Leucothyreus femoratus (Coleoptera: Scarabaeidae): Feeding and Behavioral Activities as an Oil Palm Defoliator

Author(s): Luis C. Martínez, Angelica Plata-Rueda, José C. Zanuncio and José E. Serrao

Source: Florida Entomologist, 96(1):55-63.
Published By: Florida Entomological Society
https://doi.org/10.1653/024.096.0107
URL: http://www.bioone.org/doi/full/10.1653/024.096.0107

LEUCOTHYREUS FEMORATUS (COLEOPTERA: SCARABAEIDAE): FEEDING AND BEHAVIORAL ACTIVITIES AS AN OIL PALM DEFOLIATOR

Luis C. Martínez[1,*], Angelica Plata-Rueda[2], José C. Zanuncio[1] and José E. Serrao[3,*]
[1]Departamento de Entomologia, Universidade Federal de Viçosa, 36570-000, Viçosa, Minas Gerais, Brazil

[2]Departamento de Fitotecnia, Universidade Federal de Viçosa, 36570-000, Viçosa, Minas Gerais, Brazil

[3]Departamento de Biologia Geral, Universidade Federal de Viçosa, 36570-000, Viçosa, Minas Gerais, Brazil

Corresponding authors; E-mail: jeserrao@ufv.br; luis.castrillon@ufv.br

Abstract

Leucothyreus femoratus Burmeister (Coleoptera: Scarabaeidae) is an important insect pest of oil palm plantations, because larvae and adults feed on plant roots and leaves, respectively. This suggests the necessity of comprehending the pest's feeding and behavioral habits for pest management. Food consumption and injury to leaves of *Elaeis guineensis* Jacq. (Arecales: Arecaceae, African oil palm) by adults of *L. femoratus* in Colombia were studied. Locomotion of adults was evaluated with respect to 6 behaviors, i.e., emergence, hiding in the ground, walking, flying, feeding, and mating. In addition, larvae were collected from the roots of other plants found in the oil palm plantation in order to determine possible alternative hosts. Leaf consumption per adult *L. femoratus* was 13 mm^2/day/insect (χ^2 = 19.33, P < 0.0001). Leaf injury was in the form of squares or rectangles and cumulative defoliation reached 15.5% in 60 days. The insect showed predominantly nocturnal feeding and mating (χ^2 = 95.53, P < 0.05; χ^2 = 207.01, P < 0.05, respectively). Larvae of *L. femoratus* were found in abundance on the roots of *Croton trinitatis* Millsp. (Euphorbiaceae, road side croton) and *Imperata cilindrica* (L.) P. Beauv. (Poaceae, cogon grass). The feeding habits of larvae and adults of this insect may be main factors in their adaptation to oil palm plantations. The understanding of the feeding habits and behaviors of *L. femoratus* are important to define strategies for the management of their populations in oil palm plantations.

Key Words: defoliation, *Elaeis guineensis*, behavior, host plants, root feeder, feeding habit

Resumen

Leucothyreus femoratus Burmeister (Coleoptera: Scarabaeidae) es una plaga importante en plantaciones de palma de aceite, ya que las larvas y los adultos se alimentan de raíces y hojas, respectivamente. Esto sugiere la necesidad de comprender la alimentación del insecto y los hábitos de comportamiento para el manejo de esta plaga. El consumo alimentario y el daño a las hojas de *Elaeis guineensis* por parte de adultos de *L. femoratus* en Colombia fueron estudiados. La actividad locomotora de los adultos se evaluó con respecto a 6 comportamientos, es decir, emergencia y ocultamiento en el suelo, caminata, vuelo, alimentación y apareamiento. Además, las larvas se recolectaron en las raíces de otras plantas que se encuentran en plantaciones de palma de aceite con el fin de determinar los posibles hospederos alternos. El consumo foliar de *L. femoratus* por adulto fue de 13 mm^2/día/insecto (χ^2 = 19.33, P < 0.0001). La lesión en la hoja presentó una forma de cuadrados o rectángulos y la defoliación acumulada alcanzó el 15.5% en 60 d. El insecto mostró predominantemente hábitos de alimentación y apareamiento nocturnos (χ^2 = 95.53, P < 0.05; χ^2 = 207.01, P < 0.05). Las larvas de *L. femoratus* fueron encontradas en abundancia, en las raíces de *Croton trinitatis* Millsp. (Euphorbiaceae, croto) e *Imperata cilindrica* (L.) P. Beauv. (Poaceae, vende aguja). Los hábitos de alimentación de las larvas y adultos de este insecto puede ser el factor principal para su adaptación en plantaciones de palma de aceite. La comprensión de los hábitos alimenticios y el comportamiento de *L. femoratus* son importantes para definir estrategias en el manejo de sus poblaciones en plantaciones de palma de aceite.

Palabras Clave: comportamiento, defoliación, *Elaeis guineensis*, fitófagos plantas hospederas, rizófagos

---

In Colombia, extensive monocultures of oil palm (*Elaeis guineensis* Jacquin; Arecales: Arecaceae) support the growth and development of defoliating insects that can impair the productivity of commercial plantations. The introduction and establishment of *E. guineensis* in Neotropical ecosystems has been attended by biotic and abiotic stresses, which facilitate the proliferation of endemic phytophagous species (Mariau et al. 1991; Martínez et al. 2009). Oil palm defoliators are representatives of different insect taxa, and therefore there are variations in the nature of their damage, in their population dynamics, and whether several defoliator species are permanently present to simultaneously damage the plant (Genty et al. 1978; Chung et al. 1995; Zeddam et al. 2003; Martínez et al. 2009).

Many species of insects consume the leaf tissue of mature palms and have the potential to cause a significant defoliation. The effects on performance in the palms were investigated by manual defoliation to simulate pest attack (Wood et al. 1974). In the first year, 50% defoliation causes a loss in harvest up to 40%, if limited only to the upper half of the canopy, i.e., all palmate leaves in the upper half of the canopy destroyed (Wood et al. 1974). Defoliation by insects reduces palm oil production from 5 to 30 tonne/ha/yr (Giblin-Davis & Howard 1989). Defoliation of the top level of the canopy is very detrimental, and the plant may need up to 2 years to rebuild the canopy (Young 1977; Corley 1983; Henson 1990; Darus & Basri 2000). Thus canopy defoliation reduces plant size and biomass (Young 1977; Henson 1991; Dufrene & Saugier 1993; Corley & Donough 1995).

Scarabaeidae (Coleoptera) larvae live in the soil and feed on decaying organic matter, whereas adults of some species feed on plant tissues and in some cases become insect pests (Pardo-Locarno et al. 2006). Rutelinae beetles in some countries in the Americas feed on roots of forage plants of pastures and on other crops (Micó et al. 2003; Arakaki et al. 2004; Ramirez-Salinas et al. 2004; Vallejo & Morón 2008). *Melolontha melolontha* (F.), *Omaloplia spireae* (Pallas) and *Popillia japonica* Newman, damage leaves of a variety of plants in Asia and Europe (Fulcher et al. 1998; Egert et al. 2005; Özbek 2011). *Apogonia expeditionis* Ritsema, *Apogonia cribicollis* Burmeister, *Adoretus borneensis* Kraatz and *Adoretus compressus* (Weber) are nocturnal defoliators of oil palm plantations in Malaysia (Hartley 2002; Nordin et al. 2004). *Leucothyreus femoratus* Burmeister is an insect pest of oil palm. Their larvae are found in the ground feeding on different plants, whereas the adults are defoliators that cause considerable damage to oil palms (Martínez et al. 2000). The life cycle of this insect from eggs to adult has a duration of 170 days, and the survival rate is 97%. Males and females are easily distinguished by different leg colorations (Martínez et al. 2000).

Lepidopteran larvae from different families are the main defoliators in oil palm plantations in Colombia (Mariau et al. 1991; Howard et al. 2001; Martínez et al. 2009); these insects remain continuously on leaves, making it easier to establish different control strategies (Mariau et al. 1991; Darus & Basri 2000). The absence of *L. femoratus* on *E. guineensis* leaves, in daytime hinders the acquisition of biological knowledge including behavior, feeding activity, and potential as insect pest.

This study evaluated the foliar consumption and damage caused to *E. guineensis* by *L. femoratus*, the behaviors of the adult insects and various plant species fed on by the larvae in oil palm plantations. The goal of this study was to contribute to the baseline of knowledge of *L. femoratus* as a basis for establishing integrated programs to manage this defoliating beetle.

Materials and Methods

Insects

In field conditions, 533 adults of *L. femoratus* (♂ = 251, ♀ = 282) were captured at night in 2-yr old commercial plantations of oil palm in the municipality of San Vicente, Santander, Colombia (N 06°54' W 73°28'), with an average temperature of 27.32 °C, 75-81% RH, 1,350-2,200 h/yr sunshine and 1,879 mm annual rainfall. The insects were transferred into polystyrene boxes (40 × 40 × 60 cm) to the Entomology Laboratory of the Universidad Nacional de Colombia, Bogotá and reared at 26 ± 2 °C and 75 ± 5% RH; these insects were used to establish a breeding colony under laboratory conditions. Males and females of *L. femoratus* were isolated in glass vials (Ø 10 cm × 50 cm, capacity) containing 5 cm of soil and fed *E. guineensis* leaves. Eggs oviposited in the soil were collected (n = 2,474) every 24 h and were placed in Petri dishes (Ø 90 mm × 15 mm) with damp paper. Newly emerged first instar larvae were placed individually in plastic boxes (Ø 10 cm × 15 cm, capacity) with perforated lid. To each box was added a layer of sterilized soil (5 cm) in depth, and the larvae were fed with *Zea mays* (L) roots every 24 h. *Zea mays* roots were grown with hydroponics, cut off and placed in each box at the rate of 5 g/larva. The different stages of *L. femoratus* were obtained as follows: first instar larvae = 2,461, second instars = 2,056, third instars = 1,864; pupae = 1,256 and adults = 967. Adults were placed in glass containers (30 × 30 × 30 cm) covered with a nylon mesh and fed *E. guineensis* leaves (Martínez et al. 2000). Healthy adults without amputations or malformations were used in the bioassays.

Defoliation under Field Conditions

The accumulated defoliation caused by *L. femoratus* was evaluated in twenty 2-yr-old palm trees. In the field, the consumed foliar area was measured by an acetate sheet (25 × 35 cm, with

1 mm^2 grids) superimposed on 3 leaves per palm, in the upper, median and basal canopy every 10 day for 60 days.

Consumption Rates

Males and females of *L. femoratus* were isolated in glass vials (Ø 10 cm × 15 cm, capacity) containing 5 cm of soil in the bottom and fed young *E. guineensis* leaflets wrapped in cotton cloth to prevent weight loss from dehydration. Foliar consumption (mm^2) by individuals of both sexes (n = 200; ♂ = 100, ♀ = 100) from the time of adult emergence to 60 d post-emergence was measured daily. The consumed foliar area was measured by an acetate sheet (25 × 35 cm with 1 mm^2 grids).

Behavioral Activities

The most common behavioral activities of *L. femoratus* were observed and determined before the bioassay: emergence from and return into the soil, walking, flying, feeding and mating. Males and females of *L. femoratus* (n = 100; ♂ = 50, ♀ = 50) were kept in 5 groups of 20 insects (♂ = 10, ♀ = 10) in glass containers (30 × 30 × 50 cm) each with a nylon mesh cover and a wire mesh bottom to facilitate drainage. Five glass containers were used as arenas for recording behavioral activities. Each arena had a 5-cm deep soil layer maintained at 80% RH by periodic irrigation by a sprinkler. Five leaflets of *E. guineensis* were hung with clips from the nylon cover and changed every 24 h. Virgin insects obtained from the breeding colony were placed in the arena 24 h before each data recording session; and insects that died during the bioassay were replaced. Behavioral activities were recorded with a camera (SONY SNC-CH180) and the number of locomotory events of each insect was recorded every 30 min both during the scotophase and photophase (12 h: 12 h L:D) at 27 °C for 30 d. Photophase and scotophase periods were simulated with white fluorescent and red light (Toshiba, 150 W), respectively (Hamasaka et al. 2002).

Sampling Larvae on Roots

Larvae of *L. femoratus* on the roots of weeds present in oil palm crops were sampled in the field. Sampling was conducted on 20 plant species, considered the most abundant in commercial plantations in Colombia (Table 1). Sampling was conducted in 1-yr old *E. guineensis* crops (Tenera variety: 'Deli × Ghana') in the municipality of San Vicente, Santander, Colombia (N 06°54' W 73°2'). Each samples of each plant species was taken in an area of 30 × 30 cm, 15 cm deep, and 2 m distant from the stem of a palm tree. Larvae of *L. femoratus* found in association with the roots of each

TABLE 1. PLANT SPECIES GROWING IN *ELAEIS GUINEENSIS* PLANTATIONS IN THE MUNICIPALITY OF SAN VICENTE, SANTANDER, COLOMBIA.

Species	Family	Common name
Andropogon bicornis (L)	Poaceae	Beard grass
Clidemia hirta (L). D. Don	Melastomataceae	Soap bush
Croton trinitatis Millsp.	Euphorbiaceae	Road side croton
Cyperus diffusus Vahl	Cyperaceae	Umbrella sedges
Cyperus ferax Rich	Cyperaceae	Umbrella sedges
Cyperus luzulae (L). Rottb ex Retz.	Cyperaceae	Umbrella sedges
Desmodium heterocarpon (L)	Fabaceae	Beggar lice
Homolepis aturensis (Kunth) Chase	Poaceae	Cumin grass
Hyptis atrorubens Poiteau	Lamiaceae	Bush mints
Imperata cilíndrica (L). P. Beauv.	Poaceae	Cogon-grass
Mimosa pudica (L)	Fabaceae	Bashful
Paspalum conjugatum P.J. Bergius	Poaceae	Bahia grasses
Peltaea speciosa (Kunth) Standl.	Malvaceae	Slimy
Phyllanthus niruri (L)	Euphorbiaceae	Stone breaker
Pueraria phaseoloides (Roxb.) Benth.	Fabaceae	Kudzu
Rhynchospora nervosa (Vahl) Boeckeler	Cyperaceae	Beak rush
Scleria melaleuca (Rchb.f.ex.Schltdk.Cham.)	Cyperaceae	Cutter
Sida acuta Burm. F.	Malvaceae	Wire weed
Stachytarpheta cayennensis (Rich.) Vahl.	Verbenaceae	Verbena
Steinchisma laxa (Sw.) Zuloaga	Poaceae	Slick grass

Leaf base (at least initially) forms a closed tubular sheath that encircles the stem. Leaf blade is well developed with a single midrib or rachis and is usually split partly or completely into leaflets (pinnate leaves) or leaf segments (palmate leaves).

plant were collected and quantified. Three collections were made every 4 months during 2010, with 20 samples/plant (n = 60 samples/plant species).

Data Analysis

A paired t-test was used to compare the means of the daily consumption rates of males and females of *L. femoratus*. Behavior activity and the defoliation of young palm plants were analyzed by linear regression (Sokolove & Bushell 1978). Data from number of larvae found in association with host plants were analyzed by ANOVA and HSD at a significance level of 5% (Tukey 1949).

Results

Defoliation under Field Conditions

The damage to *E. guineensis* leaves by *L. femoratus* increased linearly (R^2 = 0.9026) during the 60 days of observation (Fig. 1). The loss of leaf area began in the upper leaves of the canopy followed by partial or total damage to the basal leaves (Figs. 2 and 3). Mean area of the palm leaves tested was 24,852.2 mm^2. Loss of leaf area in the upper canopy level averaged 18,567.1 mm^2 (74.1% defoliation), 20,655.3 mm^2 (83.1 % defoliation) in the mid canopy level, and 23,132.8 mm^2 (93.9% defoliation) in the lower canopy level.

Damage caused by *L. femoratus* showed variations in number of leaves damaged, and in the size and shape of lesions. The main feature of the lesion was its rectangular or square shape extending from the leaflet border to the central vein (Fig. 4). Damage was greater at the apex than at the base of leaflet (Fig. 5). More serious injuries occurred in leaves in close contact with other leaves, which included damaged vascular ducts and necrosis and drying around the lesions.

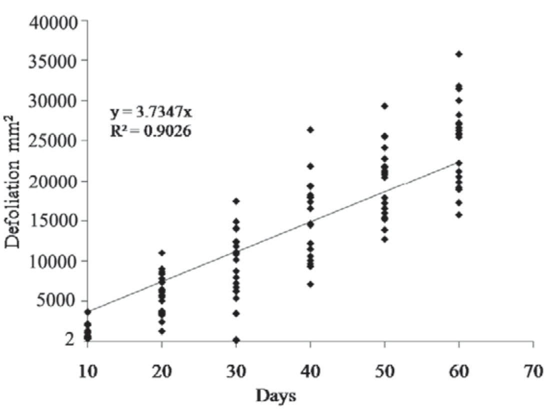


Fig. 1. Defoliation of twenty 2-yr-old *Elaeis guineensis* oil palm trees by a heavy *Leucothyreus femoratus* infestation during 60 days in a field plantation in the municipality of San Vicente, Santander, Colombia (N 06°54' W 73°28').

Consumption Rates

The average leaf area consumed by *L. femoratus* males during 60 days averaged 492.1 mm^2 with an average of 8.2 mm^2/male/day (χ^2 = 19.33, $P < 0.0001$). The average foliar area consumed per *L. femoratus* female in 60 days was greater than per male, being 744.6 mm^2/female and average of 12.4 mm^2/female/day. The mean foliar area consumed was 13 mm^2/day/insect.

Behavioral Activities

The behaviors of *L. femoratus* occurred during the scotophase. However, variations on each activity evaluated occurred during the photophase in the insects' underground refuges (Figs. 6 and 7). Emergence from the ground occurred from 17:30 to 23:00 h with peak emergence at 19:00 h (χ^2 = 9.29, $P < 0.05$) (Fig. 8). After emergence the beetles walked on the ground surface in the direction of nearby palm leaves. Walking activity occurred from 18:00 to 05:30 h with a peak at 19:00 h (χ^2 = 12:38, $P < 0.05$) (Fig. 9). Feeding was observed from 18:30 to 05:30 h with the most intense activity at 02:30 h (χ^2 = 95.53, $P < 0.05$) (Fig. 10). Flight occurred from 18:30 to 05:30 h and peaked at 22:00 h (χ^2 = 11.35, $P < 0.05$) (Fig. 11). Flight was observed from the soil and leaf surfaces, and was directed at searching for other individuals. Mating occurred from 20:00 to 03:00 h with a peak at 01:00 h (χ^2 = 207.01, $P < 0.05$) (Fig. 12). Males and females mated several times on the leaves while the females were feeding. The return to the soil occurred from 03:00 to 06:30 h with a peak at 05:00 h (χ^2 = 36.33, $P < 0.05$) (Fig. 13).

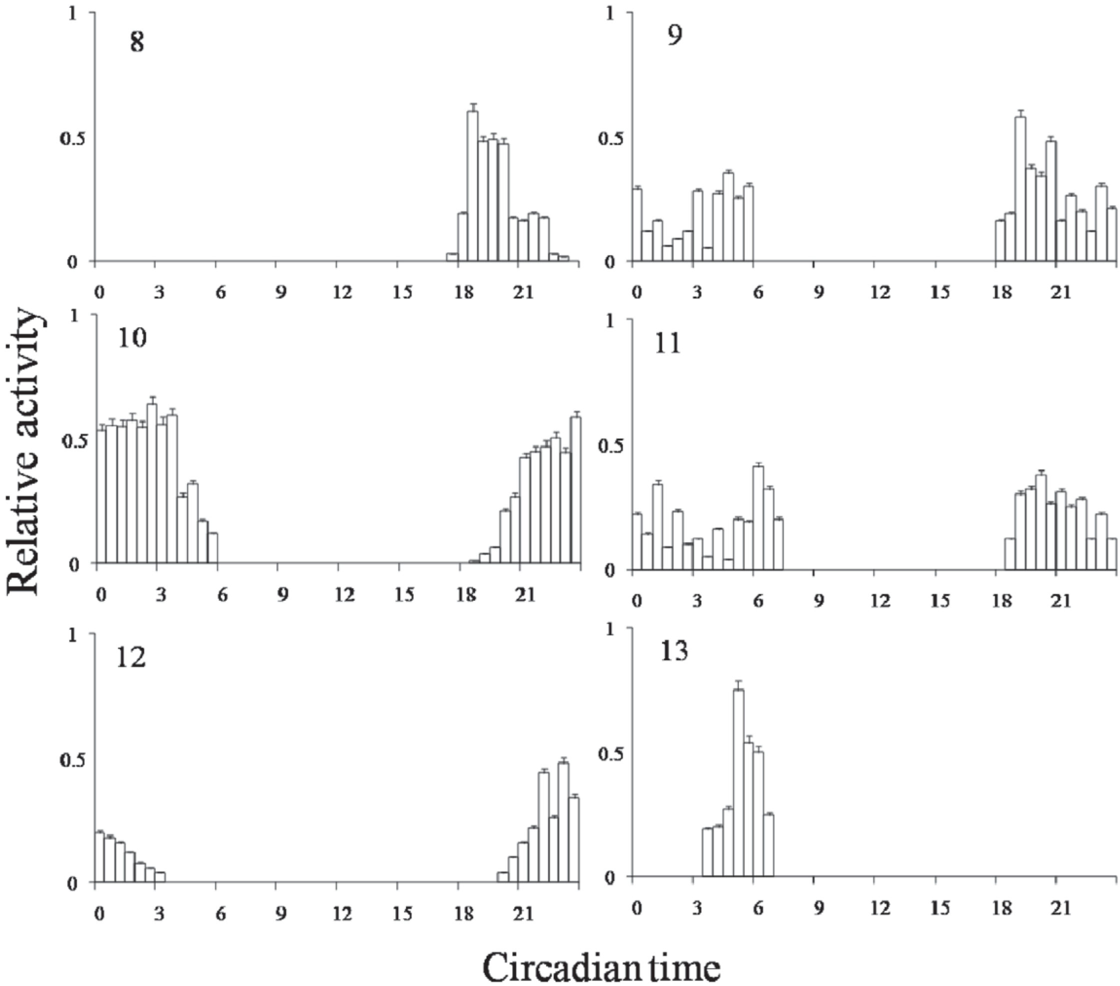
Sampling Larvae on Roots

Mean numbers of *L. femoratus* larvae were high on the roots of *I. cilindrica*, and *C. trinitatis* with 6.6 and 6.1 larvae/plant, respectively ($F_{1,19}$ = 51.95, $P < 0.05$). *Cyperus diffusus* Vahl (Cyperales: Cyperaceae) and *Cyperus ferax* Rich had averages of 2.6 and 1.3 larvae/plant, respectively. *Homolepis aturensis* (Kunth) Chase (Poales: Poaceae), *Peltaea speciosa* (Kunth) Standl. (Malvales: Malvaceae), and *Steinchisma laxa* (Sw.) Zuloaga (Poales: Poaceae) had on average 2.1 larvae/plant, while the other plants sampled had lower numbers of larvae (Fig. 14). Larvae of *L. femoratus* were not found in roots of *Mimosa pudica* (L.) (Fabales: Fabaceae), *Pueraria phaseoloides* (Roxb.) Benth. (Fabales: Fabaceae), *Paspalum conjugatum* P. J. Bergius (Poales: Paceae), *Sida acuta* Burm. F. (Malvales: Malvaceae), and *Stachytarpheta cayennensis* (Rich.) Vahl (Lamiales: Verbenaceae).

Figs. 2-7. Injury caused by *Leucothyreus femoratus* to *Elaeis guineensis* in Colombia. 2. Initial defoliation in a 2-yr-old palm plantation. 3. Defoliation during 60 days in a 2-yr-old palm plantation. 4. Square and rectangular lesions in leaf borders by feeding of *L. femoratus*. 5. Injury in the upper leaves of the canopy. 6. Habitus of beetle when it emerged from the ground during the scotophase. 7. Habitus of beetle in its underground refuge during the photophase.

Discussion

Nocturnal adult beetles defoliate trees, shrubs, and grasses in various ecological regions (Vallejo et al. 1998). The variation in the daily foliar consumption for males and females of *L. femoratus* may be caused by differences in the size between the 2 sexes (Martinez et al. 2000). The square or rectangle shape of the foliar damage was similar to that reported for this insect in other palms such as *Cocos nucifera* L., *Elaeis oleifera* (Kunth) Cortés, and *Bactris gassipaes* HBK (Martinez et al. 2000). The feeding preference of *L. femoratus* adult suggest that this insect may be classified



Figs. 8-13. Relative levels of activity of various behaviors of *Leucothyreus femoratus* adults during the scotophase (18:00 to 06:00 h) and photophase (06:00 to 18:00 h). Each depicts the activity during 30 min. 8) Emergence from ground; 9) Walking; 10) Feeding; 11) Flight; 12) Mating; and 13) Return to the ground.

as monophagous, since phytochemical characteristics are common among species of Arecaceae (Asmussen et al. 2006; Bjorholm et al. 2006). The phenology and physiology of young palms before the reproductive phase is affected by the damage caused by *L. femoratus*; secondary compounds derived from plants injuries have important effects on herbivores, and in many cases, act as attractants and phago-stimulants (Vallejo et al. 1998; Johns et al. 2004; Diagne et al. 2006).

Damage by *L. femoratus* to *E. guineensis* leaves during 60 d showed 36% accumulated loss of leaf area in the palm trees. The functional damage to leaves decreases the photosynthetic rate and growth of young leaves, stem, and roots, while the partial defoliation results in increased closed leaves with and a low rate of foliar replacement (Henson 1990; Darus & Basri 2001). Studies in monthly oil yields determined a production shortfall in the first 10 months after defoliation, with physiological consequences on the ground including abortion of inflorescences, male flower production and decrease in the number of new leaves (Wood et al. 1974; Henson 1991; Martínez et al. 2009). The palms evaluated under field conditions were affected by *L. femoratus*, at all levels. This corresponds well with the observations of a plantation severely attacked by other insect species (Mariau et al. 1991; Howard et al. 2001; Martínez et al. 2009). The lower leaf damage has less effect because they contribute relatively little to total photosynthesis into canopy. The consequences of the leaf damage caused by *L. femoratus* may be higher in mid and upper levels than in the lower level, and the mid and upper levels have the highest photosynthetic activity. Damage by *L. femoratus* to leaves of young palm trees may affect the economic viability of commercial plantations by

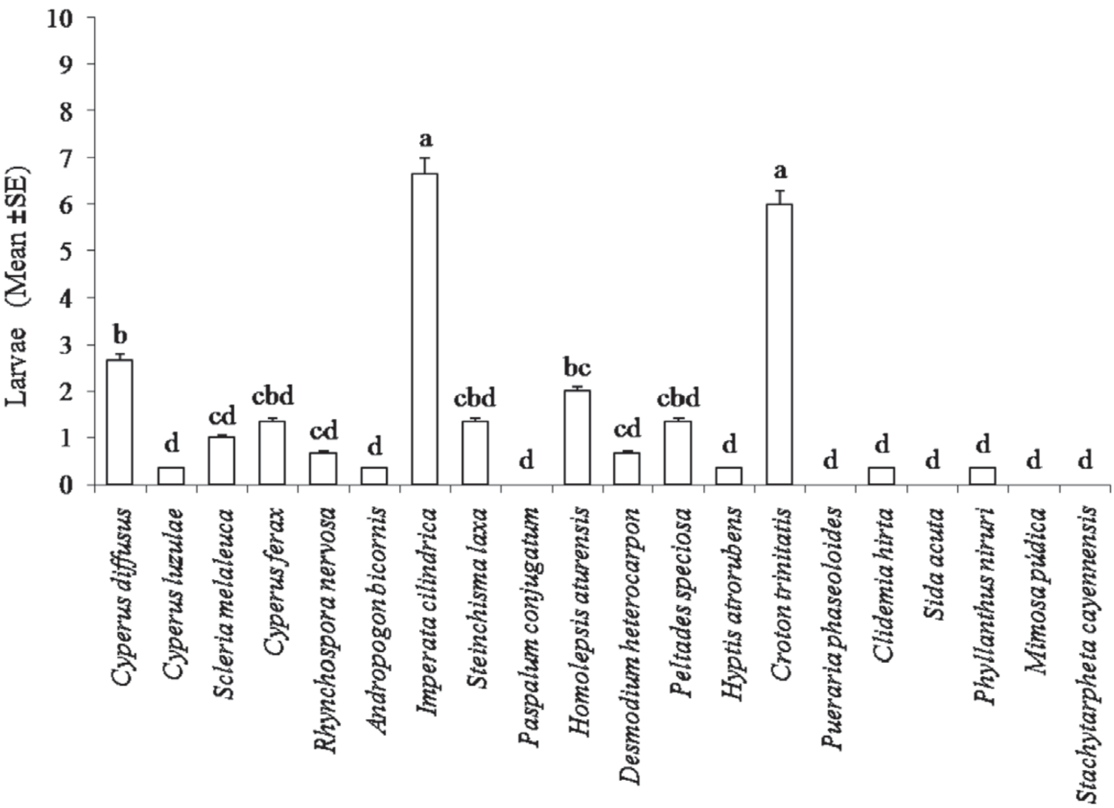


Fig. 14. Mean (± SE) numbers of *Leucothyreus femoratus* larvae in association with roots of plants found in *Elaeis guineensis* plantations.

delaying flowering, fruiting, and harvesting for up to 2 yr (Wood et al. 1974; Corley 1983). Prevention of defoliation during the plant's vegetative period increases the economical costs of pest control (Hartley 2002; Nordin et al. 2004).

The studied behavioral activities of *L. femoratus* adults were related mainly to feeding and mating. Feeding sites were also the main sites for mating, which explains the close relationship between these 2 activities. Functional and behavioral responses of insects to damaged *E. guineensis*, i.e., chemical communication, have been reported by different authors (Oehlschlager et al. 1993; Rochat et al. 2000). Kairomones released during injury of the plant, together pheromones, affect the directional walking and flying in beetles (Giblin-Davis et al. 1994; Diagne et al. 2006). The emergence from and return to soil by *L. femoratus* occurred at the beginning and end of the scotophase during 12 h. Under field conditions, *L. femoratus* is attracted to white light (Pardo-Locarno et al. 2006; Vallejo & Morón 2008) and changes between photophase and scotophase could be attributed to temperature changes. These environmental signals may be the cause of the emergence and return to underground in several beetle species (Naylor 1963; Nisimura et al. 2005).

The proximity and presence of other plant species in oil palm plantations may explain the abundance of larvae and adults of *L. femoratus* in this crop. High numbers of *L. femoratus* larvae of this insect were associated with the roots of *I. cilindrica* and *C. trinitatis,* while such numbers were low for *C. diffusus*, *C. ferax*, *H. aturensis*, *S. laxa* and *P. speciosa*. The development of the beetle on these weeds results in continuous pressure on the crop. In Colombia, *L. femoratus* was reported as a pest of *Manihot esculenta* Crantz (Euphorbiales: Euphprbiaceae) and some grasses (Pardo-Locarno et al. 2006; Vallejo & Morón 2008). Other species of *Leucothyreus* are also reported as root feeders and defoliators of Fabaceae, Poaceae, and Arecaceae (Rodrigues et al. 2010). Larvae of *L. femoratus* were not found in association with roots of *M. pudica*, *P. phaseoloides*, *P. conjugatum*, *S. acuta* and *S. cayennensis*, suggesting that management of *L. femoratus* may be satisfactory with the replacement of understory plants by velvetbean, *P. phaseoloides*, in oil palm plantations. The use of plants such as wild ground nut, *Calopogonium muconoides* Desv. (Fabales: Fabaceae), and velvetbean, *Pueraria javanica* (Benth.) Benth., have been successfully used for this purpose in Malaysia (Caliman et al. 1990).

Our findings contribute to the understanding of the feeding habits and behavior of *L. femoratus*. The daily foliar consumption rate, and defoliation features in young plants indicate that *L. femoratus* has the potential to be a significant pest in *E. guineensis* plantations. The nocturnal behavioral activities indicate that this insect has more effective survival strategies than other insect pests in oil palm plantations with greater adaptability of larvae and adults in the agroecosystem. Altogether, these results contribute to the strategic use of effective tactics to control and manage *L. femoratus* populations.

Acknowledgments

We thank Arnulfo Guarín by contributions in identification of native plant species. To Universidad Nacional de Colombia, Palmeras Yarima SA (Colombia) for facilities and to Brazilian research agencies CNPq, CAPES and FAPEMIG.

References Cited

Arakaki, N., Kishita, M., Nagayama, A., Fukaya, M., Yasui, H., Akino, T., Hirai, Y., and Wakamura, S. 2004. Precopulatory mate guarding by the male green chafer, *Anomala albopilosa sakishimana* Nomura (Coleoptera: Scarabaeidae). Appl. J. Zool. 39: 455-462.

Asmussen, C. B., Dransfield, J., Deickmann, V., Barfod, A.S., Pintaud, J-C., and Baker, W. J. 2006. A new subfamily classification of the palm family (Arecaceae): Evidence from plastid DNA. Bot. J. Linn. Soc. 151: 15-38.

Bjorholm S., Svenning, J. C., Baker, W. J., Skov, F., and Balslev, H. 2006. Environmental and spatial controls of palm (Arecaceae) species richness across the Americas. Global Ecol. Biogeogr. 14: 423-429.

Caliman J. P., Concaret J., Olivin J., and Dufour, F. 1990. Maintenance of physical soil fertility under oil palm in humid tropical regions. Oléagineux 45: 103-110.

Corley, R. H. V. 1983. Photosynthesis and age of oil palm leaves. Photosynthetica 17: 97-100.

Corley, R. H. V., and Donough C. R. 1995. Effects of defoliation on sex differentiation in oil palm clones. Exp. Agr. 31: 177-189.

Chung, G. F., Sim, S. C., Hon, K. M., and Ramli, K. 1995. Monitoring and surveillance system for integrated pest management of leaf eating caterpillars in oil palm. Planter 71: 253-263.

Darus, A., and Basri, M. W. 2000. Intensive IPM for management of oil palm pests. Oil Palm Bull. 41: 1-14.

Diagne, A., Story, R. N., and Hammond, A. M. 2006. Adult *Phyllophaga ephilida* host plant feeding preference. Florida Entomol. 89: 391-395.

Dufrene, E., and Saugier, B. 1993. Gas exchange of oil palm in relation to light, vapour pressure deficit, temperature and leaf age. Funct. Ecol. 7: 97-104.

Egert, M., Sting, U., Bruun, L. D., Bianca Pommerenke, B., Brune, A., and Friedrich, M. W. 2005. Structure and topology of microbial communities in the major gut compartments of *Melolontha melolontha* larvae (Coleoptera: Scarabaeidae). Appl. Environ. Microbiol. 71: 4556-4566.

Fulcher, A. F., Ranney, T. G., and Burton, J. D. 1998. Role of foliar phenolics in host plant resistance of *Malus taxa* to adult Japanese beetles. Hortscience 33: 862-865.

Genty, P., Desmier De Chenon, R., and Morin, J. 1978. The oil palm pest in Latin America. Oléagineux 33: 325-419.

Giblin-Davis, R. M., and Howard, F. W. 1989. Vulnerability of stressed palms to attack by *Rhynchophorus cruentatus* (Coleoptera: Curculionidae) and insecticidal control of the pest. J. Econ. Entomol. 82: 1185-1190.

Giblin-Davis, R. M., Weissling, T. J., Oehlschlager, A. C., and Gonzalez, L. M. 1994. Field response of *Rhynchophorus cruentatus* (Coleoptera: Curculionidae) to its aggregation pheromone and fermenting plant volatiles. Florida Entomol. 77: 164-177.

Hamasaka, Y., Watari, Y., Arai, T., Numata, H., and Shiga, S. 2002. Retinal and extraretinal pathways for entrainment of the circadian activity rhythm in the blow fly, *Protophormia terraenovae*. J. Insect Physiol. 47: 867-875.

Hartley, M. J. 2002. Rationale and methods for conserving biodiversity in plantation forests. Forest Ecol. Manag. 155: 81-95.

Henson, I. E. 1990. Photosynthesis and source-sink relationships in oil palm (*Elaeis guineensis* Jacq.). Trans. Malaysian Soc. Plant Physiol. 1: 165-171.

Henson, I. E. 1991. Limitations to gas exchange, growth and yield of young oil palm by soil water supply and atmospheric humidity. Trans. Malaysian Soc. Plant Physiol. 2: 39-45.

Howard, F. W., Moore, D., Giblin-Davis R. M., and Abad, R. G. 2001. Insects on palms. CABI Publ. Intl., U.K.

Johns, C. V., Stone, C., and Hughes, L. 2004. Feeding preferences of the Christmas beetle *Anoplognathus chloropyrus* (Coleoptera: Scarabaeidae) and four paropsine species (Coleoptera: Chrysomelidae) on selected *Eucalyptus grandis* clonal foliage. Austral. For. 67: 184-190.

Mariau, D., Desmier De Chenon, R., and Sudharto, P. S. 1991. Oil palm insect pests and their enemies in South East Asia. Oléagineux 46: 400-476.

Martínez, L. C., Aldana, J. A., Calvache, H., and Villanueva, A. 2000. Biología de *Leucothyreus femoratus* (Coleoptera: Scarabaeidae) defoliador en palma de aceite. Palmas 21: 212-220.

Martínez, L. C., Hurtado, R. E., Araque, L., and Rincón, V. 2009. Avances de la campaña regional para el manejo de la información de insectos defoliadores en la zona central. Palmas 30: 51-61.

Micó, E., Morón, M. A., and Galante, E. 2003. New larval descriptions and biology of some new World Anomalini beetles (Scarabaeidae: Rutelinae). Ann. Entomol. Soc. Am. 96: 597-614.

Naylor, E. 1963. Temperature relationships of the locomotor rhythm of *Carcinus*. J. Exp. Biol. 40: 669-679.

Nisimura, T., Numata, H., and Yoshioka, E. 2005. Effect of temperature on circadian rhythm controlling the crepuscular activity of the burying beetle *Nicrophorus quadripunctatus* Kraatz (Coleoptera: Silphidae). Entomol. Sci. 8: 331-338.

Nordin, A. B. A., Simeh, M. A., Amiruddin, M. N., Weng, C. K., and Salam, B. A. 2004. Economic feasibility of organic palm oil production in Malaysia. Oil Palm Ind. Econ. J. 4: 29-38.

Oehlschlager, C. A., Chinchilla, C. M., González, M., Jiron-Porras, L. F., Mexzon, R., and Morgan, B. 1993. Development of a pheromone-based trapping system for *Rhynchophorus palmarum* (Coleoptera: Curculionidae). J. Econ. Entomol. 86: 1381-1392.

Özbek, H. 2011. *Omaloplia spireae* (Pallas) (Coleoptera: Scarabaeidae), a new pest of sea buckthorn, *Hippophae rhamnoides* L., in Turkey. Turkish J. Zool. 35: 437-440.

Pardo-Locarno, L. C., Morón, M. A., and Montoya-Lerma, J. 2006. Descripción de los estados inmaduros de *Leucothyreus femoratus* Burmeister con notas sobre su biología e importancia agrícola en Colombia. Folia Entomol. Mexicana 45: 179-193.

Ramírez-Salinas, C., Morón, M. A., and Castro-Ramírez, A. E. 2004. Descripción de los estados inmaduros de tres especies de *Anomala, Ancognatha y Ligyrus* (Coleoptera: Melolonthidae: Rutelinae y Dynastinae) con observaciones de su biología. Acta Zool. Mexicana 20: 67-82.

Rochat, D., Ramírez-Lucas, P., Malose, C., Aldana, R., Kakul, T., and Morin, J. 2000. Role of solid phase micro-extraction in the identification of highly volatile pheromones of two rhinoceros Beetle *Scapanes australis* and *Strategus aloeus* (Coleoptera, Scarabaeidae, Dynastinae). J. Chromatogr. A 885: 433-444.

Rodrigues, S. R., Puker, A., and Tiago, E. F. 2010. Aspectos biológicos de *Leucothyreus dorsalis* Blanchard (Coleoptera, Scarabaeidae, Rutelinae). Rev. Bras. Entomol. 54: 431-435.

Sokolove, P. G., and Bushell, W. N. 1978. The chi-square periodogram: it's utility for analysis of circadian rhythms. J. Theor. Biol. 72, 131-160.

Tukey, J. W. 1949. Comparing individual means in the analysis of variance. Biometrics 5: 99-114.

Vallejo, F., Morón, M. A., and Orduz, S. 1998. First report and description of immature stages of *Phyllophaga obsoleta* (Blanchard) (Coleoptera: Melolonthidae) in Colombia. Coleopts. Bull. 52: 109-117.

Vallejo, F., and Morón, M. A. 2008. Description of the immature stages and redescription of the adults of *Ancognatha scarabaeoides* Erichson (Coeloptera: Scarabaeidae: Dynastinae), a member of the soil white grub assemblage in Colombia. Coleopts. Bull. 62: 154-164.

Wood, B. J., Liau, S. S., and Knecht, J. C. X. 1974. Trunk injection of systemic insecticides against the bagworm, *Metisa plana* (Lepidoptera: Psychidae) on oil palm. Oléagineux, 29: 499-505.

Young, A. M. 1977. Notes on the defoliation of coconut palm (*Cocos nucifera*) by the butterfly *Opsiphanes quiteria quirinus* in northeastern Cost Rica. Deutche. Entomol. Z. 24: 353-365.

Zeddam, J. L., Cruzado, J. A., Rodriguez, J. L., Ravallec, M., and Subilete, E. C. 2003. A cypovirus from the South American oil-palm pest *Norape argyrrhorea* and its potential as a microbial control agent. Biocontrol 48: 101-112.