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BIOLOGICAL ASPECTS AND FOOD CONSUMPTION OF OIL PALM FRUIT SCRAPER, *Demotispa neivai* (Coleoptera: Chrysomelidae)

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ABSTRACT

In Colombia, the beetle Demotispa neivai *(Bondar) damages oil palm fruits, resulting in loss of yield and oil production. As little is known of important aspects of its biology, life cycle, biometrics and food consumption, important aspects of the biology of the species was studied. Experiments were conducted under laboratory conditions in the municipality of Barrancabermeja, Santander, Colombia. Life cycle and description of developmental stages of* D. neivai *were determined, taking into account stage-specific survival. The duration of the life cycle of* D. neivai *was determined to be 269.91 ± 5.51 days, with an overall survival rate of 96.7%. Biometrical measurements were taken of the insect's width, length and weight. Adults are red beetles, males and females being differentiated by size. The width, length and weight of insects were proportional to their growth stage.* D. neivai *has a consumption rate that increased with the growth of the insect but was reduced at the adult stage ($Y= 0.001x^{6.2285}$, $R^2= 0.901$). This insect's life cycle and adult longevity, and size are factors that could be considered in determining its feeding habits and pest status in oil palm.*

Keywords: biometry, carpophagous, consumption rate, *Demotispa neivai*, life cycle.

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INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq. Arecales, Arecaceae) favour the growth and development of insects that may impair the productivity of commercial plantations in Colombia. 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, favouring colonisation by phytophagous species endemic to the agroecosystem (Mariau *et al*., 1991; Darus and Basri, 2000; Martínez *et al*., 2009). Oil palm pests 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; Martínez *et al*., 2009). These pests that cause damage to palms tree are notorious in their physiology and are characterised by partial or total removal of tissue, vascular necrosis, reduced plant size and biomass loss (Henson, 1991; Corley and Donough, 1995).

The fruit scraper of oil palm, *Demotispa neivai* Bondar (Coleoptera: Chrysomelidae) is distributed geographically in Brazil, Colombia, Ecuador,

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Panama, Suriname and Venezuela (Genty *et al*., 1978; Martínez *et al*., 2013a). This insect was also reported to feed on other palms like *Bactris gasipaes* (Kunth), *Cocos botryophora* (Mart.), *Cocos nucifera* (L.) and *Desmoncus polyacantha* (Mart.) Kuntze (Staines, 2002). Injuries caused by *D. neivai* on the exocarp are recognised by the grey colour, corky appearance and drying of the fruit due to loss of tissue from the first week of fruit formation (Genty *et al*., 1978; Martínez *et al*., 2009). Damage can bring about 7% losses in palm oil extraction (Genty *et al*., 1978; Martínez *et al*., 2009).

Chrysomelidae species constitute a large group of herbivorous insects with approximately 37 000 described species and many are pests of economic importance (Booth *et al*., 1990). Species of the Cassidinae subfamily can gnaw or scrape plant tissues in leaves and fruits of Arecaceae (Marinoni *et al*., 2001). In Colombia, the insects *Delocrania cossyphoides* Guérin, *Cephaloleia vagelineata* Pic, *Alurnus humeralis* Rosemberg and *Spathiella tristis* Boheman (Coleoptera: Chrysomelidae) have been reported as phytophagous in oil palm plantations (Genty *et al*., 1978). The measurement of food the consumption rate can determine the extent of damage and estimate losses caused by such insect herbivores (Jolivet *et al*., 1988; Booth *et al*., 1990). Knowledge of the biology of insect pests in oil palm also allows an indication of weak points to exploit for their control (Mariau *et al*., 1991; Martínez *et al*., 2013b). This study aims to meet these objectives by determining life cycle, biometric parameters and food consumption rate of *D. neivai* in oil palm. External morphological descriptions of developmental stages of the species were also provided.

MATERIAL AND METHODS

Insects

Field specimens of *D. neivai* adults (n=1823; ♂=895, ♀=928) were done manually in oil palm fruits of 10-year-old commercial plantations of oil palm in the municipality of Puerto Wilches, Santander, Colombia (N 07°20′, W 73°53′), which has an average temperature of 27.32°C, 75%-81% relative humidity, 135-220 hr yr^{-1} of sunshine and 1879 mm annual rainfall. The captured adults were transferred into polystyrene boxes (40 x 40 x 60 cm) in the Entomology Laboratory of Universidad de La Paz (Barrancabermeja, Santander, Colombia) under conditions of controlled temperature (27 ± 2°C), humidity (75 ± 5%) and light (12:12 h L:D), for mass rearing. 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 the studies.

Life Cycle

A pair of male and female adults (*D. neivai*) was isolated in glass vials (5 cm x 25 cm) with tulle fabric cover and were fed with *E. guineensis* fruits. Eggs oviposited in fruits were collected every 24 hr and were placed in Petri dishes (90 mm x 15 mm) lined with damp filter paper. Emerged first-instar larvae were placed individually in plastic boxes (10 cm x 15 cm) with a perforated lid and were fed with oil palm fruits. Pupae and adults were placed in glass containers (30 x 30 x 30 cm) that were covered with nylon mesh and adults were fed with fruits. Data on the insect's life cycle, range of longevity, and survival (%) were recorded at intervals of 6, 12 and 24 hr per 10 months.

Biometry and Description

The developmental stages of the insects were described from their external morphology. Measurements were conducted on 400 individuals. To determine the length and width, an electronic caliper was used and an analytical balance for weight. Additionally, images of each developmental stage were taken using a digital camera (D40, 18-55 mm, Nikon Corp., Tokyo, Japan).

Food Consumption Rate

Larvae and adults of *D. neivai* were isolated and separated into plastic boxes (10 x 15 cm) with a tulle fabric cover. The rate of food consumption was measured through offering insects *E. guineensis* fruitlets, with pedicels coated with paraffin to prevent weight loss through drying. Images of the areas eaten were taken every 24 hr with a digital camera (D40, 18-55 mm, Nikon Corporation, Japan) fixed at 15 cm macro focus with natural and flash light (SB-700 Nikon Corporation, Japan). The collection of images was archived in JPEG format with colour resolution of 300 dpi. These images were analysed using digital analysis software UTHSCSA Image Tool v. 2.0 (University of Texas, USA). Area consumed by *D. neivai* was measured in mm^2 with pixels based on RGB histogram (Red 700 nm, Green 546.1 nm, and Blue 435.8 nm).

Data Analysis

Life cycle and biometry data of *D. neivai* were analysed using a one-way analysis of variance (ANOVA) and honestly significant difference (HSD) test at a significance level of P=0.05 (Tukey, 1949). Daily consumption rate was estimated by linear regression. All statistical parameters were analysed with GLMMIX procedure using SAS v.9.0 for Windows (SAS, 2002).

RESULTS

Life Cycle

Individuals were obtained representing the different developmental stages of *D. neivai*: egg (n = 391), first instar larva (n = 359), second instar larva (n = 354), third instar larva (n = 339), fourth instar larva (n = 328), fifth instar larva (n = 324), pupa (n = 313) and adult (♂ = 153, ♀ = 157). The individual stages and larval instars were characterised by distinct duration times. Duration of the total *D. neivai* life cycle was 269.9 ± 5.51 days, including egg, 7.93 ± 0.21; larva, 23.47 ± 1.08; pupa, 5.72 ± 0.16; and adult, 232.79 ± 5.03 days (*Table 1*). The longevity of males and females were 224.1 ± 6.4 and 241.4 ± 8.6 days respectively ($F = 29.16$, $P < 0.05$). Survivorship from the egg to pupa emergence was 96.7%.

Biometry and General Description

D. neivai has different dimensions and weight in their various stages of development (*Table 2*). The freshly laid egg is flattened, oval (0.8 x 0.8 mm) and transparent. Before hatching, the egg becomes semi-circular and increases up to three times in volume. During this period, it is possible to observe the cephalic capsule of neonates through the transparent membrane of the egg (*Figure 1*).

Larva of *D. neivai* has a dorso-ventrally flattened body without scoli but with anal furca in the eighth abdominal segment. Its integument is laterally extended, red-brown in colour, with few setae. The head is slightly flattened with parietal depression and three pairs of ocelli. The pronotal plate is broad with mesonotum and metanotum similar in form (*Figure 2*). The clypeus has a smooth surface with labrum twice longer than wide. The mandibles have a condyle on the base and four teeth at the apex and maxillae with elongated thistle and two bristles on the outer margin. The labium has a membrane in

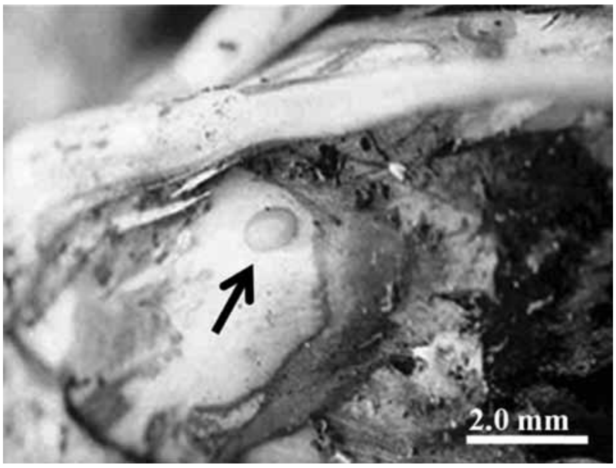

Figure 1. Egg stage of Demotispa neivai.

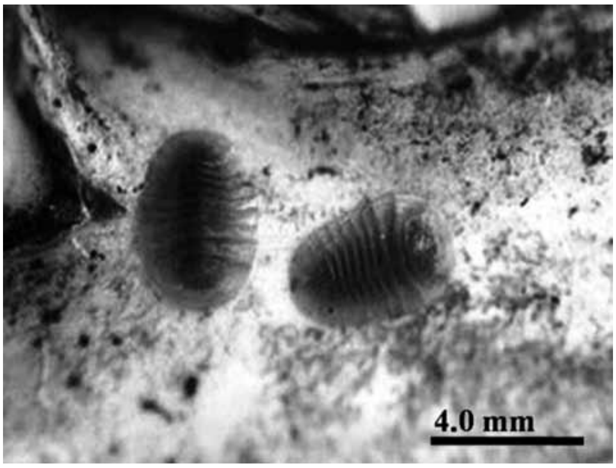

Figure 2. Larva stage of Demotispa neivai.

TABLE 1. DURATION OF THE DEVELOPMENTAL STAGES OF *Demotispa neivai* (Coleoptera: Chrysomelidae) UNDER LABORATORY CONDITIONS (27 ± 2°C, 75 ± 5% relative humidity and 12 hr scotophase)

Stage	Duration (days)	Individuals	Range	Survival (%)
Egg	7.93 ± 0.21	400	7-10	97.9
1st instar	3.26 ± 0.48	380	3-4	92.1
2nd instar	4.21 ± 1.03	340	4-6	98.6
3rd instar	5.15 ± 1.24	320	5-7	95.8
4th instar	5.92 ± 1.12	300	5-7	97.2
5th instar	4.93 ± 0.21	280	4-5	96.7
Larvae	23.47 ± 1.08	380	18-25	-
Pupae	5.72 ± 0.16	260	5-7	91.1
Adult ♂	224.15b ± 6.41	110	184-257	94.6
Adult ♀	241.43a ± 8.61	110	234-276	95.4
Egg-adult	269.91± 5.51	400	151-192	96.7

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

TABLE 2. MEAN (± SD) WIDTH, LENGTH AND WEIGHT OF THE DEVELOPMENTAL STAGES OF *Demotispa neivai* (Coleoptera: Chrysomelidae) UNDER LABORATORY CONDITIONS (27 ± 2°C, 75 ± 5% relative humidity and 12 hr scotophase)

Stages	Width (mm)		Length (mm)		Weight (mg)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Egg	0.86 ± 0.76	0.81 -1.10	0.96 ± 0.24	0.85 - 1.08	1.09 ± 0.28	0.74 - 1.54
Larva	-	-	-	-	-	-
1st instar	1.33 ± 0.39	0.87 - 1.79	2.17 ± 0.37	1.43 - 2.91	1.21 ± 0.86	0.97 - 2.12
2nd instar	2.08 ± 0.23	1.24 - 2.20	3.95 ± 0.37	2.67 - 4.77	2.75 ± 0.74	2.32 - 3.53
3rd instar	2.54 ± 0.50	1.62 - 2.60	4.73 ± 0.70	3.91 - 5.64	4.29 ± 0.62	3.67 - 7.93
4th instar	3.00 ± 0.78	2.37 - 4.77	5.11 ± 0.48	4.29 - 6.87	12.43 ± 0.24	9.94 - 21.88
5th instar	3.93 ± 0.33	3.12 - 5.94	6.49 ± 0.25	5.68 - 7.10	21.56 ± 0.85	16.21 - 35.83
Pupa	3.10 ± 0.68	2.97 - 4.27	5.85 ± 0.26	4.17 - 6.85	27.55 ± 0.90	21.05 - 36.18
Adult male	2.71b ± 0.17	2.26 - 3.76	5.41 a ± 0.11	4.47 - 5.16	12.25b ± 0.48	9.84 - 12.79
Adult female	3.21a ± 0.12	3.18 - 3.93	5.35 b ± 0.14	5.27 - 6.34	12.46a ± 0.34	10.41 - 13.54

Note: SD - Standard deviation, [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).

submental and mental area on each side and three bristles arranged in a triangle close to the palpi. The palps are unarticulated and subconical; apex with sensory processes. After hatching, first instar larvae consume exuvia as first food. The tightening and sclerotisation of the body occurred between 6 to 12 hr, the larvae remaining motionless. The size of the larvae was variable in each instar: first instar 1.3 x 1.4 mm; second 2 x 3.9 mm, third 2.5 x 4.7 mm; fourth 3 x 5.1 mm and fifth 3.9 x 6.4 mm. The weight of larvae increased with the instars. The larvae moved very little, often hiding in the bracts of the fruits.

The pupa is exarate, elongated oval, red and brown in colour. The bowed head and mouthparts are directed backwards, with indistinguishable eyes, antennae, mandibles and palpi. The thoracic structures are differentiated, with short legs and being only observed ventrally. The abdomen has nine movable segments (*Figure 3*). Its dimensions are smaller (3.1 x 5.8 mm) compared to the fifth larval instar.

The adults are red, oval, dorsally flattened and laterally convex with a small head. The maxillary palps have segments of nearly equal in length. The bases of the antennas are separated by a keel in the front. The eyes are slightly protruding, pronotum with curved lateral margins, pentagonal scutellum and oval elytra covering almost the entire abdomen. The abdomen has four visible sternites (*Figure 4*). The adults are generally smaller than the pupa (♂= 2.7 x 5.4 mm, ♀= 3.2 x 5.3 mm). In adult stage, the females having higher measurements with 3.21 mm x 5.35 mm and 12.46 mg, while males were 2.71 mm x 5.41 mm and 9.84 mg (F = 7.58, P < 0.05).

Figure 3. Pupa stage of Demotispa neivai.

Figure 4. Adult stage of Demotispa neivai.

Food Consumption Rate

Average daily food consumption by *D. neivai* in the development stages were: first instar 1.21 mm^2, second instar 2.71 mm^2, third instar 4.29 mm^2, fourth instar 12.43 mm^2, fifth instar 21.56 mm^2 and adult 12.35 mm^2 (R^2= 0.901; *Figure 5*). Consumption increased with the growth of the insect but was reduced at the adult stage ($Y = 0.001x^{6.2285}$). Injury caused by *D. neivai* showed variations in size, number and shape of the exocarp in young fruits or those prior to maturity (*Figure 6*).

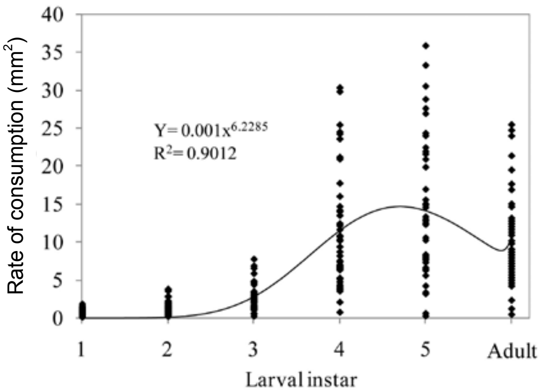

Figure 5. Daily consumption rate of larvae and adults Demotispa neivai *on oil palm exocap (X^2, $P < 0.0001$).*

Figure 6. Injuries caused by Demotispa neivai *to* Elaeis guineensis *fruits.*

DISCUSSION

The life cycle of *D. neivai* 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 *D. neivai* life cycle was 269.9 ± 5.51 days, including egg, 7.93 ± 0.21; larva, 23.47 ± 1.08; pupa, 5.72 ± 0.16; and adult, 232.79 ± 5.03 days. Embryonic stage of *D. neivai* shows similarity to other species Cassidinae (Rossini *et al*., 2002). The average duration of larval increased with the progress of instars 1, 2, 3 and 4, while 5 instar was lower. The duration of pupal stage was shorter than the egg and larva stage, the adult insects lives for a long duration. Populations of *D. neivai* 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 *Calyptocephala gerstaeckeri* Boheman and *Metriona elatior* Klug (Coleoptera Chrysomelidae) showed that their populations can be univoltine or multivoltine (Rossini *et al*., 2002; Córdova-Ballona and Sánchez-Soto, 2008). The egg-to-adult survival of *D. neivai* under laboratory conditions was high, with a value of 96.7%. The life cycle of other insect pests in oil palm, such as *Alurnus humeralis* Rosemberg and *Coelaenomenodera elaidis* Mlk. (Coleoptera: Chrysomelidae) were successfully determined under laboratory conditions (Philippe, 1977; Genty *et al*., 1978). Mortality of *D. neivai* was higher in the transition from larva-pupa stage. The duration of the adult stage was higher in females than in males, with a difference of 17 days.

The size and weight of *D. neivai* were variable among individuals and were proportional to the growth of the eggs, larvae and pupae. Eggs increased in dimension until the time of hatching. The adult stage differed in size and weight by sex; the females having higher measurements with 3.21 mm x 5.35 mm and 12.46 mg, while males were 2.71 mm x 5.41 mm and 9.84 mg ($F = 7.58$, $P < 0.05$). Sexual dimorphism of *D. neivai* adults was verified by differences of morphological structures between males and females (Martínez *et al*., 2013a). Studies performed on the biometry of *Calyptocephala gerstaeckeri* Boheman and *Metriona elatior* Klug (Coleoptera: Chrysomelidae) noted variations during the growth and development of each insect (Rossini *et al*., 2002; Córdova-Ballona and Sánchez-Soto, 2008). It is possible that differences in the dimensions of *D. neivai* may be explained by the conditions of reproduction and quality of food used under constant conditions of temperature, humidity and light (26 ± 2ºC, 75 ± 5% and 12 hr light:dark). Different studies showed that beetles under controlled laboratory conditions can vary in their body size among individuals (Jolivet *et al*., 1988; Booth *et al*., 1990). The eggs of this insect are contained in a thin membrane that covers the top and are fixed on the exocarp. Some species of Chrysomelidae have this type of membrane to provide protection against natural enemies (Buzzi, 1996; Williams, 2002). Morphological characteristics of the larva and pupa of *D. neivai* generally coincide with species Cassidinae (Jolivet *et al*., 1988; Lawrence, 1991).

The variation in the daily fruit consumption for larvae and adults of *D. neivai* may be related to the differences in size between the two sexes (Martínez *et al*., 2013a,b). *D. neivai* has a consumption rate that increases with the growth of the insect but reduces at the adult stage ($Y= 0.001x^{6.2285}$, $R^2= 0.901$). The feeding preference of *D. neivai* suggests that this insect may be classified as monophagous, as phytochemical characteristics of fruits are common among species of Arecaceae in America (Bjorholm *et al*., 2005; Asmussen *et al*., 2006; Martínez *et al*., 2013b). Carpophagous insects are considered pests important agricultural crops in different ecological regions (Unsicker and Mody, 2005; Vallat and Dorn, 2005). Larvae and adults of this insect under natural conditions have been observed to be feeding on flowers and closed leaves of *E. guineensis* during periods with low rainfall. Species such as *Calyptocephala gerstaeckeri* and *Demotispa pallida* (Coleoptera: Chrysomelidae) have been reported as carpophagous and filophagous and are also associated with the Arecaceae species (Córdova-Ballona and Sánchez-Soto, 2008; Flowers and Shaboo, 2009). *D. neivai* causes continuous damage to immature fruits. It is possible that the phenology of immature fruits and metabolic activity prior to the reproductive stage contribute to the high level of damage. Damage to the oil palm fruits may affect economic viability in commercial plantations, with delays in the production of palm oil of between 6-12 months (Hartley, 1977; Howard *et al*., 2001).

CONCLUSION

The results of this research have contributed details of the life cycle and biometry of *D. neivai*, 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 fruits and status as a pest. This work may help in a better understanding of the biology of this insect as the results would contribute valuable knowledge for the control and management of the *D. neivai* populations.

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