Biology and reproductive traits of *Drymoea veliterna* (Druce, 1885) (Lepidoptera: Geometridae)

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Abstract: Despite the urban and landscape impact caused by *Drymoea veliterna* (Druce, 1885) (Lepidoptera: Geometridae) larvae on trees of the genus *Croton* L. (Euphorbiaceae) in the Neotropics, there is no information about its biology and reproductive traits. In this study, we describe the life cycle and reproductive traits of this species. Its life cycle lasts approximately 56 days, the larvae develop during 24 days on average and the longevity of the females is 7 days on average. Females have an average fecundity of 207 eggs. Regarding their reproductive system, the presence of previtellogenic eggs in the reproductive tract of the females is emphasized. The bursa copulatrix and a highly sclerotized signum is depicted. The number of spermatophores found in the reproductive tract of the females was quantified. Male and female genitalia were schematized.

Key words: Immature stages, life history, fitness components, genital dimorphism, *Croton*.

Introduction

The family Geometridae is distributed worldwide and one of the three most species-rich families of the order Lepidoptera, with approximately 21000 known species (Scoble 1995, 1999). A distinctive autapomorphy is the presence of the ansa, a unique structure to Geometridae, located in the tympanal organ, near to the base of the abdomen (Cook & Scoble 1992; Scoble 1999). Furthermore, maybe the best-known character is the peculiar movement exhibited by the larvae, also called inchworms, as they seem to measure the ground by curving their bodies into loops (Scoble 1999). This behaviour is complemented by lack or
reduction of three pairs of prolegs, A3 to A5 (Sugiura & Yamazaki 2006; Sihvonen et al. 2011).

The forty-five percent of the species of this family belong to the largest subfamily Ennominae, which comprises several species that can cause extensive damage to forest and ornamental plants (Scoble 1992, 1999). One third of the moths of this subfamily occurs in the Neotropics (Pitkin 2002) and at least six defoliator species were recently reported from Colombia: Cargolia arana (Dognin, 1895); Chrysomima semilutearia (Felder & Rogenhofer, 1875); Drymoea veliterna (Druce, 1885); Glena bisulca Rindge, 1967; Melanolophia commotoria (Maassen, 1890) and Oxydia trychiata Guenée, 1858 (Vélez Ángel 1974; Bustillo 1976; Scoble 1992; Rodas & Madrigal 1996; Hernández Duran et al. 2014).

Drymoea veliterna is a pest of Croton L. (Euphorbiaceae), one of the most diverse genera of plants in the tropics, with more than 1200 species known worldwide (Govaerts et al. 2000). Ornamental native species such as C. bogotanus Cuatrec. and C. funckianus Müll. Arg. are widely used to restore wildlife corridors and protect watersheds, and are also involved in the restoration of secondary forests, which are considered an important carbon sink (Mahecha Vega et al. 2004; Rojas Rodriguez et al. 2006; Infante-Betancour et al. 2008). These two Croton species are especially affected by larvae of D. veliterna in Colombia.

Based on literature records and label data, the species is known to occur in Colombia and Ecuador. Druce (1885) described Nelo veliterna based on specimens collected by Clarence Buckley and William Chapman Hewitson. Specimens’ labels accounted for the following collecting locations: Chiguinda, Morona Santiago province, Ecuador; Intag, Imbabura prov., Ec.; Sarayaku, Pastava prov., Ec.; Fusagasugá, Cundinamarca department, Colombia; Pacho, Cundinamarca dept., Col. and Tolima dept., Col. The male syntypes from Ecuador, deposited in the Natural History Museum, London, U.K., have been revised by Scoble (1999), who established a new combination, Melanoptilon veliterna. Pitkin (2002) synonymized the former genera Melanoptilon Herrich-Schäffer, 1855; Nelo Walker, 1854; Nelopsis Warren, 1895 and Sangala Walker, 1854 with Drymoea Walker, 1854, and so transferring this species to the latter genus.

Little is known about the biology and reproductive aspects of *D. veliterna*. Recently, Hernández Duran et al. (2014) indicated that the females of this species present polyandry, a mating system in which they mate with more than one male per breeding season. Taking into account that this species is considered a forest pest, a polyandrous mating system can have significant effects on population ecological factors. In addition to the previously established ecological and behavioural variables that determine the fitness of *D. veliterna* (Hernandez Duran et al. 2014), this research provides valuable information about the biology and population control of this species.

In this study, the life cycle of *D. veliterna* and the internal and external genitalia of males and females are illustrated, along with some population attributes related to reproduction aspects such as: male and female longevity, fecundity and female fertility.

**Material and methods**

**Rearing**

Pupae and adults (30 males and 30 females) of *D. veliterna* were collected on heavily infested *Croton* spp. trees in Bogotá, Colombia. The breeding was performed in the entomology laboratory at the Centro de Bio-Sistemas of the Jorge Tadeo Lozano University, Chia, Colombia. The larvae were reared at average room temperature of 23.5 ± 2.0°C and
relative humidity of 60%. Leaves of Croton species were provided both as food for the larvae and oviposition substrates for the caged imagines, which were fed with pollen and a 10% honey mixture.

A sample of 40 larvae was selected from the present rearing to determinate the duration of the larval instars. The larvae were transferred to net sleeves, approximately 30 cm long and 15 cm wide, each containing four larvae and a branch of the food plant. The different stages were distinguished by counting the number of exuviae and cephalic capsules collected in the rearing sleeves. Daily observations were made in order to record the cephalic capsule width and larval length.

**Longevity**

The longevity of the adults was assessed by recording the survival time of each individual imago. The collected data allowed to obtain a total mean longevity, calculated as the timespan from egg hatching to imago’s death.

**Fecundity and fertility**

Fecundity, defined as the average number of eggs laid by a female in its reproductive life span, was determined by counts of the eggs laid on Croton spp. by the female imagines. Fertility was determined by counting the number of hatched eggs. In either case, 30 females served as a sample for this study.

**Preparation of genitalia**

Dissections of newly emerged females were performed to describe their reproductive system, following the method proposed by Chapman (2013). Male genitalia was prepared, adhering to the technique described by Leston (1953), by clearing the abdomen with KOH (10%), then dehydrated in glacial acetic acid and dissected. The genitalia were then stored in microvials of alcohol. Dissections and slide preparations were achieved using a Nikon AW100 camera and a KOZO Stereo Microscope.

**Results**

**Descriptions**

**Eggs** (Figs 1A–B). Average 0.8 mm long and 0.6 mm wide, ovoid-shaped. Size corresponds to that of individual females, and is found within the range observed by Peterson (1962) for other species of Geometridae. Deposited in single-layered clusters of 50 to 70 eggs. Freshly deposited eggs are greenish and turn brown a few days after oviposition. The unfertilized eggs can be easily recognized as they remain greenish with a reddish brown patch and soon begin flattening. It was possible to see through the eggshell during the last 48 hours before the hatching of the larvae. Eggs hatched in 8 to 12 days (Table 1).

**First instar** (Fig. 1C). Head: black. Body: bright green with white setae. The freshly hatched larvae start feeding on their own egg shell. Length: average 7.3 mm. Duration: average 8 days (Table 1).

**Second instar** (Fig. 1D). Head: black. Body: green with a dorsal black line, edged with white spots; white spiracular line, paralleled by a brown lateral line dorsally and a bright yellow line beneath. Length: average: 10.5 mm. Duration: average 3 days (Table 1).
### Table 1. *Drymoea veliterna*: duration of life stages, cephalic capsules width and length of larvae at different instars. \( N \) = number of observations, \( SD \) = standard deviation.

<table>
<thead>
<tr>
<th>Stage</th>
<th>( N )</th>
<th>Duration Mean (days) ± SD</th>
<th>Cephalic capsule width Mean (mm) ± SD</th>
<th>Larva length Mean (mm) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>40</td>
<td>10 ± 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>29</td>
<td>8 ± 1.3</td>
<td>0.50 ± 0.01</td>
<td>7.3 ± 0.92</td>
</tr>
<tr>
<td>L2</td>
<td>23</td>
<td>3 ± 1.0</td>
<td>0.80 ± 0.03</td>
<td>10.5 ± 0.83</td>
</tr>
<tr>
<td>L3</td>
<td>21</td>
<td>1.9 ± 0.55</td>
<td>1.00 ± 0.09</td>
<td>15 ± 1.2</td>
</tr>
<tr>
<td>L4</td>
<td>20</td>
<td>5 ± 2.1</td>
<td>1.20 ± 0.04</td>
<td>20 ± 2.6</td>
</tr>
<tr>
<td>L5</td>
<td>20</td>
<td>4 ± 1.8</td>
<td>1.50 ± 0.06</td>
<td>26 ± 2.9</td>
</tr>
<tr>
<td>Prepupa</td>
<td>20</td>
<td>2.2 ± 0.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupa</td>
<td>19</td>
<td>17 ± 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imago</td>
<td>19</td>
<td>5 ± 1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total mean longevity:</td>
<td>56.1</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Third instar** (Fig. 1D). Head: black with several dark spots. Body: green, similar to the previous instar and with a broader yellow lateral line. Length: average 15 mm. Duration: average 1.9 days (Table 1).

**Fourth instar** (Fig. 1D). Head: black with several dark spots, with a bluish spot in the centre. Body: brown with a dorsal black line, black spiracles, white subspiracular line and a subtle dark brown lateral superspiracular line. Length: average 20 mm. Duration: average 5 days (Table 1).

**Fifth instar** (Fig. 1D). Head: turquoise, with scattered black spots and distinct white spots on the fronto-clypeus. Body: green without dorsal lines, black spiracles surrounded by yellow spots and a white subspiracular line with a black lateral line above and a brown line beneath. Length: average 26 mm. Duration: average 4 days (Table 1). Prepupae (Fig. 1F) last average 2 days before pupating.

**Pupae** (Fig. 1G). The obtecta pupa (Johnson & Triplehorn, 2005) is green when recently formed and turns brown as soon as the sclerotization of the cuticle is complete. This process occurs within a few days. Clusters of wild pupae can be found on the tree trunks. The average pupa is 1.1 cm long and the cremaster is strongly sclerotized and bifurcated posterad. Duration: average 17 days (Table 1).

**Adult sexual dimorphism** (Figs 1H–I). Both sexes show the same wing pattern, with an orange triangular spot on the forewings. The male can be distinguished by the bipectinate antennae, while the female’s antennae are filiform (Forbes, 1925). Females have a larger abdomen than males, but both sexes have the same wingspans measuring 1.2 cm on average. The abdomen is bigger in females, accommodating the eggs.

**Behaviour**

Gregarious at all instars, the larvae have typical appearance and movement of inchworms (Fig. 1E). Both larvae and adults are active during the day. We have not observed the adults in the wild know which flowers they take nectar from.
Longevity

The females live longer than males. The average life of a female can last as much as 7 days while the males one last 5 days. The pairing last three hours on average and then the females start the oviposition process within a few hours on the underside of leaves of *Croton* spp. The
sex proportion for the laboratory-reared population of *D. veliterna* was of 2 females for every male (2:1). The total mean longevity was of 56.1 days from egg hatching to imago’s death.

**Fecundity**

The estimated number of eggs laid per female of *D. veliterna*, in laboratory conditions, was between 200 and 320 eggs on average. Wild females can lay between 180 and 250 eggs on average, over the course of several oviposition events. In the present study, the average number of eggs laid, calculated from a population of 30 females, was 207 eggs and the number of eggs laid per oviposition event was between 15 and 120 eggs.

**Fertility**

On average, 40.4% of the larvae hatched from the oviposition of 15 females from the experimental group, with an average of 95.5 eggs laid.

**Female genitalia**

The female external and internal genitalia were examined (Figs 2D–E). The number of ovarioles per ovary is approximately 150-200 and occupy most of the abdominal cavity. The oocites are previtellogenic. The bursa copulatrix was examined and the spermatophores transferred by the male were observed. Up to five spermatophores per bursa could be observed. Located on the inner wall of the bursa, the signum (Fig. 2F) with five sclerotized tips, is an important structure that helps break the spermatophores. According to Cordero (1995) signa act during and after the copula, and can affect the male sperm selection.

**Male genitalia**

The male external and internal genitalia were examined (Figs 2A–C). The structure of the claspers (or valvae) are characteristic of Ennominae moths. The aedeagus doesn’t show any structure for the sperm removal from the female reproductive system: cornuti are absent so the spermatophore is broken only by the signum and perhaps contractions of the abdomen. The spermatophores transferred to the bursa copulatrix were depicted (Fig. 2G).

**Discussion**

Infested trees yielded up to about five *D. veliterna* larvae. Larvae were usually observed on the underside of *C. bogotanus* leaves. Similar to other larvae of geometrids pest species, such as *Perixera illepidaria* (Guenée 1858) (Kumar et al. 2014), *D. veliterna* larvae are voracious as they feed, leaving behind only the midribs and veins of the leaves. The duration of larval development on such trees is 24 days on average (Table 1).

The colour variation between larvae of different instars (Fig. 1D) is common among geometrids. The behaviour is peculiar, as both larvae and adults are active during the day, compared to most other geometrid species that are mostly active at night (Scoble 1992).

Although *D. veliterna* larvae can defoliate an entire tree, they do not cause the *Croton* spp. trees to die. In contrast, *Pinus patula* Schiede ex Schltdl. & Cham., which is attacked by *C. semilutearia* larvae, eventually dies after the foliage dries (Rodas & Madriñan 1996).

Regarding the adults, the estimated population sex ratio is three females per two males (Hernandez et al. 2014). Furthermore, this population is characterized by a polyandrous mating pattern: females mate with more than one male during their lifespan. Female longevity can be affected by the number of matings, and increases when a female mates multiple times. Mating frequency depends on ecological and behavioural variables such as male availability (Wedell et al. 2002; Valimaki & Kaitala 2006).
Figure 2. Male and female genitalia of *D. veliterna*. **A**, lateral (above) and dorsal (below) views of male genitalia; **B**, schematic lateral view of male genitalia showing aedeagus (ae.), saccus (sac.), uncus (un.), valva (val.), vinculum (vin.); **C**, aedeagus drawing of the same specimen; **D**, female genitalia; **E**, schematic representation of female genitalia showing ovaries (ov.), ovarioles (ovl.), corpus bursae (c.b.), and ductus bursae (d.b.); **F**, signum (sig.); **G**, lateral view of female genitalia showing ovipositor (ovp.), papillae anales (p.a.), ostium (os.) and tail of spermatophore (t. of sp.) protruding from d.b.
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