Neotropical Entomology
https://doi.org/10.1007/s13744-024-01197-8

SCIENTIFIC NOTES

Sex dimorphism in pupae and adults of the specialist *Ipomoea batatas* defoliator *Bedellia somnulentella* (Lepidoptera: Bedelliidae)

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Received: 8 April 2024 / Accepted: 30 July 2024

Abstract
Bedellia somnulentella Zeller, 1847 (Lepidoptera: Bedelliidae), a global pest of the sweet potato *Ipomoea batatas*, was recorded in Brazil, but morphological information on the sexual dimorphism of this insect is scarce. The objective was to evaluate morphological characters of sexual dimorphism of *B. somnulentella* pupae and adults. External structures with sexual dimorphism were not detected in the last abdominal segments of *B. somnulentella* pupae. The females of this insect are heavier, which could be a distinctive sex characteristic. A pair of frenulum on the hind wings of females and only one on those of males, in addition to elongated cerci and bipartite genitalia in the latter and smaller cerci involving the last abdominal segment and an ovipositor in females, differentiate sexes of *B. somnulentella*.

Keywords Leaf miner · Morphology · Sweet potato

Introduction

Two genital openings, one for mating and one for oviposition, are reported for Ditrysia (Lepidoptera) females, which includes 98% of the world butterfly and moth species (Kristensen & Skalski 1999; Capinera 2008). Yponomeutoidea, with approximately 230 genera and 1800 described species, includes microlepidoptera, such as those in the Bedelliidae family, with one genus and 16 species (Van Nieukerken 2011).

The introduced microlepidopteran *Bedellia somnulentella* Zeller, 1847 (Lepidoptera: Bedelliidae) was recorded in Brazil defoliating the sweet potato plant *Ipomoea batatas* (Convolvulaceae) (Santos et al. 2018). The life cycle of *B. somnulentella* is approximately 30 days, with five and seven for the pupal and adult stages, respectively, without apparent sexual dimorphism (Santos et al. 2021).

Sexual dimorphism in Lepidoptera is based on life history, behavioral, and morphological traits (Allen et al. 2011), including color pattern, body shape and size, antennae, wings, and adult abdomen morphology. Sex determination in immature stages of moths (e.g., pupae) is necessary for studies such as behavioral tests with pheromones and ecotoxicological ones using virgin insects (Posada et al. 2011).

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Published online: 22 August 2024

The objective was to identify morphological characters of sexual dimorphism in *B. somnulentella* pupae and adults.

Material and methods

Bedellia somnulentella was reared in the Cellular Biology laboratory of the "Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM)" in Diamantina, Minas Gerais state, Brazil, in wooden cages (33 × 33 × 33 cm), with screened sides and a glass lid at room temperature. Images of *B. somnulentella* adults were obtained with a CANON EOS Rebel 850D camera.

Bedellia somnulentella pupae were collected from mass rearing. The body length of two groups of 15 individuals was measured using the Image J2 software (Rueden et al. 2017) and obtained 3,0 and 3,5 mm long for those in both groups. These pupae were individualized in Petri dishes (60 × 15 mm), and the sex of the resulting adults was confirmed and used in other analyses.

A pair of female and male hindwings were removed and bleached in 10% potassium hydroxide overnight for 12 h in the cold. The frenulum of these wings was removed and photographed using a Leica DM 500 microscope with an attached digital camera. Pupae and abdomens of *B. somnulentella* adults were dehydrated in an increasing series of ethanol (70%, 80%, 90%, 95%, 99%) at 2-min intervals per concentration and mounted on aluminium supports with tape adhered to the surface, kept in a desiccator with silica for 6 h and analyzed using a Hitachi model TM 3000 microscope (Hitachi High-Technologies Corporation, Tokyo, Japan) of the UFVJM Integrated Research Laboratory.

The weight (mg) of *B. somnulentella* pupae was obtained on a precision scale (Shimadzu Corporation, Kyoto, Japan), and these data were subjected to the Student *t*-test at 5% significance using the R Software (R Core Team 2021).

Results

External structures, such as fissures or pores, were not detected on the abdominal segments (Fig. 1C) or the seventh to ninth tergites of males (Fig. 1B) and females (Fig. 1D) pupae of *B. somnulentella* as sex dimorphism.

Female pupae (0.99 ± 15 mg) of *B. somnulentella* were heavier than male ones (0.68 ± 0.15 mg), which may indicate sex dimorphism.

The yellow pattern of the head, thorax, and abdomen and filiform-type appendages and antennae (Fig. 2A) is similar for females and males of *B. somnulentella*.

One frenulum was observed on the hindwings of males (Fig. 2B) and two on those of females *B. somnulentella* (Fig. 2C).

Short cerci surround the last sternite (Fig. 3B) of the abdomen of *B. somnulentella* females, which is modified into an ovipositor (Fig. 3A). A bipartite valve (Fig. 3C) and long cerci were observed in the last segment of the abdomen of males (Fig. 3D), making it possible to differentiate the sexes of *B. somnulentella* in ventral view.

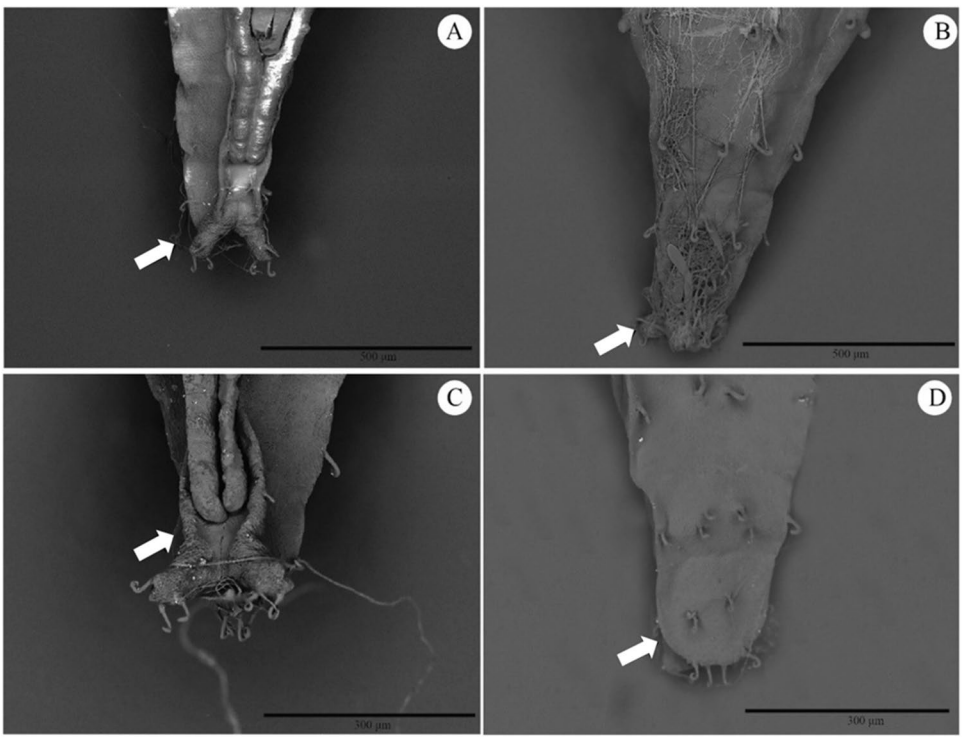

Fig. 1 The final part of the abdomen of the male pupa in ventral (**A**) and dorsal (**B**) views and the female in ventral (**C**) and dorsal (**D**) views of *Bedellia somnulentella* (Lepidoptera: Bedelliidae)

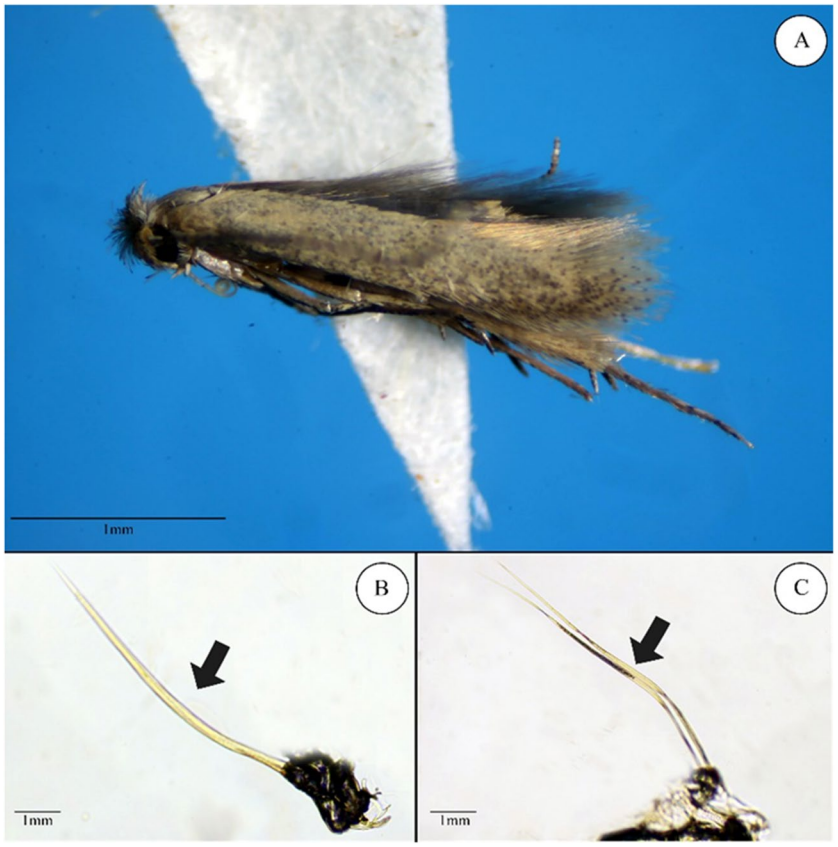

Fig. 2 Adult (**A**) and frenulum of the hind wing of male (**B**) and female (**C**) *Bedellia somnulentella* (Lepidoptera: Bedelliidae)

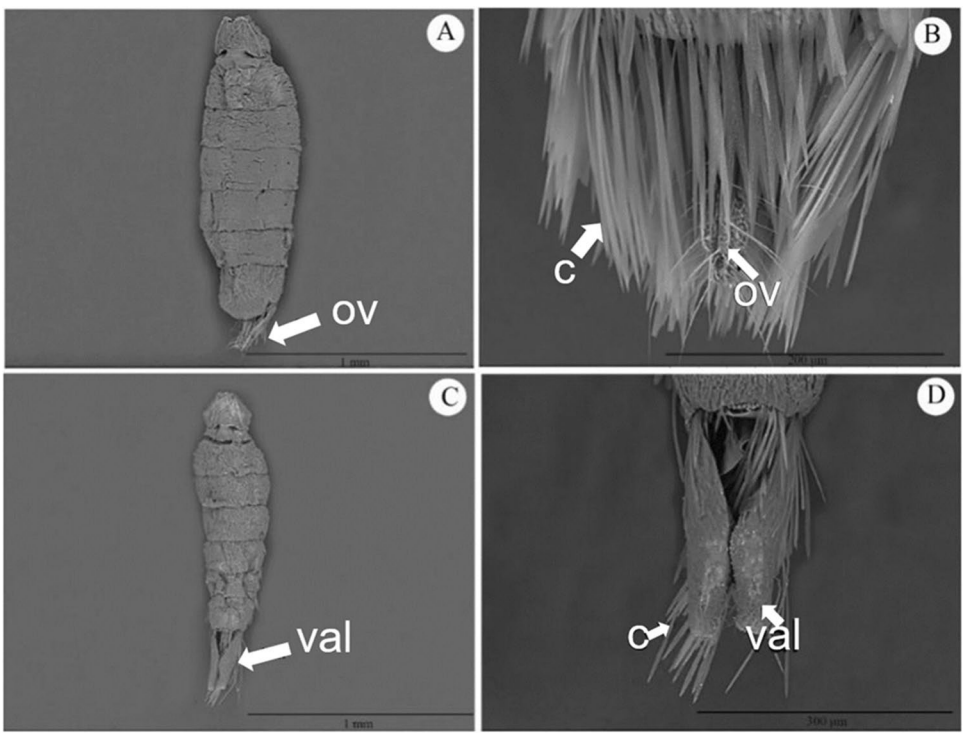

Fig. 3 Dorsal view of the abdomen (**A**), last female abdominal segment in ventral (**B**), and dorsal view of the abdomen (**C**) and last abdominal segment (**D**) of *Bedellia somnulentella* (Lepidoptera: Bedelliidae) males. Caption – ov: ovipositor; val: valve

Discussion

Anal pore, absent in the last three abdominal segments of *B. somnulentella* pupae of different sizes collected on *I. batatas* plants, makes sexing difficult at this stage. This differs from reports of this structure in other Ditrysia species, such as in pupae of the microlepidopteran *Tonza citrorrhoa* Meyrick, 1905 (Lepidoptera: Tonzidae) in the ninth abdominal segment with a distinct morphology between females and males, allowing sexing this insect (Kobayashi et al. 2018). Anal pores, with a variable shape between immature females and males, were reported in pupae of the microlepidopteran *Tuta absoluta* Meyrick, 1907 (Lepidoptera: Gelechiidae), with an anal fissure in the eighth abdominal segment of the former and the tenth in the latter, as a dimorphism in this stage (Genc 2016). A longitudinal ridge was reported on the eighth abdominal segment of the butterfly *Nymphalis polychloros* Linnaeus, 1758 female pupae (Lepidoptera: Nymphalidae) (Genc 2015). Genital opening in the middle part of the ninth abdominal segment in a short slit surrounded by a pair of semicircular ridges differentiates females and male pupae of *Mythimna separata* Walker, 1865 (Lepidoptera: Noctuidae) in ventral view (Lin et al. 2020). Still, this cleft was not detected in *B. somnulentella* pupae.

The greater weight of female than male pupae of *B. somnulentella* is a standard in butterflies and moths, as reported for male pupae of *N. polychloros* (Genc, 2015), *Syssphinx molina* Crame, 1780 (Lepidoptera: Saturniidae) (Batista et al. 2013), *T. absoluta* (Genc, 2016), and *Lycoriella ingenua* Dufour, 1839 (Diptera: Sciaridae) (Lewandowski et al. 2004). Heavier female pupae indicate sex dimorphism in *B. somnulentella*.

Similar color of the head, thorax, and wings and filiform antennae in males and females and the abdomen of males *B. somnulentella* thinner than that of their females is similar to that reported for *Conopomorpha cramerella* Snellen, 1904 (Lepidoptera: Gracillariidae) (Posada et al. 2011). The sharper body of *B. somnulentella* males agrees with that reported for *T. citrorrhoa* (Kobayashi et al. 2015), and color markings on the forewings of *Spodoptera frugiperda* J.E. Smith, 1797 (Lepidoptera: Noctuidae) (Navasero and Navasero 2020) are sex dimorphism.

A pair of frenulum in females and only one in males on the hind wings of *B. somnulentella* is similar to that reported for *Mythimna separata* Walker, 1865 (Lepidoptera: Noctuidae) (Lin et al. 2020), being an adequate parameter to sex *B. somnulentella* adults.

The external male genitalia of *B. somnulentella*, surrounded by a long cercus in the last segment and short in its females, are similar to that reported for *T. citrorrhoa* (Kobayashi et al. 2015). Circuses and shape of the genitalia of *B. somnulentella* and the bipartite male genitalia in the eighth male abdominal segment of *Leucoptera coffeella* Guérin & Méneville, 1842 (Lepidoptera: Lyonetiidae) (Posada et al. 2011; Motta et al. 2021) are parameters of sexual dimorphism. A pair of elongated limbs with cerci covering the external genitalia of females in the eighth segment and the last with a tubular shape and ovipositor surrounded by apical bristles in *B. somnulentella* females agree with that reported for *L. coffeella* (Motta et al. 2021).

Conclusion

External structures of sex dimorphism were not detected in the last abdominal segments of *B. somnulentella* pupae, but females at this stage are heavier, being a parameter of sex dimorphism. The color pattern and general body structures of males and females *B. somnulentella* are identical.

Sexual dimorphism in *B. somnulentella* is characterized by discrete anatomical differences. Females are heavier and have a pair of frenula per wing, whereas only one frenulum was observed on each wing of males. Additionally, elongated and smaller cerci involve the last abdominal segment of bipartite genitalia in males. In contrast, an ovipositor was observed in females. These distinct morphological features differentiate between male and female *B. somnulentella*.

Acknowledgements We would like to thank the "laboratório multiusuário de microscopia avançada – LMMA" sponsored by the "Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG (CEX-112-10)" and RQ-MG (FAPEMIG: CEX-RED-00010-14) for supporting the images scanning electron microscopy. To "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) – Finance Code 001".

Author contribution R.A.P.: conceptualization, data curation, research, methodology, validation, original writing; M.J.S.C.: review and editing; S.C.O.G.: formal analysis review and editing; J.C.Z.: review, and editing; J.E.S.: review and editing; C.A.S.: methodology, project administration, validation, review and editing; M.A.S.: conceptualization, formal analysis, methodology, project administration, validation, review and editing.

Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval Not applicable.

Consent for publication The authors declare consent for the publication of this study.

Conflict of interest The authors declare no competing interests.

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