Some biological aspects of *Leucothyreus femoratus* (Burmeister) (Coleoptera, Scarabaeidae), in oil palm plantations from Colombia

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Abstract

The scarabaeid *Leucothyreus femoratus* (Burmeister) is described as causing damage to oil palm leaves, marking its first report as a pest in Colombia. The presence of this insect has necessitated determination of its life cycle, biometrics and food consumption as important aspects of its biology. Experiments were conducted under laboratory conditions in the municipality of San Vicente, Santander, Colombia. Mass rearing of *L. femoratus* was conducted, simulating field conditions and eating habits under laboratory conditions. Its life cycle and description of its developmental stages were determined, taking into account stage-specific survival. The duration of the life cycle of *L. femoratus* was determined to be 170.4±6.53, with an overall survival rate of 96.7%. Biometrical measurements were taken of the insect's width, length and weight. Adults are black, and males and females are differentiated by size and by colour of their legs. The width, length and weight of the insect are proportional to the growth stage. Daily food consumption rate was evaluated in adult *L. femoratus,* and damage to leaves of *Elaeis guineensis* is described. Adult *L. femoratus* consumed 13 mm^2 of foliage per day, and injury to leaves of *E. guineensis* was square or rectangular in shape. This insect's life cycle duration and size are factors that could be considered in determining its feeding habits and pest status. Details of the life cycle, physical description and consumption rate of *L. femoratus* can help in the development of strategies to manage its populations in oil palm plantations.

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Introduction

Extensive monocultures of oil palm (*Elaeis guineensis* Jacquin; Arecales, Arecaceae) promote the growth and development of defoliating insects that may impair the productivity of commercial plantations in the Americas. Different biotic and abiotic changes were induced by the introduction and establishment of *E. guineensis* in neotropical ecosystems, where it expands continuously as a crop, favoring colonization by phytophagous species endemic to the agroecosystem (Mariau *et al*., 1991; Martínez *et al*., 2009). Oil palm defoliators are represented by different insect species that exhibit variations in the nature of their damage, their population dynamics, and whether several species may be permanently present to simultaneously damage the plant (Genty *et al*., 1978; Chung *et al*., 1995).

Defoliation by insects reduces palm oil production by 5-30 ton/ha/year (Wood *et al*., 1974). Defoliation of the top level of the canopy is very detrimental, and the plant may need up to two years to rebuild the canopy after being damaged (Corley, 1983; Henson, 1990). Foliar damage in palm can have a significant physiological impact, characterized by partial or total removal of the leaf, meristematic tissue destruction, vascular necrosis, reduced plant size, and biomass loss (Henson, 1991; Dufrene & Saugier, 1993; Corley & Donough, 1995). Although lepidopteran larvae from different families are the major insect defoliators in oil palm crops (Mariau *et al*., 1991; Martinez *et al*., 2009), some scarabaeid larvae are also problematic pests.

Scarabaeidae (Coleoptera) larvae live in the soil, feeding on decaying organic matter, whereas adults of some species feed on plant tissues and in some cases become an economic pest (Rodriguez-Del-Bosque, 1998; Pardo-Locarno *et al*., 2006). Rutelinae beetles in some countries in the Americas feed on roots of pastures and crops; (Rodrigues *et al*., 2008; Mico *et al*., 2003; Ramirez-Salinas *et al*., 2004). Species such as *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; Kulkarni *et al*., 2007). Studies on the biology of oil palm pests such as (*Oryctes rhinoceros* (L.) and *Strategus aloeus* (L.) have been used as a starting point for the adoption of control methods and strategies (Bedford, 1976; Ahumada *et al*., 1995).

The occurrence of *Leucothyreus femoratus* (Burmeister) (Coleoptera, Scarabaeidae) in oil palm crops marks the first report of this species as pest in Colombia. The objective of this study was to determine the life cycle, biometric details and food consumption rate of *L. femoratus* in oil palm, and to provide external morphological descriptions of its developmental stages.

Materials and methods

Insects

Field specimens of *L. femoratus* adults (n=533; ♂=251, ♀=282) were captured at night by hand in 2-year-old commercial plantations of oil palm in the municipality of San Vicente, Santander, Colombia (N 06°54', W 73°28'), which has an average temperature of 27.32°C, 75-81% relative humidity, 135-220 h/year of sunshine and 1879 mm annual rainfall. The captured adults were transferred into polystyrene boxes (40×40×60 cm) in the Plant Protection laboratory of Yarima Oil Plantation (San Vicente, Santander, Colombia) under conditions of controlled temperature (26±2°C), humidity (75±5%) and light (12:12 h L:D), where it was mass reared. The photophase and scotophase were simulated using fluorescent light and red light (IRO 110V 60W; Toshiba Lightning and Technology Corp., Tokyo, Japan). Only healthy adults without missing legs or malformations were used in bioassays.

Life cycle

Males and females of *L. femoratus* were isolated in glass vials (10×50 cm) containing 5 cm of soil, and were fed *E. guineensis* leaves. Eggs oviposited in the soil were collected every 24 h and were placed in Petri dishes (90×15 mm) lined with damp filter paper. Emerged first-instar larvae were placed individually in plastic boxes (10×15 cm) with a perforated lid and containing a 5-cm layer of sterilized soil, and were fed *Zea mays* (L.) roots every 24 h. *Z. mays* roots were cut from hydroponically grown plants, and placed in the boxes at a rate of 5 g of root/larva. Adults were placed in glass containers (30×30×30 cm) that were covered with nylon mesh and fed *E. guineensis* leaves. Data on the insect's life cycle, range of longevity, and survival (%) were recorded at intervals of 6, 12 and 24 h.

Biometry and description

Developmental stages of the insects were described using the main aspects of its external morphology. Measurements were conducted on 210 individuals, to determine length and width using an electronic caliper, and weight using an analytical balance. Additionally, images of each developmental stage of *L. femoratus* were taken using a digital camera (D40, 18-55 mm, Nikon Corp., Tokyo, Japan).

Consumption rates and damage

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

Data analysis

Life cycle and biometry data of *L. femoratus* were analyzed using a one-way analysis of variance (ANOVA) and honestly significant difference (HSD) test at a significance level of P=0.05 (Tukey, 1949). A paired t-test was used by comparing means of the daily consumption by males and females. All statistical parameters were analyzed with GLMMIX procedure using SAS v.9.0 for Windows (SAS, 2002).

Results

Life cycle

Individuals were obtained representing the different developmental stages of *L. femoratus*: egg (n=359), first instar larva (n=355), second instar larva (n=319), third instar larva (n=294), pupa (n=276) and adult (♂=128, ♀=124). The mean duration of *L. femoratus* life cycle of was 170.4±6.53 (F=39.32, P<0.05), and the individual stages and larval instars were characterized by distinct duration times and an overall survival rate of 96.7% (Table 1).

Biometry and description

There are significant differences in the dimensions and weights of the different developmental stages of *L. femoratus* (F=9.21, P<0.05; Table 2). The egg (Figure 1A) is white and oval (1.5'1.7 mm at oviposition), and expands to three times its initial size before hatching, due to growth and development of the neonate within. Near to hatch, it is possible to observe the cephalic capsule of the neonate through the

Table 1. Duration of the developmental stages of *Leucothyreus femoratus* (Coleoptera: Scarabaeidae) under laboratory conditions (26±2°C, 75±5% relative humidity and 12 h scotophase).

Stage	Duration (days)	*N*	Range	Survival (%)
Egg	8.73±0.11	360	7-10	99.9
1° instar	12.26±0.48	330	11-13	98.7
2° instar	24.21±1.05	300	21-26	96.9
3° instar	67.35±2.28	270	63-72	98.1
Larvae	103.7±3.44	330	63-72	-
Pupae	9.27±0.80	270	8-10	92.1
Adult ♂	46.35[b]±4.81	120	45-57	98.6
Adult ♀	51.04[a]±2.11	120	48-60	95.8
Adults	48.69±2.18	240	45-60	-
Egg-adult	170.4±6.53	360	151-192	96.7

N, individuals tested. [a,b] Values for adult males and females are significantly different (P<0.05, Tukey's test).

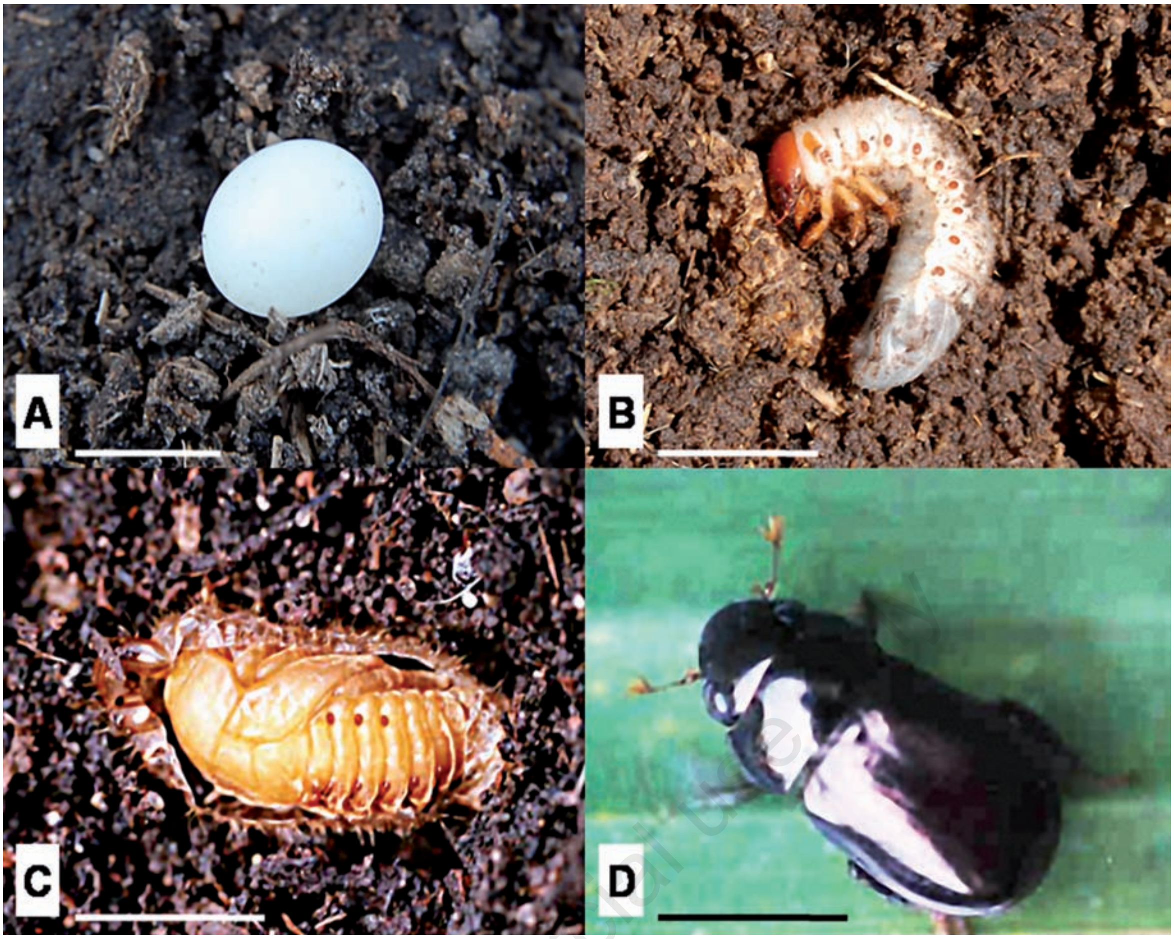

Figure 1. Stages of *Leucothyreus femoratus* (Coleoptera: Scarabaeidae) *habitus*. Egg (A) (bar=1 mm); larva (B); pupa (C); adult (D) (bar=5 mm).

Table 2. Mean (±SD) width, length and weight of the developmental stages of *Leucothyreus femoratus* (Coleoptera: Scarabaeidae) under laboratory conditions (26±2°C, 75±5% relative humidity and 12 h scotophase).

Stages	Width (mm)		Length (mm)		Weight (mg)	
	Mean±SE	Range	Mean±SE	Range	Mean±SE	Range
Egg	1.5±0.03	1.4-1.9	1.7±0.02	1.5-1.9	1.91±0.04	1.3-2.7
Larva						
1° instar	2.3±0.18	1.5-3.1	5.6±0.03	4.3-6.9	2.13±0.23	1.7-3.7
2° instar	3.6±0.12	2.8-4.5	11.9±0.1	1.6-2.9	14.5±3.16	13.4-26.1
3° instar	6.8±0.11	5.4-12.0	20.3±0.1	17.1-24.9	74.4±14.02	56.3-123.8
Pupa						
Male	6.4^{b}±0.13	10.9-13.6	9.4^{b}±0.09	5.0-5.9	74.1^{b}±8.63	67.5-99.2
Female	7.1^{a}±0.08	12.4-14.3	12.1^{a}±0.1	5.6-6.8	100.6^{a}±7.18	73.5-124.4
Adult						
Male	4.5^{b}±0.1	3.9-6.5	8.3^{b}±0.10	7.9-9.12	20.2^{b}±1.28	17.2-31.1
Female	5.7^{a}±0.1	5.5-6.8	10.6^{a}±0.1	9.3-11.2	22.9^{a}±1.45	18.2-35.9

SE, standard error. ^{a,b} Values between males and females of the same stage followed by a different letter are significantly different (P<0.05, Tukey's test).

transparent membrane of the egg. Eggs are laid singly, then covered with substrate material by the female using her hind legs. The scarabeiform larva (Figure 1B) has a white body with short setae, and a brown pigmented head with visible epicranial and frontal sutures. There are five medium setae around the antennae. The ocelli group is visible at the base of the antennae. The clypeus and labrum are trapezoidal; the maxilla has asymmetrical lacinia with two unci, and a stridulatory area possessing ten teeth and short palidia. First instar larvae consume the exuvia as an initial food source after hatching. The hardening and sclerotization of the head requires 4-6 h, during which time the larva remains motionless. Dimensions of the larvae were variable depending on the instar (first instar, 2.3×5.6 mm; second instar, 3.6×11.9 mm, third instar, 6.8×20.3 mm). Larvae were seen situated around the roots of *Z. mays* and showed little mobility; cannibalism occurred during the third instar. The pupa (Figure 1C) is exarate, elongated and oval, and yellow in colour but turning brown at the end of the stage, with a bowed head and mouthparts directed backwards; eyes, antennae, mandibles and palps are clearly distinguishable. The thorax has distinct structures, and the abdomen is mobile with nine segments. Dimensions of the pupa are smaller, compared with the third instar larva (♂=6.4×9.4 mm, ♀=7.1×12.1 mm), ($F=41.27$, $P<0.05$; Table 2). Pupae are found in nesting chambers made during the last larval stage. The nesting chambers, constructed by the third instar larvae, are built with soil substrate mixed with saliva. The adult (Figure 1D) is black with large eyes; the clypeus is circular with a bent apex. The mandibles are exposed and lobed. The epipleura elytra does not possess points; protarsomeres are long, ventrally flattened, and possess setae. Males have yellow legs, a concave abdomen and the last sternite emarginated; females have black legs, a convex abdomen, and the last sternite with margin entire. Adult dimensions are smaller than those of the pupa (♂=4.5×8.6 mm, ♀=5.7×10.6 mm), ($F=8.65$, $P<0.05$; Table 2).

Consumption rate and damage

The average leaf area consumed by females, 12.4 mm^2/d, was significantly higher than by males, 8.2 mm^2/d (paired t-test, $N=200$, $t=-0.0021$, $P=0.998$). Damage caused by *L. femoratus* showed variations in the number, size and shape of leaves damaged. The main lesion feature was a rectangular or square-shaped area of damage extending from the leaf border to the central vein (Figure 2A). Damage was greater at the apex than at the base of the leaf (Figure 2B). More serious injuries occurred on leaves in close contact with other leaves. Also evident were damaged vascular duct channels and dried out areas around the lesions.

Discussion and conclusions

The life cycle of *L. femoratus* presented variations in the length of its developmental stages; in this insect, the longevity of the larvae was longer while the embryonic period was shorter. Duration of the total *L. femoratus* life cycle was 170.4±6.53, including egg, 8.73±0.11; larva, 103.7±3.44; pupa, 9.27±0.80; and adult, 48.69±2.18 ($F=39.32$, $P<0.05$). Populations of *L. femoratus* could be found in all developmental stages under natural conditions. Differences in duration of developmental stages could explain the multivoltinism of this species. Studies on the life cycle and ecology of *Leucothyreus dorsalis* (Blanchard) showed that their populations can be univoltine or multivoltine (Rodriguez-Del-Bosque, 1998; Rodrigues *et al*., 2010). The egg-to-adult survival of *L. femoratus* under laboratory conditions was high, with a value of 96.7%. The life cycles of other insect pests in oil palm, such as *Oryctes rhinoceros* (L.), *Strategus aloeus* (L.), and *Scapanes australis* (Boisduval) (Coleoptera, Scarabaeidae), were successfully determined under laboratory conditions (Bedford, 1976; Ahumada *et al*., 1995). Mortality of *L. femoratus* was higher in the pupal stage. One possible reason might be cannibalism observed during the study, especially in third instar larvae that consume smaller individuals and pupae. Similar antagonistic behavior involving severe attacks on the abdomen and locomotor appendages was observed in *Oryctes agamemnon* (Burmeister) (Soltani *et al*., 2008). It is unknown whether this insect shows similar behavior under natural conditions. The duration of the adult stage was higher in females than in males, with a difference of 3-12 days.

The size and weight of *L. femoratus* were variable among individuals and were proportional to growth of the eggs and larvae. Eggs increased in dimension until the time of hatching. The pupa and adult stages differed in size and weight by sex, the females having higher measure-

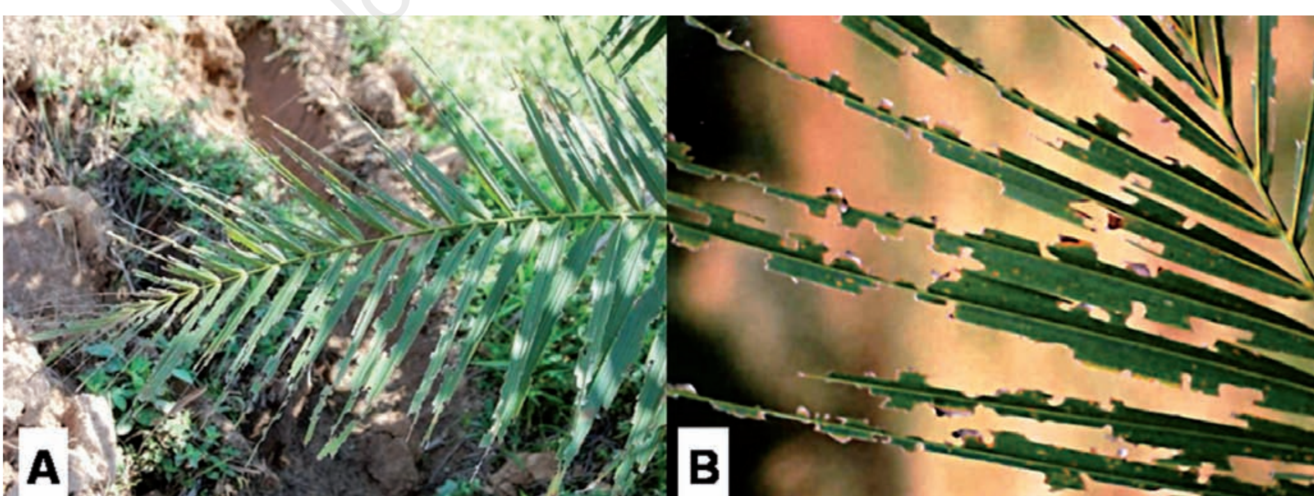

Figure 2. Injury caused by *Leucothyreus femoratus* to *Elaeis guineensis* in Colombia. Characteristic damage (A); initial defoliation in 2-year-old oil palm plantation (B).

ments in both cases. Studies performed on the biometry of *L. dorsalis*, *Anomala inconstans* (Burmeister) and *Anomala denticollis* (Bates) (Coleoptera, Scarabaeidae) noted variations during the growth and development of each insect (Ramirez-Salinas and Castro-Ramírez, 2000; Rodrigues *et al*., 2010). It is possible that differences in the dimensions of *L. femoratus* may be explained by the conditions of reproduction and quality of food used under constant conditions of temperature, humidity and light (26±2°C, 75±5% and 12 h L:D). Different studies showed that beetles under controlled laboratory conditions can vary in their body size among individuals (Ritcher, 1958; Bedford, 1980). Sexual dimorphism of *L. femoratus* was verified by differences in size and in colour of the legs between males and females. The colouring process was observed during sclerotization, corresponding with the developmental changes observed in the insect.

The variation in the daily foliar consumption for males and females of *L. femoratus* may be related to the differences in size between the two sexes (Martinez *et al*., 2009). The square or rectangular 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 gasipaes* (Kunth) (Martinez *et al*., 2009). The feeding preference of *L. femoratus* adults suggests that this insect may be classified as monophagous, as foliar phytochemical characteristics are common among species of Arecaceae (Bjorholm *et al*., 2005; Asmussen *et al*., 2006). In Malaysia, the insects *Apogonia expeditionis* (Ritsema), *Apogonia cribicollis* (Burmeister), *Adoretus borneensis* (Kraatz) and *Adoretus compressus* (Weber) (Coleoptera, Scarabaeidae) have been reported as defoliators in oil palm plantations, and other native plants (Hartley, 2002; Nordin *et al*., 2004). *L. femoratus* causes continuous damage to young plants. It is possible that the phenology of young palms and metabolic activity prior to the reproductive stage contribute to the high level of damage. The progressive loss of functional leaves affects photosynthesis, leading to reduced growth in young leaves, stems and roots (Henson, 1990; Darus & Basri, 2001). Damage to the canopy in young palms may affect economic viability in commercial plantations, with delays in flowering, fruiting and production of 1-2 year (Wood *et al*., 1974; Corley, 1983; Giblin-Davis & Howard, 1989).

The results of this research have contributed details of the life cycle and biometry of *L. femoratus*, and indicate that the food habits of the larva and adult may allow greater adaptability in commercial plantations of *E. guineensis*. The life cycle and size of this insect could be considered as factors in determining its potential damage in oil palm and status as a pest. This work may help to better understand the biology of this insect; altogether, these results contribute to the strategic use of effective tactics to control and manage *L. femoratus* populations.

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