) of *C. minuta* in the CDC-Tiko palm plots surveyed.

This study also revealed that the female population of the pest is significantly and negatively correlated to the cumulated time intervals of 7 days and 30 days of rainfall counted before the observations with respectively rs = - 0.30 and P = 0.03; rs = - 0.39 and P = 0.01. Moreover, the correlation between the females and the cumulated time interval of 2 days of rain counted before the observations is negative and non-significant at the threshold of 5% with rs = -0.22 and P = 0.12 . There is also a negative and significant correlation between the number of adult males and the cumulated time intervals of 7 days and 30 days of rain counted before the observations with Pearson correlation coefficients respectively rs = - 0.32 and P = 0.02 ; rs = -0.41 and P = 0.01. However the male population was not correlated to the cumulated time interval of 2 days of rain counted before the observations (rs = -0.25; P = 0.07).

3.2. Identification of the natural enemies of *Coelaenomenodera minuta* in the CDC-Tiko palm plots

A total of ten natural enemies of *C. minuta* were registered during this study. Six belong to the class *Insecta* and four to class *Arachnida*. In the class of insects, six (6) different genera of the order *Hymenoptera* and the family of *Formicidae* were observed. They belong to two (2) sub-families (*Myrmicinae*, *Formicinae*) and four (4) tribes (*Tetramoriini*, *Crematogastrini*, *Pheidolini*, and *Camponotini*). The arachnid class observed consists of four (4) types of the order *Arachnida* and four (4) families (*Salticidae*, *Gnaphosidae*, *Philodromidae*, *Araneidae*). These natural enemies were identified from some external morphological characters of individual adults.

3.2.1. Natural enemies of C. minuta of the class of insects

One of the natural enemies observed, *Tetramorium sp* (*Hymenoptera*: *Formicidae*; *Myrmicinae*, *Tetramoriini*) is represented in Plate 1 a) and a'). *Head capsule:* The head is not heart-shaped on the front view; presence of 12 articled antennae without club; the antenna insertion is deep and protected; Mandibles made of eight pointed teeth with different sizes; eyes disposed on the median of the head length; weak frontal carinae; visible frontal lobe; reduced clypeus and median portion. *Alitrunk*: Presence of promesonotum and orifice with metapleural gland; propodeum with a pair of spines; petiole and postpetiole nodiform in profile. *Gaster*: Presence of 4 segments with the first segment longer than the second; anal orifice on ventral side.

Another observed natural enemy is *Crematogaster sp* (*Hymenoptera: Formicidae; Myrmicinae*, *Crematogastrini*) (Plate 1 b). The genus *Crematogaster* is a widespread and distinctive lineage of myrmicine ants with most species tropical, where they form dominant elements of the arboreal fauna (Longino, 2003). It has been found that the deployment of *Crematogaster* species can lead to a decline of the leaf miner pest population (Timti, 1991). A system for monitoring and keeping the pest population below threshold level by the use of *Crematogaster* species proved effective, and it is recommended in young palm plantings even in areas where the pest is endemic (Timti, 1991). *Head capsule:* heart-shaped; antennae with 11 segments and presence of club; no eyes ; far frontal carinae; Mandibles made of 4 teeth, basal tooth is a denticle. *Alitrunk*: mesosoma, presence of promesonotum; spiny propodeum; petiole and postpetiole present, but petiole dosally flattened without node; opening of metapleural gland present. *Gaster*: heart shaped from dorsal view and movable around the alitrunk; terminal anal opening.

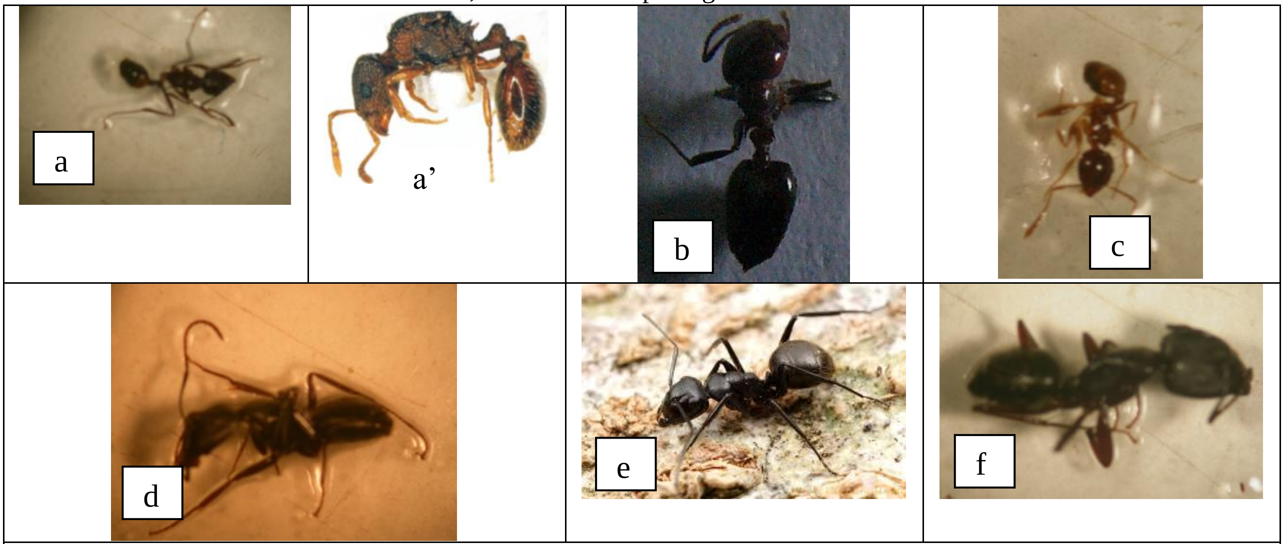

Plate 1: Natural enemies of *C. minuta* of the class of insects

a) *Tetramorium sp* (*Hymenoptera*: *Formicidae*; *Myrmicinae*, *Tetramoriini*). Photos by Author; **a')** *Tetramorium parvioculum sp. n., (Hymenoptera: Formicidae; Myrmicinae, Tetramoriini) Queen, lateral view* (Source: Rhian & Keith, 2009). **b)** *Crematogaster sp* (*Hymenoptera*: *Formicidae*; *Myrmicinae*, *Crematogastrini*); **c)** *Pheidole harrisonfordi sp.* (*Hymenoptera : Formicidae, Myrmicinae, Pheidolini*); **d)** *Camponotus sp.* (*Hymenoptera: Formicidae; Formicinae, Camponotini*); **e)** *Camponotus brutus* (*Hymenoptera: Formicidae; Formicinae, Camponotini*) (Source: Alex Wild, 2014); **f)** *Orthonomyrmex chrysutus guest* (*Hymenoptera: Formicidae; Formicinae, Camponotini*).

The third observed natural enemy of *C. minuta* is *Pheidole sp.* (*Hymenoptera: Formicidae, Myrmicinae, Pheidolini*) (Plate 1 c). The ant genus *Pheidole*, belonging to the tribe Pheidolini in the subfamily Myrmicinae, contains 957 named species in the world and is hyper diverse, especially in tropical/subtropical regions. The genus is one of the most abundant ant genera in natural forest ecosystems, and it is considered a key-stone taxon because its members are predators, scavengers, seed dispersers, seed predators, prey for other animals, and soil-mixing agents (Katsuyuki, 2008). *Head capsule:* heart shaped; 12 articled antennae; club made of 3 articles; reduced eyes located at the median of the head length; scape reduced to 2/3 of the head capsule and lightly convex; protected antennae insertion; frontal carina far but closer to the posterior margin of clypeus; reduced clypeus; mandible made of 5 minute teeth and 4 more developed teeth with slightly different sizes. *Alitrunk***:** made of a pronotum and fused mesonotum; propodeum with reduced spines; presence of opening of metapleural gland. *Gaster* with first tergite more developed than the second and occupying half of the gaster; post petiole and petiole present but the post petiole dorsally fixed on the first tergite; anal orifice ventral.

The fourth enemy observed is *Camponotus sp*. (*Hymenoptera: Formicidae; Formicinae, Camponotini*) (Plate 1 d). *Head capsule:* lightly heart shaped ; antennae made of 12 articles without club ; scape with same border as the posterior of the head; developed frontal carina ; un-covered antennae insertion; small posterior eyes; large clypeus without median portion; mandible with 7 robust teeth with decreasing size from ápex to base ; Pronotum and mesonotum separated by a promesonotal suture; absence of metapleural glande; absence of post petiole but presence of petiole ; propodeum without spines. *Gaster***:** non mobile on alitrunk; 1st tergite of gaster small compared to the second; presence of dorsally aligned hair; circular and terminal anal opening.

The fifth observed enemy was *Camponotus brutus* (*Hymenoptera: Formicidae; Formicinae, Camponotini*) (Plate 1 e). *Head capsule* **:** slightly heart shaped; antennae made of 12 articles without club; scape longer than the posterior margin of the head ; developed frontal carina right to the eyes; antennae insertion not covered ; small posterior eyes ; large clypeus and without median portion ; mandible with 6 robust teeth with decreasing size from apex to base; palpal formula 5 : 4. Pronotum and mesonotum separated by promesonotal suture; no metapleural gland; absence of post petiole but presence of petiole; propodeum without spines. *Gaster*: non mobile on alitrunk; 1st tergite of gaster small compared to the 2nd; presence of dorsally aligned hair; circular and terminal anal opening.

The sixth natural enemy of *C. minuta* observed is *Orthonomyrmex chrysutus guest* (*Hymenoptera: Formicidae; Formicinae, Camponotini*) (Plate 1 f). *Head capsule:* slightly long; antennae made of 12 articles without club; scape longer than the posterior margin of the head ; developed frontal carina ; antennae insertion not covered and far from clypeus; small posterior eyes ; large clypeus; mandible with 6 robust teeth with decreasing size from apex to base; palpal formula 5 : 4; Pronotum and mesonotum separated by promesonotal suture; no metapleural gland; absence of post petiole but presence of petiole; propodeum without spines. *Gaster*: non mobile on alitrunk; 1st tergite of gaster small compared to the 2nd; presence of dorsally aligned hair; circular and terminal anal opening.

3.2.2. Natural enemies of C. minuta of the class of arachnids

The seventh natural enemy observed is *Plexippus sp.* (*Arachnida : Araneae ; Salticidae*) (Plate 2 a). *Gnathosoma*: cephalothorax large at its anterior part; 8 eyes at positions 4:2:2; Chelicerae with retro marginally crossed teeth; palp without club ; leg I robust, pale brown, with tibia, 3 pairs of ventral spines ; fovea slightly visible ; band of marginal white hair on carapace. *Idiosoma*: Abdomen pale brown with band of marginal white hairs; epigyne with oblong opening; body size 6 mm.

The eigth natural enemy observed is *Zelotes sp.* (*Arachnida : Araneae; Gnaphosidae*) (Plate 2 b). *Gnathosoma* : Presence of 8 heterogenous eyes arranged in two rows 4 :4; palp with club covered by spines and hairs ; carapace and legs uniformly black. *Idiosoma* : cylindrical grayish abdomen with a black antero-dorsal band in V form; anterieur cylindrical spinneret; body size 5.8 mm.

The nineth natural enemy observed is *Philodromus sp.* (*Arachnida : Araneae ; Philodromidae*) (Plate 2 c). *Gnathosoma*: Truncated head margin; 8 homogenous eyes in two equidistant rows; Chelicerae with retro marginally crossed teeth, robust and hairy; robust club shaped palp; presence of 2 claws on legs I and II ; legs II longer than legs I which in turn are longer than legs III and IV ; femur I thin and bearing 3 pairs of dorsal spines, 4 pairs of lateral spines; tibia with 2 pairs of lateral and ventral spines; fovea visible and coloured black ; body hairy. *Idiosoma*: ovoid yellow abdomen which is posteriorly pointed, with a dorsal zigzag line; large epigyne; slightly conical spinneret; body size: 7.5 mm.

The tenth natural enemy observed is *Araniella sp.* (*Arachnida: Araneae ; Araneidae*) (Plate 2 d). *Gnathosoma* : Cephalothorax with a constriction between the browniish head and the pale brown thorax; median eyes very closed together, 2 pairs of lateral eyes of same size; Chelicerae with crossed teeth, robust; palpae simple and hairy at the apex ; fovea very visible ; tibia I bearing 4 pairs of spines and metatarsels with 3 pairs oof spines. *Idiosoma* : greenish abdomen, spherical with 3 pairs of black spots in the middle of the back ; complex epigyne with small spherical organs, presence of black and white marginal bands ; body size: 7 mm

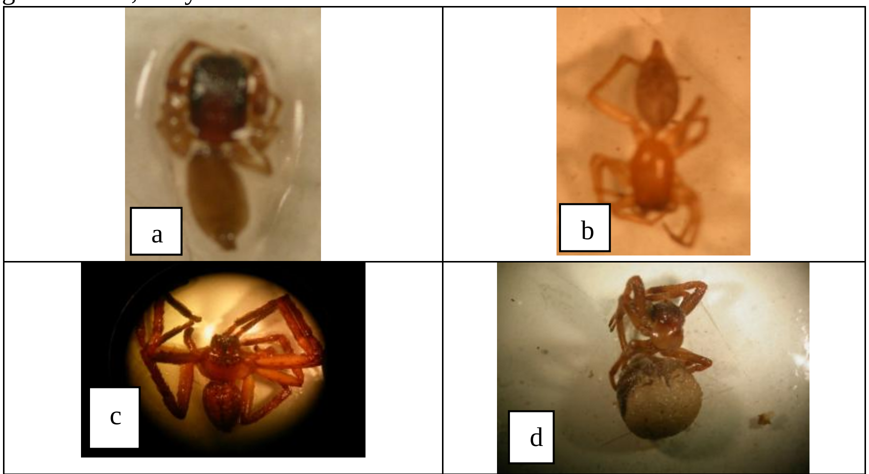

Plate 2: Natural enemies of *C. minuta* of the class of arachnids

a) *Danaus plexippus sp.* (*Arachnida : Araneae ; Salticidae*); **b)** *Zelotes sp.* (*Arachnida : Araneae; Gnaphosidae*); **c)**: *Philodromus sp.* (*Arachnida*: *Araneae ; Philodromidae*); **d)** *Araniella sp.* (*Arachnida : Araneae ; Araneidae*).

3.2.3. Differential infestation of oil palm leaflets by C. minuta with respect to crown level

Results of the present study (not shown) have revealed that *Coelaenomenodera minuta*, attacks the oil palm differentially with respect to crown levels. The basal level of the crown is the most attacked by the pest. This observation suggests that there should be an intense attraction of palm leaflets of the basal level to the adults of this pest.

4. Discussion

Together with abiotic factors, natural enemies (of pests) contribute to the relatively low numbers of some species (Jorge, 2004). Before World War II and the generalized use of synthetic chemical products in agriculture, problems of pests had generally been managed using cultural practices and information on the life cycles and biology of the pests (Maho *et al*., 2013). By the end of the 1950s and at the beginning of the 1960s, the increased level of chemical resistance of insect populations and the damages caused by pesticides on non targeted organisms became a major concern. This led entomologists to develop and encourage the concept of integrated control (Jeannette, 2009). Chemical control (Philippe, 1990) is the last recourse that should be used in case of emergency (Maho *et al*., 2013). Gressit (1959) cit. Jorge (2004) suggests numerous measures for the control of *Promecotheca* pests of palm and cocao plantations in the Pacific Rim including conservation and mass breeding of natural enemies; destruction of heavily infested host-plants; and periodic monitoring to detect early stages of infection.

Most insect pests of plants are leaf miners. Leaf-mining is the consumption of foliar material contained within the epidermal layers, without eliciting a major histological response from the plant (Jorge, 2004). A leaf-mining organism is one in which, minimally, one of its life stages actively tunnels or mines the usually flattened expansions of shoots and leaves. Leaf-miners overwhelmingly consume the relatively softer tissue, or parenchyma, contained between the epidermal layers, although some leaf miners tend to consume vascular tissues (Hering, 1951 Cit. Jorge, 2004). Numerous insects bore or penetrate the shoot or the roots causing significant economic damage (Metcalf and Metcalf, 1993 Cit. Jorge, 2004).

4.1. Differential infestation as a function of plant age and crown level

In the course of this work, it was observed that *Coelaenomenodera minuta* differentially attacks the foliar crown of palm trees (results not shown). This situation could be due either to the physiology of the leaves, the intensity of light or the relative humidity which reaches the different levels of the crown. The basal level of the crown being the most attacked as compared to the others could be due to the fact that at this level, *C. minuta* finds a potential food source for its nutrition and a favorable site for shelter and for its development. This observation suggests that there is a strong attraction of leaflets of the basal level of the crown of palm trees on the adults of the pest, since the correlation between the rate of attack of leaflets and the number of adults of the pest is positive and highly significant. These observations are in line with those made by Lecoustre and Reffye (1983) who found that the basal leaves which are the oldest are the most devastated and remain the most attractive to *C. minuta*. They are seemingly the best sites where the pest lays eggs.

The differences between the plots proved non-significant on the attack rate of *C. minuta*. This could be explained by the biophysical homogeneity of the site and the analogous aggressiveness of the parasitic pressure of adults of the pest during its feeding on the leaflets of the host plant. The work of Lecoustre and Reffye (1983) showed that the attack of *C. minuta* is proportional to the surface area of the leaflet. According to our observations on the leaflets attacked by the adults of *C. minuta*, this assertion could be slightly mitigated given that for the same foliar level, leaflets of the tips of the palms which are more reduced in surface are often more attacked than those of the median portion. The attack could also be related to the degree of appetite or to the physiological status of the pest because the females lay the eggs at the end of the pickling furrow or nutrition slot (Shearing, 1964; Lecoustre & Reffye, 1984; Djob, 1997). Lepesme (1944) pointed out that, with the coleoptera; the influence of the trophic factor is noticeable on the development and the specific abundance. The feeding of *C. minuta* both at the larval and adult stages played a role in their fertilization.

In addition, there is a highly significant difference between the different palm groves studied and the number of adults and larvae captured as well as on the infestation of leaflets by *C. Minuta*, with a clear predominance of the mature on the young palm grove. This suggests that there should be an age effect of the biological factor (host plant) or the state of maturity of the plant that could influence the attraction of individuals of *C. minuta*. It is considered that the population abundance of insects is often directly related to the state of development of the organ attacked (Du Merle and Mazet, 1983; Turgeon, 1986; Foahom, 1990). This could be the case with *C. minuta* because the young palm grove was not significantly attacked by *C. minuta* throughout the study period. However, Shearing (1964) showed that *C. minuta* attacks palm trees of all ages.

The plots of the adult palms hosted the highest number of different development stages of *C. minuta* as well as the infestation of leaflets during the study. The plots P6 and P7 respectively hosted more of larvae and adults of the pest and were the most infested compared to other plots. These two plots geographically occupied the border positions in the experimental site of mature plants and were directly located close to an old palm grove which was not under this study. They could thus be considered as parasitic homes in the site. This result confirms that of Lecoustre and Reffye (1983) who showed that *C. minuta* accumulates on the borders of plantations as if it cannot cross the inter plot distances. Thus the abundance of *C. minuta* in these plots could be linked to the influence of the border effect to the old plantation and of the movement of adults of *C. minuta* from one palm to another of the same tree sampled or of neighboring trees.

In addition, the favorable influence of the microclimate of the micro biotope within the foliar crown and even the movement of adults of the pest in a palm grove could be the reason for the abundance of larvae and adults, as well as the infestation of the leaflets at the basal level of the crown. According to Lecoustre and Reffye (1983), *C. minuta* moves lesser and lesser in the course of its life time.

The statistical difference observed between the months with a high significance on the response variables, can be explained by the influence of certain climatic conditions during the study period. To this effect, the infestation of the leaflets and the abundance of pest larvae significantly higher in the month of December could be related to the influence of weather conditions. During this period, no rainfall was recorded (Fig. 1). The infestations of adults observed in the month of February could be similarly interpreted as above given that this period coincides with the full dry season in the study area. The adults of *C. minuta* were less vulnerable to weather with a negative and significant correlation between the cumulative time intervals of total rainfall and the number of captured adults.

The proportional inadequacy observed between the abundance of larvae sampled and the number of adults captured could be explained by the fact that, according to Lecoustre and Reffye (1983), the distribution of the number of eggs per laying location is variable. In addition, according to IRHO (1989), fertility is extremely variable during the year on the same site and these variations are often brutal. The significant mortality of the pest during different stages of its developmental cycle is often linked to the presence of the parasitic activity and predators in the sites (Mariau and Morin, 1971).

4.2. Sex ratio of *C. minuta*

In general, the study shows that the sex ratio is fluctuating but mostly dominated by the females (Fig. 4), with a ratio of 01 female to 0.6 male during the year. This sex ratio should probably be linked partly to the ability of the eggs laid by the females to produce either the females or the males and on the other hand, to their mortality rate during their life cycle. However, a negative and significant correlation was observed between the abundance of both males and females and the cumulative rainfall of 7 days on the one hand and of 30 days on the other hand (r_s = -0.32; P = 0.03 and r_s = -0.41; P = 0.01 respectively); meanwhile, it is not significant for the total cumulative rainfall of 2 days before sampling (r_s = -0.24; P>0.05) (Mondjeli *et al.*, 2013). This result suggests that the male and female sexes of *C. minuta* could be influenced by seasonal patterns of rainfall but to a low extend in the study area.

4.3. The natural enemies of *Coelaenomenodera minuta*

Concerning the natural enemies of *C. minuta* caught in full predation in the palm groves, results suggest that apart from some *Hymenoptera* of the family *Formicidae*, other arthropods of the Class *Arachnida* and more particularly those of the order *Araneae* could also be explored. However, according to Nyouma cit. Anonymous (1997), members of the class of insects of the family *Formicidae* are as well predators of the larvae and adults of *C. minuta*. This is the case of *Oecophylla longinoda*, *Crematogaster sp.* (Timti, 1991), *Tetramorium sp.*, as well as the *Macronuscoides*. Our results confirm those of Nyouma cit. CTA (1997) given that predators such as *Tetramorium sp* and *Crematogaster sp* were observed on their prey in our study site. Mariau and Morin (1971) indicated that post-embryonic mortality of *C. minuta* is linked to the activity of pests and predators; but more probably of the existence of viruses in the populations. Similarly, some species of insects of the family *Eulophidae*, *Achrysocharis Leptocerus*, *Sympiesis aburiana* and *Pediobus setigerus* parasite on the populations of *Coelaenomenodera minuta* (IRHO, 1972).

5. Conclusion

Good knowledge of a pest and its natural enemies constitutes an imperative and preliminary step towards the development of an efficient control program against it. Biological factors and natural enemies contribute to the reduction of the number of certain species. Among control measures against oil palm pests include conservation and mass production of natural enemies, destruction of heavily infested host plants, periodical surveillance to detect early infestation stages, etc (Jorge, 2004).

The present study and the one carried out by the same authors on the spatio-temporal distribution of *C. minuta* in the same area (Mondjeli *et al.*, 2013) reveal that the adult palms host more individuals of *Coelaenomenodera minuta* in relation to the young palm grove. The basal crown level of the palm trees hosts the pest throughout its life cycle more than the other crown levels. The sex ratio of the pest is slightly fluctuating but in general, biased in favor of females. Arthropods other than insects of the order of *Hymenoptera* such as *Arachnida* are the natural enemies (predators) of *C. Minuta*. With regard to the results of this study, it would be interesting to carry out the systematic pruning of basal leaves of the oil palm crown at the end of the rainy season. This would reduce the parasitic pressure of the pest on the trees. Moreover, a pest monitoring system should be installed in the palm groves within the study area in oil palm plantations from 3 years of age, before any intervention. Rational phytosanitary treatments should only be carried out in the mature plantations from the month of November, using systemic insecticides for the eggs and larvae found in the parenchyma of leaves; and then in late January with contact insecticides for adults.

In view of developing an effective integrated pest management (IPM) method against this pest, the following recommendations are worthwhile: strengthening the field of biological control by making a more elaborate inventory of natural enemies of *C. minuta* , with respect to the agro ecological zones; study of the biology and reproductive cycle of natural enemies; study of the spatio-temporal evolution of natural enemies as has been the case in Benin (Coffi *et al*., 2013); assessment or test of the effectiveness of the level of predation of different natural enemies identified on the different stages of development of the life cycle of *C. minuta* ; study of the relation between various constituent elements of palms at different crown levels of the trees on the attraction of the pest. Finally, it will be essential to do further survey and prepare a key for natural enemies of *C. minuta* in the study area.

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References

Alex, W. (2014). *Camponotus*-Alex Wild Photography. Retrieved on 22/07/2014 from www.alexanderwild.com.

Aneni, T.I., Aisagbonhi, C.I., Adaigbe, V.C. and Okere, C.I. (2014). Ecology of *Cotterelia podagrica* (*Hymenoptera: Eulophidae*): A Potential Parasitoid of the Oil Palm Pest, *Coelaenomenodera elaeidis* (*Coleoptera: Chrysomelidae*). *Journal of Academia and Industrial Research (JAIR)*, 3 (2), pp.63-66.

Aneni, T.I., Aisagbonhi, C.I., Iloba, B.N., Adaigbe, V.C. and Irorere M. (2012). Efficacy of Stamina 50 (Thiocyclam hydrogenoxalate) on *Coelaenomenodera elaeidis* (*Coleoptera – Chrysomelidae – Hispinae*) in Okomu oil palm plantation, Nigeria. *Journal of Applied and Natural Science*, 4 (1), pp. 30-35.

Anonymous (1995). Memento of the agronomist. Ministry of cooperation, Paris.

Anonymous (2003). *Projet d'appui de la recherche agricole au développement de la palmeraie villageoise*. IRAD, PNRPH-La Dibamba.

Anonymous (1997). *Integrating biological control and host plant resistance*. Proceedings of a CTA/IAR/STAGE IIBC seminar. Addis Ababa, Ethiopia.

Bachy, A. (1963). Insectes et animaux nuisibles au palmier à huile. *Oléagineux*, 173 p.

Barbault, R. (1990). *Ecologie générale. Structure et fonctionnement de la biosphère*. Masson, Paris, 244 p.

Barry, B. (1994). *Identification Guide to the ant genera of the world*. Harvard University Press, Cambridge, Massachusetts. London, England, 201 pp.

Bartlett, M.S. (1978). *An introduction to stochastic processes*, Cambridge University Press, USA.

Bernal, R. (1997). FAO Focus TCDC/CTPT. *Annual Report.*

Bernard, N., Martin, N., Celestin, N., Marie, P. & Eric, C. (1998). Recueil des fiches techniques. Service d'information et d'assurance conseil pour l'adaptation et la diffusion technologique. *Voix des paysans Eschborn, Allemand*, 150, pp. 141-148.

Blaak, G. (1976). A village palm oil mill. *Oil news. GB,* 23, pp. 5-11.

Cachan, P. (1957). L' hispidae mineur (*Coelaenomenodera elaeidis* Maul) parasite du palmier à huile dans la zone guinéenne. *Agron. Trop.*, 12, pp. 610-632.

Cao, T.T.V. (1995). "Organisation de la variabilité génétique chez le palmier à huile (*E. guineensis* Jacq.). Conséquence pour l'amélioration des populations et la création variétale." *Thèse de doctorat*, INA, Paris-Grignon, 200 p.

Coffi, A., Philippe, R. and Glitho, I. (2013). "Fluctuations in Natural Populations of the Leaf miner (*Coelaenomenodera lameensis*) in Relation to Different Origins of Oil Palm (*Elaeis sp.*) in South Benin," *American Journal of Plant Sciences*, 4 (9), pp. 1846-1852. doi: 10.4236/ajps.2013.49227.

Corley, R.H.V. (2003). Oil palm: a major tropical crop. *Burotrop*, 19, pp. 5-8.

Cotterell, G.S. (1925). The hispid leaf miner (*Coelaenomenodera elaeidis* Maul) of oil palms (*E. guineensis* Jacq.) on the Gold Coast. *Bull.Ent. Res*, XVI (1), pp. 77-83.

Crowson, R.A. (1955). The national classification of the families of Coleoptera, London (Nathaniel Lloyd), 187 p.

CTA (1997). "Integrating biological control and host plant resistance." Proceedings of a CTA/IAR/IIBC seminar. Addis Abeba, Ethiopia.

Delvare, G. & Aberlenc, H.P. (1989). "Les insectes d'Afrique et d'Amérique tropicale. Clés pour la reconnaissance des familles", pp. 163-200.

Dimkpa, S.O.N., Appiah, S.O. Afreh-Nuamah, K. and Yawson G.K. (2010). The Susceptibility of Some Oil Palm Elaeis guineensis Jacq Progenies to Coelaenomenodera lameensis Berti and Mariau, (Coleoptera: Chrysomelidae). Current Research Journal of Biological Sciences, 2(3), pp. 168-172.

Djob, B.J. (1997). Management of oil palm leaf miner (*Coelaenomenodera minuta* Uhm.). Annual report. CDC-IRA Research Centre, Ekona.

Du Merle, P. & Mazet, R. (1983). Stades phénologiques et infestations par Tortrix viridana L. (Lep. : Tortricidae) des bourgeons du chêne pubescent et du chêne vert. *Oecol. Applic*., 4(1), pp. 47-53.

Fanguin, J. (1978). L'huilerie de palme et son évolution. *Oléagineux*, 587, pp. 28-32.

Faure (1918). Précis de recherche opérationnelle. Dunod, Paris, Fr.

Foahom (1990). Effet de la phénologie du *Mansonia altissima* A chev. sur la dynamique des populations de *Godasa sidae* F. (Lep. : Noctuidae. Aganaine). In: Mbiapo F., Mbofung C. (éds.). Biosciences et développement : priorités. Ngaoundéré, Cameroun, *Proceedings*, 1, pp. 437-441.

Fold, N. (2003). Oil palm markets and trade. *Burotrop*, 19, pp. 11-13.

Heinrichs, E.A. & Barrion, A.T. (2004). Rice-feeding insects and selected natural enemies in West Africa. *Biology, ecology, identification*, pp. 195-222.

IRHO (1972). *Rapport d'Activité*. Institut de Recherches pour les Huiles et Oléagineux.

IRHO (1980). Le palmier à huile, fascicule I : classification, morphologie et biologie. La Mé 65 p.

IRHO (1981). La culture du palmier à huile, I. les stades juvéniles. IRHO-La Mé. 108 pp.

IRHO (1982). *Rapport d'Activité*. Institut de Recherches pour les Huiles et Oléagineux Document no 11.

IRHO (1987). *Rapport d'Activité*. Institut de Recherches pour les Huiles et Oléagineux Document no 3.

IRHO (1988). *Revue internationale des corps gras*. Institut de Recherches pour les Huiles et Oléagineux Document no 4. Publication mensuelle.

IRHO (1991). *Rapport d'Activité*. Institut de Recherches pour les Huiles et Oléagineux, *Numéro spécial*, 47 (6): 220 p.

Jacquemard, J.C. (1995). Le palmier à huile. Maisonneuve et Larose. Paris. 207 p.

Jacquemard, J.C., Baudouin, L. & Noiret, J.M. (1997). Le palmier à huile. In: Charrier, A., Jacquot, M., Hamon, S., Nicolas, D. (éds). L'amélioration des plantes tropicales. CIRAD et ORSTOM, Paris, pp. 507-531.

Jeannette, W. (2009). "Research review: The 50th anniversary of a great idea," *California agriculture*, 63 (4).

Jorge, A.S. (2004). Leaf-mining Chrysomelids In: New Developments on the Biology of *Chrysomelidae*. Ed. P. Jolivet, J. A. Santiago-Blay & M. Schmit. SPB Academic Publishing by the Hague, The Netherlands, 83 p.

Katsuyuki, E. (2008). A revision of Northern Vietnamese species of the ant genus *Pheidole* (*Insecta: Hymenoptera: Formicidae: Myrmicinae*). Magnolia Press, Auckland, New Zealand. *Zootaxa*, 1902, pp. 1-118.

Lecoustre, R. & Reffye, P. (1983). Théorie de la mesure et de l'estimation de l'extension des attaques de *Cœlaenomenodera* sur les plantations de palmier à huile. *Rapport interne IRHO*, 20 p.

Lecoustre, R. & Reffye, P. (1984). Contribution à la mise au point d'une lutte intégrée contre *Coelaenomenodera minuta* Uhm., principal ravageur de *Elaeis guineensis* en Afrique de l'ouest. Modélisation de la dynamique des populations de *Coelaenomenodera minuta* et applications pratiques. *Oléagineux*, 39 (10), pp. 461-469.

Lepesme, P. (l944). Les Coléoptères des denrées alimentaires et des produits industriels entreposés. P. Lechevalier, Paris. 335 p.

Longino, J.T. (2003). The Crematogaster (*Hymenoptera, Formicidae, Myrmicinae*) of Costa Rica. *Zootaxa*, 151, pp. 1-150.

Maho-Yalen, J.E., Ntsomboh-Ntsefong, G. & Ambang, Z. (2013). "Development of Integrated Pest Management system in Agricultural Production in Cameroon and the Central African Sub Region." *World Journal of Agricultural Research,* 1 (6), pp. 133-142. doi: 10.12691/wjar-1-6-8.

Mariau, D. & Morin (1971). La biologie de *Coelaenomenodera elaeidis* Mlk. II. Description et biologie des principaux parasites. *Oléagineux*, 26 (2), pp. 83-88.

Millar, I.M., Uys, M.V. & Urban, R.P. (2000). "Collecting and preserving insects and arachnids." SAFRINET, the southern African (SADC) loop of Bionet-International. 105 p.

Mondjeli, C., Ntsomboh-Ntsefong, G., Ngando-Ebongue, G.F., Ajambang-Nchu, W., Amah-Parh, I. and Dibog, L. (2013). Spatio-temporal distribution of *Coelaenomenodera minuta* Uhmann (*Coleoptera: Chrysomelidae*), a serious insect pest of oil palm (*Elaeis guineensis* Jacq.) in the South-west region of Cameroon. *Albanian J. Agric. Sci*., 12 (3), pp. 479 - 483.

Mpe, J.M., Nyassé, S. & Ekotto, E.E.F. (2002). "Diagnostic phytosanitaire de la palmeraie de la société agricole Rock Farm de Ndonkol." *Rapport de mission. Ministère de l'agriculture*; Sous Direction de la Protection des Végétaux.

Pantzaris, T. (1988). "Le livret des usages de l'huile de palme." Porim Ed. Kaala lumpur, Malaisie, 214 p.

Philippe, R. (1990). Practical chemical control methods against *Coelaenomenodera minuta* Uhmann (*Coleoptera - Chrysomelidae – Hispinae). Oléagineux*, 45 (4), pp. 165-173.

Philippe, R.. (1990). Etude de l'action de l'Evisect S sur *Coelaenomenodera minuta* (*Coleoptera - Chrysomelidae – Hispinae. Oléagineux*, 45 (4), pp. 143-163.

Pouvreau, A. (1984). "Cultures tropicales oléagineuses." *In*: Pesson P. et Louveau J. (éds). *Pollinisation et productions végétales*, INRA, Paris, pp. 342-348.
Rhian, G. & Keith, B. (2009). *Tetramorium parvioculum sp*. n. (*Formicidae: Myrmicinae*), a new species of the *T. simillimum* group from Gibraltar. *Boletín Sociedad Entomológica Aragonesa*, 45, pp. 157−161.
Selabie, M. (1999). Evaluation des performances des plantes de palmier à huile (*E. guineensis*) inoculées par les bio fertilisants michoriziens ou traitées par engrais chimiques en pépinière. *Mémoire DESS*, Université de Yaoundé I. 51 p.
Shearing, C.H. (1964). A serious attack of hispid leaf miner (*Coelaenomenodera elaeidis* Mlk.) at Mpundu palms estate. Report, 14 p.
Tano, D.K.C., Seri-Kouassi, B.P., Aboua, L.R.N. (2013). The effect of three plants aqueous extracts on feed intake and reproduction parameters of Coelaenomenodera lameensis Berti and Mariau (Coleoptera: Chrysomelidae) the pest of oil palm (Elaeis guineensis Jacq.). Journal of Animal & Plant Sciences, 17 (2), pp. 2527-2539. Available online at http://www.m.elewa.org/JAPS; ISSN 2071-7024
Tano, D.K.C., Seri-Kouassi, B.P., Aboua, L.R.N., Koua, K.H. (2011). Effect of Azadirachtin A systemic injection on *Coelaenomenodera lameensis* Berti and Mariau (*Coleoptera: Chrysomelidae*) an oil palm (*Elaeis guineensis* L) pest. *Journal of Asian Scientific Research*, 1(5), pp.271-284
Timti, I.N. (1991). Control of *Coelaenomenodera minuta* Uhlmann with *Crematogaster* species. *International Journal of Pest Management*, 37(4):403-408.
Turgeon, J.J. (1986). The phenological relationship between the larval development of the spruces bud moth *Zeiraphera Canadensis* (*Lep.: Olethreulidae*), and white spruce in Northern New Brunswick. *Can. Ent.*, 118, pp. 345-350.