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DOI: <https://doi.org/10.3897/arphapreprints.e85917>

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Morphological description of *Laevicaulis stuhlmanni* (Simroth, 1895) (Pulmonata, Veronicellidae) from Egypt

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Abstract

Background

Terrestrial slugs are becoming abundant quarantine pests attacking many agricultural and horticultural crops as well as ornamental plants in Egyptian fields resulting in increasing loss of the commercial value and decreasing the economic quality .

Recently, a number of quarantine-significant terrestrial slugs have been recorded in Egyptian ornamental plant nurseries and gardens such as *Deroceras reticulatum* (O.F. Müller, 1774, *Deroceras laeve* (O.F. Müller, 1774) (Agriolimacidae), *Limacus flavus* (Linnaeus, 1758), *Ambigolimax valentianus* (d'A. de Férussac, 1821) (Limacidae) and *Laevicaulis alte* (d'A. de Férussac, 1821).

New information

This paper provides a detailed morphological and anatomical description of the veronicellid slug *Laevicaulis stuhlmanni* (Simroth, 1895) that has been recently recorded from Egypt. This population from Egypt is compared with *Laevicaulis striatus* recently reported and described from Libya and with available data in literature. Some notes and a distribution map of the veronicellids introduced in Northeastern Africa are provided.

Keywords

Slug, taxonomy, morphology, genitalia, Northeastern Africa

Introduction

The genus *Laevicaulis* Simroth, 1913 is native to sub-Saharan Africa. However, *Laevicaulis alte* (d'A. de Férussac, 1822) has been introduced by human activity to other areas of the world, where it has become abundant and causes considerable damage to agricultural crops (Gomes and Thomé 2004). Recently three *Laevicaulis* species have been reported in agricultural fields and gardens in north-eastern Africa: *Laevicaulis alte* and *Laevicaulis stuhlmanni* (Simroth, 1895) from Egypt (Ali 2017a, Ali 2017b, Ali and Robinson 2020) and *Laevicaulis striatus* (Simroth, 1896) from Libya (Liberto et al. 2021). In this paper, the external morphology and genitalia of *Laevicaulis stuhlmanni* from Egypt is described in detail, comparing these characters in *Laevicaulis striata* from Libya and with the available literature data.

Materials and methods

The slug species *Laevicaulis stuhlmanni* was collected from the indoor ornamental plants garden of a hotel located in El Gezira Street, on Gezira Island, El Zamalek district, Cairo, Egypt (30°03'27.4"N 31°13'28.1"E) in April 2016 in the late evening when they are typically more active. The specimens were collected from humid areas such as near irrigation tubes, close to water faucets, under leaf litter and stones. The collected samples were transferred to the Malacology laboratory, Department of Zoology and Agricultural Nematology, Faculty of Agriculture, Cairo University in Giza. The slugs were preserved in 85% ethanol and they were dissected as described in Gomes et al. (2013). The specimens were measured by using electronic caliper for: total body length, total body width, foot length, foot width, width of right and left hyponota and the distance of the female genital pore from the posterior end of the slug body (n= 15), recording the external features and characters that are important in identifying the species. These include the position of the female genital pore, width of the foot relative to the hyponotum, in addition to the position and the shape of the anus.

The reproductive system was dissected out using a scalpel, scissors and needles. In the anatomical description, proximal denotes the part which is closest to the gonad and distal the part which is closest to the female sexual pore. All the specimens were studied by Nikon SMZ1500 stereomicroscope. Some organs of genitalia were measured by a digital gauge. Photographs were taken with a Nikon digital Sight DS-Fil camera attached to the Nikon SMZ155 stereomicroscope. Some drawings based on these photographs were made using CorelDraw X5.

Taxon treatment

Laevicauli stuhlmanni (Simroth, 1895)

- GBIF <https://www.gbif.org/species/11057552>

- molluscabase <https://www.molluscabase.org/aphia.php?p=taxdetails&id=1255847>
- Encyclopedia of Life <https://eol.org/pages/52584426>
- Wikipedia https://en.wikipedia.org/wiki/Laevicaulis_stuhlmanni
- Barcode of Life <https://www.molluscabase.org/aphia.php?p=taxdetails&id=1335505>

Material

- a. scientificName: *Laevicaulis stuhlmanni* (Simroth, 1895); scientificNameID: urn:lsid:marinespecies.org:taxname:1255847; kingdom: Mollusca; class: Gastropoda; family: Veronicellidae; continent: Africa; country: Egypt; stateProvince: El Gezira Street, on Gezira Island, El Zamalek district; county: Egypt; samplingProtocol: collecting by hand and observation; year: 2006; month: 4; day: 15; habitat: garden; eventRemarks: collecting at late hours of night in activity periods; individualCount: 25; sex: hermaphrodite; lifeStage: juvenile and adults; preparations: whole animal (ETOH); catalogNumber: USDA 144250 ; occurrenceRemarks: found on grass in Marriot Hotel in Cairo; recordedBy: Reham Fathey Ali; institutionCode: USDA – USDA APHIS National Malacology Collection, Academy of Natural Sciences, Philadelphia, Pennsylvania, USA; collectionCode: "Terrestrial slugs"; basisOfRecord: PreservedSpecimen

Description

General description of external shape

Regarding the external morphology, the slug has flattened body; the notum has dark brown background, with a light longitudinal color band running down the center, in some specimens, it is reduced to very small or tiny dots (Fig. 1). Some specimens have a darker band on the both sides of the notum, these bands are connected together on the head and in the back, and could be thick or thin, or as rows of dark spots (Figs 1, 2).

This species laid multiple egg masses during its activity months. In Figs 1, 2, the eggs look oval to spherical elongate and translucent. The eggs are joined together by a thin interconnecting thread producing a gradually spiral-like egg mass with distinct fecal ribbon deposited on the top of the eggs. The hyponata are a uniform light brown. The head has two pairs of tentacles that are hidden under the notum, the first (lower) shorter chemotactic pair and a longer (upper) pair of ocular tentacles. The specimens of *Laevicaulis stuhlmanni*, preserved in alcohol had been measured (n=15) length 44.53 ± 4.94 mm ranged 36–52 mm, width 15.87 ± 2.1 mm ranged 12–19 mm, foot length 37.87 ± 7.56 mm ranged from 23–48 mm, foot width 5.7 ± 1.71 mm ranged from 4–9 mm, right hyponota width 5.17 ± 1.28 mm ranged from 3–7 mm, left hyponota width 5.00 ± 1.36 mm ranged from 3–7 mm.

Diagnosis

Genitalia description:

The male genital pore is located anteriorly on the body surface below the mouth and the female genital pore in the left hyponotum in the posterior portion of the body. The male genital complex is composed of two parts, the phallus *sensu stricto* and the

phallic gland, both are enclosed in a muscular sheath that shares a common atrium and connects to the male genital pore.

The phallus is slender (Figs 3, 4) and has a sub-distal annular swelling. In some specimens the phallus is less slender, with a distal swelling, caused by the invagination of the distal part.

The phallic gland is composed of a conical papilla that rises from a vase-shaped base, on the opposite side there are a number digitiform tubules. The digitiform tubules number ranged from ten to seventeen, averaging 12.5 ± 1.8 tubules. In three specimens, it was noticed that one of the tubules branched into two smaller tubules (Fig. 3).

The gland papilla is at the same level with phallus papilla tip in some samples, or higher (Figs 5, 6). However, two specimens the phallus papilla stalk was longer than gland papilla or not at the same level (Fig. 7).

The papilla of the phallic gland is pointed conical and different in length and width relative to its base in each individual; at the base of the papilla four to five thin lines of wrinkles can be seen as a result of contracting and expanding of the papilla during the mating process; up to seven to twelve thin lines wrinkles differed as indication of number of mating process times as an individual variation (Fig. 7).

The female genitalia characterized by hermaphroditic gonad (ovotestis) of more or less oval shape, with rounded acini; from it arises a convoluted hermaphroditic duct; the albumen gland is conic and very large; it is followed by a large and convoluted ovispermiduct; the vas deferens can be divided into four parts: the proximal posterior vas deferens (from the fertilization complex, to the prostatic gland) the distal posterior vas deferens (from the prostate to the ligament duct) the middle vas deferens (from the ligament duct, in anterior direction inside the integument) and the anterior vas deferens (from the exit of the tegument to the phallus); prostatic gland is dark yellow to pale coffee color and smoother in surface; the ligament duct is a short duct that connect the middle vas deferens to the short duct of the bursa copulatrix; bursa copulatrix is large and oval (Fig. 8). The distribution map of *Laevicaulis stuhlmanni*, *Laevicaulis alte* and *Laevicaulis striatus* are illustrated in Africa (Fig. 9).

Distribution

The slug species *Laevicaulis stuhlmanni* were collected from the indoor ornamental plants garden of a hotel located in El Gezira Street, on Gezira Island, Cairo, El Zamalek district, Egypt (30°03'27.4"N 31°13'28.1"E).

Biology

The species *Laevicaulis stuhlmanni* was reported for the first time under the *nomen nudum* *L. stuhlmanni aegypti* (Ali 2017a, Ali 2017b), and the biological attributes such

as life cycle, reproductive output, generation period and life span had been documented and described.

As in all veronicellid species, the slug is a hermaphrodite possessing both male and female genitalia and self-fertilization can occur. However, no cross-fertilization was observed for this species under laboratory conditions. The reproductive season of this species starts in March, when the temperature rises, and lasts until November. Incubation period ranges from 10 to 19 days at a temperature of 30°C and a humidity between 52 % and 64 %. The oviposition period averaged 23 days, each slug can produce about five egg clutches with average 47 eggs/clutch under laboratory conditions. *Laevicaulis stuhlmanni* reaches sexual maturity after 53 to 115 days after hatching, depending on environmental conditions. Total life span ranged between 127 to 188 days.

Taxon discussion

Laevicaulis stuhlmanni is a leatherleaf slugs native of eastern central Africa (Congo, Ruanda, Burundi). It is phytophagous and often occurs in large numbers beneath decaying vegetation in its natural habitat but also in commercial plantations. *Laevicaulis stuhlmanni* is usually active during the night while it is buried in the ground during the day. It is a protandric hermaphrodite and member of a genus that includes some widespread and invasive pests such as *Laevicaulis alte*.

Taxonomic remarks

The systematics of the genus *Laevicaulis* is uncertain, due to the description of several taxa in the second half of the 1800s based on the external characters such as body color and body mesurments of the slug that not always usufel in species identification espicially in veronicellid group or on inadequate descriptions of the genitalia. *Laevicaulis stuhlmanni* has two described subspecies, but their validity is questionable.

Laevicaulis striatus and *L. stuhlmanni* have similar female genitalia and phallic gland. However, the phallus in the two species has a different apex.

In (Simroth 1895: 62), the original description of *L. stuhlmanni* describes a cylindrical phallus, slightly tapered distally, with a flat terminal disk, in the middle of which the sperm duct opens.

The descriptions and figures of *L. stuhlmanni* in Simroth (1896): 18, Pl. 3, figs. 6 B-C, and the synonym *Vaginula aequatorialis* and those of Forcart (1953): 74-76, Pl. 5, figs. 1 A-E are consistent with the original description of *L. stuhlmanni*. However, part of Forcart's description of *L. stuhlmanni* (Forcart 1953: 75, Pl. 4 figs 10 A-B) is not consistent with *L. stuhlmanni*'s original description, while it fits well to *L. striatus* of the same Forcart's paper (Forcart 1953).

Simroth (1896) describes the new species *Vaginula striata* based on external features of sexually immature specimens. In (Forcart 1953: 79-86, Pl. 5, figs 3 A, C) reviews *L. striatus* based on adult specimens sampled in the type locality. These specimens are characterized by the phallus with a subdistal annular swelling.

The important character is that *L. stuhlmanni* has a phallus with a flat terminal disc, while *L. striatus* has a phallus with a subdistal annular swelling.

However, as shown by Colosi (1927) for *L. somalicus* (Colosi 1927) and as evidenced by Forcart (1953) (P1. 4, Fig. 10; P1. 5, Figs. 1, 3) for *L. stuhlmanni* and *L. striatus*, the length of the phallus and the shape of the phallic apex are variable according to the contraction or erection of the phallus, therefore it cannot be excluded that *L. striatus* is a synonym of *L. stuhlmanni*. Pending a modern taxonomic review involving a molecular analysis of the *stuhlmanni/striatus* group, we prefer to attribute the population examined here and the one reported from Libya as *L. striatus* (Simroth, 1896) in Liberto et al. (2021) to the older taxon *L. stuhlmanni* (Simroth, 1895). The *L. stuhlmanni* populations described by Forcart (1953) have a variable external color: greyish, reddish, yellow, brown or blackish-brown, the sole is unicolored blackish always much darker than the hyponota or light with blackish margin ("subspecies" *atrolimabratius*).

Laevicaulis stuhlmanni from Egypt and Lybia has an external coloration more similar to that described by Forcart (1953) for *L. striatus*: notum redish-brown, yellow or greenish-brown unicolored or with a median stripe, flanked on each side by two rows of irregular dark spots or stripes; hyponota and foot lighter than the notum.

The length of the phallus stalk in Forcart (1953) (when not contracted) is similar to that measured in the population from Cairo i.e. one or one and a half times the length of the papilla of the phallic gland, whereas in the populatios from Benghazi it is longer, i.e. two and a half times.

Recently, Ali and Robinson (2020) recorded *Laevicaulis alte* from Abo Rawash, Giza, Egypt. *L. alte* is distinguished from *L. stuhlmanni* by having a very dark notum with a pale thin well-defined white or creamy line on the dorsal surface, running of the length of the body; the lighter hyponota have a creamy or gray in color; both surfaces minutely granular; the phallus with a sub-basal annular swelling (Grimpe and Hoffmann 1925, Forcart 1953, Benthem-Jutting 1952, Brodie and Barker 2012, Prakash et al. 2015).

Discussion

The Veronicellidae is a common phytophagous family, occurring mainly in the tropical and subtropical areas of America, Asia, and Africa (Baker 1926, Aguayo 1965, Naranjo-García and Thomé 2007, Robinson et al. 2009) and to be found in tropical and subtropical region that occurs mainly in Central and South America (Thomé 1993, Santin and Miquel 2015, Oliveira Rocha 2019) Sub-Saharan Africa i.e. Democratic Republic of Congo (formerly Zaire), Malawi, South Africa, and Tanzania (Forcart 1953, Herbert and Kilburn 2004, Rowson B et al. 2017), Southern and Southeast Asia, Hawaii (Hata et al. 1997, Kim et al.

2016) and Indian Ocean Islands (Herbert and Kilburn 2004), with a first record to find the slug species *Semperula wallacei* (Issel, 1874) (Veronicellidae) in Japan (Hirano et al. 2018). The slugs are typically hermaphroditic and lack an internal shell or calcareous particles (Gude 1914, Runham and Hunter 1970, Barker 2001).

Members of the Veronicellidae are potentially very serious agricultural pests causing great economic loss for important field crops, being voracious plant feeders, and as vectors of parasites affecting humans and livestock as well as carriers for plant diseases (Gomes and Thomé 2001). In Central and South America some species are intermediate hosts of parasitic nematodes such as *Angiostrongylus costaricensis* causing abdominal angiostrongyliasis, and the rat lungworm *Angiostrongylus cantonensis* that is the etiologic agent of eosinophilic meningitis in Pacific Islands (Caldeira et al. 2007). The emergence of this new reported slug pest is due to unsuccessful quarantine barriers and plant protection regulations. We are establishing initial wide database of well-identified invasive gastropods that are found in some Egyptian fields with more new reported species that have been added to the list as potential agricultural pests (Ali and Robinson 2020). The present work recognizes *Laevicaulis stuhlmanni* as a species recently introduced to Egypt with a potentially rapid expansion in cultivated fields and irrigated gardens, with consequent damage to field crops and ornamental plants.

Acknowledgements

We are grateful to the Binational Fulbright Commission in Egypt for funding R. F. Ali for her research and stay in USA.

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Figure 1.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt; external morphology and coloration, the photos include the egg masses of this species. The eggs are joined together by a thin interconnecting thread that forming spiral-like egg mass.



Figure 2.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt and deposited eggs that darker in color ready to hatch and covered with distinct fecal ribbon on the top of the eggs.



Figure 3.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt, transverse section of the phallic sheath; the arrow points a tubule branched into two smaller tubules.



Figure 4.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt, phallus.

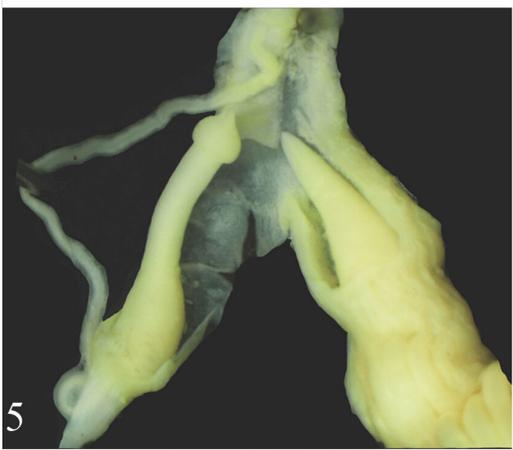


Figure 5.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt, the verge with contracted distal part, the phallus gland tip is at the same level with phallus tip.

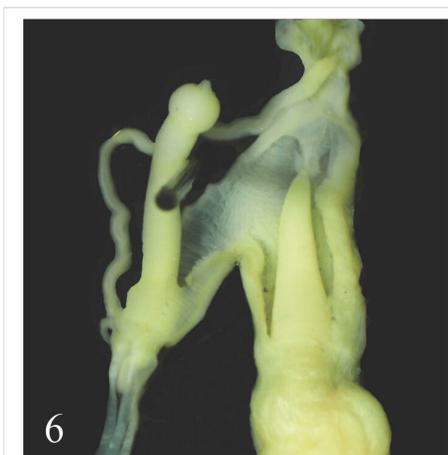


Figure 6.

Laevicaulis stuhlmanni (Simroth, 1895) Gezira Island, Cairo, Egypt, the verge with erected distal part, the phallic gland tip is not at the same level with phallus tip.

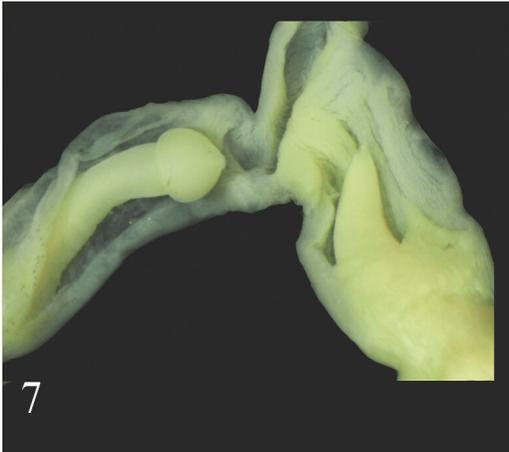


Figure 7.

Laevicaulis stuhlmanni (Simroth, 1895), transverse section of the phallic sheath, on the base of papilla there are around four to five thin lines of wrinkles.

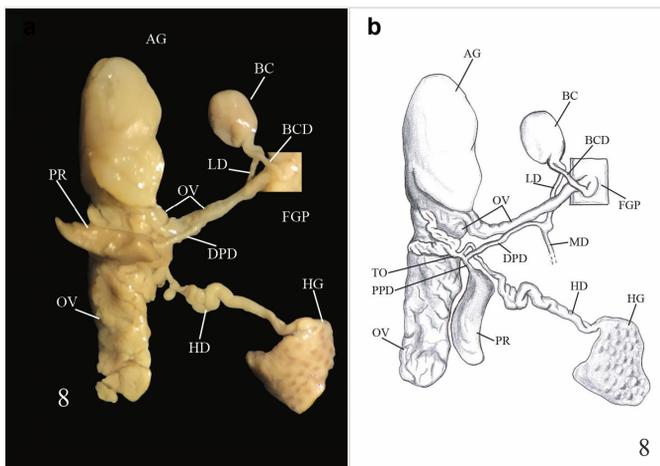


Figure 8.

Laevicaulis stuhlmanni (Simroth, 1895). AG, albumen gland; BC, bursa copulatrix; BCD, bursa copulatrix duct; DPD, distal posterior vas deferens; FGP, female genital pore; HG, hermaphroditic gonad; HD, hermaphroditic duct; LD, ligament duct; MD, medium deferens; OV, oviduct; PPD, proximal posterior vas deferens; PR, prostatic gland; TO, tube leading to oviduct.

a: Female reproductive system.

b: Illustration of the female reproductive system.



Figure 9.

Distribution map of *Laevicaulis stuhlmanni* (red dots), *Laevicaulis alte* (yellow triangle) and *Laevicaulis striatus* (green dots) in Africa.