Description and Evaluation of Metharmostis multilineata (Cosmopterigidae) and Idiophantis soreuta (Gelechiidae) (Lepidoptera: Gelechioidea) For Biocontrol Of Downy Rose Myrtle, Rhodomyrtus tomentosa (Myrtaceae)

Authors: Adamski, D., Makinson, J. R., Brown, B. T., Wright, S. A., Prattand, P. D., et al.

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DESCRIPTION AND EVALUATION OF *METHARMOSTIS MULTILINEATA* (COSMOPTERIGIDAE) AND *IDIOPHANTIS SOREUTA* (GELECHIIDAE) (LEPIDOPTERA: GELECHIOIDEA) FOR BIOCONTROL OF DOWNY ROSE MYRTLE, *RHODOMYRTUS TOMENTOSA* (MYRTACEAE)

D. ADAMSKI
Systematic Entomology Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705;
email: david.adamski@ars.usda.gov

J. R. MAKINSON
USDA, ARS, Australian Biological Control Laboratory, CSIRO Ecosystem Sciences, GPO Box 2583, Brisbane, Queensland, Australia 4001;
email: jeff.makinson@csiro.au

B. T. BROWN
USDA, ARS, Australian Biological Control Laboratory, CSIRO Ecosystem Sciences, GPO Box 2583, Brisbane, Queensland, Australia 4001;
email: bradley.brown@csiro.au

S. A. WRIGHT
USDA, ARS Invasive Plant Research Laboratory, 1911 SW 34th Street, Gainesville, FL 32608
email: susan.wright@ars.usda.gov

P. D. PRATT
USDA, ARS, Invasive Plant Research Laboratory, 3225 College Avenue, Fort Lauderdale, FL 33314
email: paul.pratt@ars.usda.gov

AND

J. W. BROWN
Systematic Entomology Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705;
email: john.brown@ars.usda.gov

ABSTRACT. Two species of Gelechioidea (Lepidoptera), ***Metharmostis multilineata*** Adamski, **n. sp**. (Cosmopterigidae), and *Idiophantis soreuta* Meyrick, 1906 (Gelechiidae), were collected in southeastern Asia for evaluation as potential biocontrol agents against downy rose myrtle, *Rhodomyrtus tomentosa* (Aiton) Hassk. (Myrtaceae), which has become an invasive weed in Florida, USA. *Metharmostis* Meyrick is reviewed and transferred from Yponomeutidae to Cosmopterigidae (Antequerinae). All life stages of *M. multilineata* are described and illustrated, with notes on its biology. In addition, protocols for rearing and host testing of *M. multilineata* are described in detail. *Idiophantis* appears to be associated with Myrtaceae, and the adult stage of *I. soreuta* is redescribed. Neither species was suitable for release in Florida.

Additional key words: classical weed biological control, Gelechioidea, Hong Kong, immatures, life-history, Myrtaceae, Southeast Asia, Taxonomy, Thailand

Downy rose myrtle, *Rhodomyrtus tomentosa* (Aiton) Hassk. (Myrtaceae), is an evergreen shrub typically growing to about 2 m in height, but some individuals reach nearly 4 m (Figs. 1–2). Native to the tropical regions of Asia, its distribution extends from India to Japan and in Southeast Asia from Thailand, Malaysia, and Indonesia east to the Philippines (Scott 1978, Herklots 1932). It is cultivated as an ornamental because of its multiple buds and attractive pink flowers (Figs. 3–4); for its edible berries, which are used as fruit and in jam; as a fire retardant species for use in fire breaks in the Himalayas; and for some medicinal purposes (World Agroforestry Centre 2011).

Scott (1978) lists the habitat of downy rose myrtle as shrubby forest, coastal scrub, or secondary forest, generally below 300 m elevation, but it may occur as high as 1300 m. It also thrives in open sandy soils, along the shore, and on river banks, and can tolerate full sun and flooding (World Agroforestry Centre 2011). Its life history characteristics make it a successful invader; it is

FIGS. 1–4. Exotic native habitat and development of *Rhodomyrtus tomentosa* in Hong Kong, SAR, China. **1**, Plants near hilltop, Luk Wu Country Trail, Sai Kung. **2**, Budding and flowering plant, Tei Tong Tsai Country Trail, Lantau Island. **3**, Budding plant, Tei Tong Tsai Country Trail, Lantau Island. **4**, Flowering and budding plant, Tei Tong Tsai Country Trail, Lantau Island.

fast growing and drought resistant (Hong Kong Herbarium 2004) and is able to withstand some frost and many soil types (Langeland & Craddock Burks 1998). Furthermore, it will re-sprout prolifically after fire and is spread by seed drop as well as by birds and mammals, which eat its fruit (EDD-MapS, Center for Aquatic and Invasive Plants 2009).

Rhodomyrtus tomentosa was available for sale from Florida nurseries as early as the late 1880s and was introduced into Highland and Lake Counties in Florida in 1905. It was first reported as "wild" (naturalized) in 1906 (Austin 2008), and was available for sale from Florida nurseries as early as in the late 1880s. It is likely that there were multiple introductions into Florida from several locations throughout its native range, although it is unclear whether all introductions contributed to the current populations in Florida (Paul Madeira, Invasive Plant Research Laboratory, pers. com.). By the 1970s *R. tomentosa* had formed extensive thickets near Orlando (Orange County), Bradenton and Oneco (Manatee County), Bonita Springs and Estero (Lee County), and Naples (Collier County) (Morton 1976). Today, there are infestations reported between Pasco and Collier counties on the west coast, in Polk and Highlands counties in central Florida and between Brevard and Dade counties on the east coast (Employment Development Department MapS, Center for Aquatic and Invasive Plants 2009). *Rhodomyrtus tomentosa* can alter native plant communities by displacing native species and changing community structure or ecological functions. In Florida it is displacing native vegetation with dense uniform thickets in the understory of native pinelands (Langeland & Craddock Burks 1998). Consequently, it is now considered a Category I noxious weed, and its use as an ornamental in Florida is prohibited according to the List of Invasive Plant Species of the Florida Exotic Pest Plant Council (2009).

Rhodomyrtus tomentosa is also a serious pest in Hawaii. Krauss (1966) reported that it was introduced there in the 1920s and had established on the islands of Kauai and Hawaii, infesting over 8,000 acres by the mid-1960s. On Kauai it forms essentially mono-dominant stands that successfully exclude most natives and even many other alien invasives (Burney & Pigott-Burney 2007).

The USDA, ARS, Australian Biological Control Laboratory (ABCL) commenced exploration for biological control agents of *Rhodomyrtus tomentosa*. In April 2001, a one-year survey of *R. tomentosa* herbivores in Thailand was conducted by the Thailand Department of Agriculture with support by ABCL. Six species were identified as having potential for further study as biocontrol agents (Winotai et al. 2005). This included two moth species, *Idiophantis soreuta* Meyrick and *Metharmostis multilineata*, with the latter species the most common insect found in the surveys ranging across six eastern and southern provinces, often encountered in large numbers boring and feeding inside young flower buds and young fruit (Winotai et al. 2005). The genus *Metharmostis* was proposed by Meyrick (1921), with the description of its type species *M. asaphaula*, collected from Nasik, Bombay, India. Prior to this research nothing was known of the biology and little of the distribution of the genus. *Idiophantis* also was proposed by Meyrick (1904). The genus includes about 20 species found principally in the Indo-Australian region, but it also is reported from the Seychelles, Madagascar, and South Africa (Moriuti 1993). *Idiophantis* appears to have a host preference for Myrtaceae (Bradley 1968; Scott Miller, Smithsonian Institution and The Papua New Guinea Binatang Research Center, pers. com.).

Starting April 2001, in collaboration with the Invasive Plant Research Laboratory (IPRL) in Florida, surveys of *R. tomentosa* have been conducted by ABCL staff throughout Hong Kong SAR; and since 2009 in the southern Chinese province of Guangxi.

Rhodomyrtus tomentosa is Hong Kong's most abundant flowering shrub, growing from sea-level to the top of the hills (Herklots 1932) (Figs. 1–4). The plant flowers from late April to July, with fruits present between June and September, coinciding with the hot and humid summer months. Young leaf shoots are prevalent between September and November before the cool and dry winter, from December to February. A study of the reproductive ecology of *R. tomentosa* undertaken in Guangdong Province, China, indicates that it took 20 days for a flower bud to develop and another 10 days for a blooming flower to develop into fruit. Almost two months were needed for a fruit to mature (Wei et al. 2009).

The purposes of this paper are 1) to document the identity, early stages, and life-history of the moth species collected from *R. tomentosa* by the Australian Biological Control Laboratory, and 2) to evaluate the potential of these species as biocontrol agents against *R. tomentosa* in Florida.

Materials and Methods

Plants of *Rhodomyrtus tomentosa* were obtained from parcels of the South Florida Water Management District Land, Palm Beach County, Florida, and from the Lake Lizzie Nature Preserve, Osceola County, Florida. These plants were transported to a secure site at the Florida Department of Agriculture and Consumer Services (FDACS), Division of Plant Industry (DPI), Alachua County, Florida, and transferred into 3.8–26.5-liter pots, and maintained for rearing and testing of potential biocontrol candidates. Plants of two nontarget native myrtaceous species, *Calyptranthes pallens* Griseb. and *Myrcianthes fragrans* (Sw.) McVaugh, were purchased from various Florida nurseries and plants of a third myrtaceous ornamental species, *Myrtus communis* L., were obtained from Woodlanders, Inc., Aiken, South Carolina and O'Toole's Herb Farm, Madison, Florida.

Cut shoots of field collected *Rhodomyrtus tomentosa* infested with *Metharmostis multilineata* were shipped directly from Hong Kong to the USDA, ARS Invasive Plant Research Lab located at the FDACS, DPI Florida Biological Control Laboratory, Gainesville, Florida in order to establish a laboratory colony under quarantine conditions. Exotic plant material was searched for wandering larvae and cocoons with viable pupae. Larvae were transferred with a small brush to fresh cut shoots of Florida *R. tomentosa*, which were held in 0.18-liter vials (1–2 shoots per vial) to complete development. Each shoot had at least one bud suitable for larval development and sites suitable for pupation. Cocoons present on leaves, stems, or buds of exotic shoots were excised along with a small section of plant material and put into 55.5-ml vials, one cocoon/vial. A small amount of honey was vertically streaked on the inner surface of each vial as a food source for adults after eclosion. The opening of each vial was covered with a square of paper toweling that was fastened with a rubber band. These vials of shoots and pupae were placed in a ventilated Plexiglas™ cage, 0.4 × 0.4 × 0.4 m, modified by placement of Horizon Total Wipes, nylon reinforced scrim wipes, 25.4 × 42.2 cm, over the screened side of the cage to maintain a higher humidity (Fig. 5).

As wandering larvae from Hong Kong were collected from plant material and placed on *R. tomentosa* from

FIGS. 5–8. Laboratory materials used to encourage development of immature stages of exotic *Rhodomyrtus multilineata*, and for adult mating and oviposition under quarantine conditions. **5**, Plexiglas® cage containing cut shoots of Florida *Rhodomyrtus tomentosa* for larval development and pupation. Also enclosed are several harvested cocoons in 55.5 ml vials, one cocoon/vial. **6**, Sub-irrigated rearing containers for infested plant material from Hong Kong. **7**, Adult mating and oviposition cage. **8**, Top view of mating and oviposition cage with three *Metharmostis multilineata* adults indicated by arrows.

Florida, the proximal ends of Hong Kong shoots with green leaves were cut and the ends placed in two floral foam Oasis® discs saturated with water to sustain shoots for any remaining larvae that might be feeding internally in the stems. Each disc of shoots was set in one half of a petri dish, 100 × 15 mm, placed in a 3.8-liter plastic container with a screened top and bottom, resting on supports about 3 cm above damp sand contained in a sub-irrigated holding container, an 18.9-liter inverted carboy with the bottom removed. The inverted carboy rested on the rim of a 7.6-liter bucket half-filled with water so that an absorbent cotton wick, which had been inserted through the neck of the carboy interfaced with a 15-cm layer of sand above to maintain the dampness of the sand. Two large Kimwipes®, 37.3 × 42.2 cm, secured by an elastic band spanned the opening of the sub-irrigated container to retard evaporation (Fig. 6). A standard institutional multifold paper towel, 23.5 × 24.1 cm, was opened and spread across the Kimwipes and tucked at the four corners into the elastic band for the same purpose.

An adult cage for mating and oviposition, Fig. 7, was fabricated from a 591-ml cold drink cup and lid, 32 mm in diameter, with screened openings on the sides for ventilation. One 16-ml opening was made for insertion and removal of adults. The opening was closed with a No. 0 stopper when not in use. A 44-mm opening was made in the bottom for insertion of cut shoots. These shoots were pushed through small slits in three layers of Parafilm® stretched across an opening of a 185-ml water-filled vial. The vial was secured to the cage vial with three 2.5 × 10 cm strips of Parafilm®. The cages were provisioned with three 1.3-ml Samco® fine-tip bulb pipettes containing a Lemon-Lime Gatorade Perform™, a Perky-Pet Brand Instant Nectar for Hummingbirds, and tap water. The transfer pipettes were inserted through holes in lids. The lid and diet bulbs were changed weekly. Old shoots with eggs were exchanged for fresh shoots, with egg-laden shoots placed in a container similar to that in Fig. 5. These shoots were checked weekly for cocoons, and when found, were placed in 14.8 ml glass shell vials, one/vial, shown next to the base/vial of the cage in Fig. 7. The opening of the vial was secured by the insertion of a square of "noseeum" screen pushed downwards into the vial and held in place with a 16 × 18 mm piece of irrigation tubing. A small drop of honey was applied to the outside of the screen with a toothpick to sustain an adult until it was collected.

Cages of exotic material and rearing containers were held under maximum security at 27°C, 16L:8-D. They were monitored daily for wandering larvae, pupae, adults, and parasitoids. Larvae and pupae were treated as above. Adults were transferred to mating and oviposition cages held in a quarantine greenhouse at 25°C, 60% RH, 16L:8D (Figs. 7–8). Inquilines and parasitoids were collected in 70% isopropyl and submitted to FDACS, DPI taxonomists for identification.

No-choice rearing trials using cut shoots of *R. tomentosa*, *C. pallens*, *M. fragrans*, and *M. communis*, were conducted in an environmental chamber at 27°C, 60% RH. Shoots were held in 55.1-ml vials and placed horizontally in plastic deli boxes, Genpak® AD48, 20.3 × 20.3 × 6.35 cm, lined with two Horizon Total Wipes.

Gross morphological observations and measurements of all life-stages were made using a Leitz RS dissecting microscope (using reflected and transmitted light) with a calibrated micrometer. Genitalia were dissected as described by Clarke (1941), except mercurochrome and chlorazol black were used as stains. The Methuen Handbook of Colour (Kornerup and Wanscher 1978) was used as a color standard.

For SEM study, larvae and eggs were cleaned in a full-strength solution of Formula 409TM detergent, and subsequently dehydrated in increasing concentrations of EtOH (10, 25, 50, 70, 95 %), ending with absolute EtOH. After dehydration, specimens were critical point dried using a BAL-TEC 030 critical point dryer. Larvae and some eggs were mounted on SEM stubs using carbon paste. The remaining portion of eggs were mounted on SEM stubs with Tempfix Mounting Adhesive. All mounted specimens were coated with gold-palladium (40/60%) using a Cressington sputter coater. The fine-structure of the larva and egg was studied with a Zeiss EVO MA15 scanning electron microscope at an accelerating voltage of 10 kV.

The holotype and paratypes from this study are deposited in The United States Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C. Voucher specimens of adults and immatures are deposited in the USNM; the Australian National Insect Collection, CSIRO, Canberra (ANIC); the Florida State Collection of Arthropods, Gainesville, Florida (FSCA); Steven Passoa Insect Collection of the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Columbus, Ohio (SPIC); and the Agriculture, Fisheries, and Conservation Department Insect Museum, Plant Protection Section, Tai Lung Experiment Station, Lin Tong Mei, Hong Kong AFDC, China. Setal nomenclature of the larva follows Stehr (1987). Pupal nomenclature follows Mosher (1916).

Adult genitalic nomenclature follows Klots (1970). Plant taxonomy, including nomenclature and authorship, follows GRIN (2008).

RESULTS

Metharmostis Meyrick, 1921

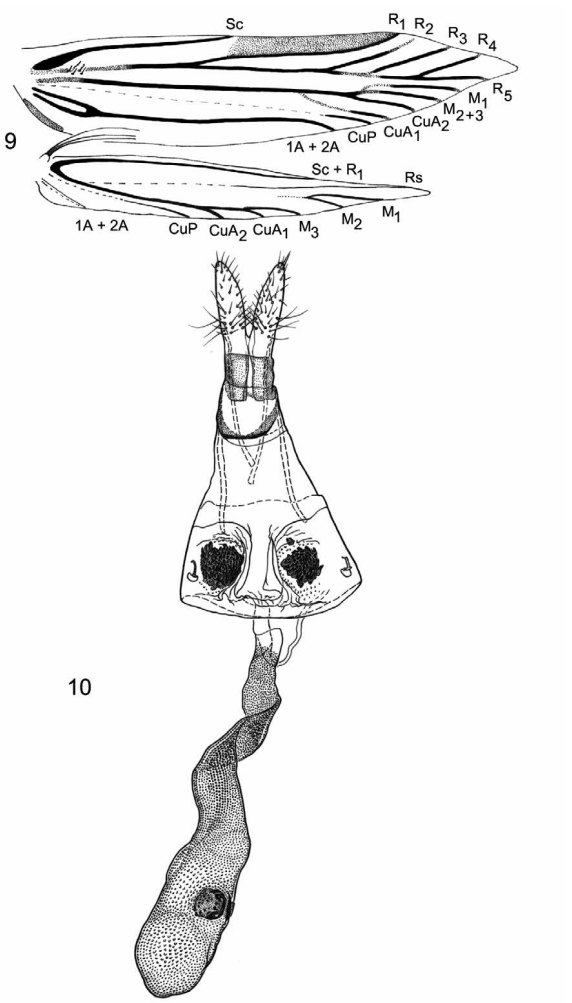
Type Species: *Metharmostis asaphaula* Meyrick, 1921: 439 [by monotypy]

Metharmostis is defined by a distinct forewing pattern that includes two rows of grayish-yellow streaks from base of cell to crossvein, the discal cell open in the forewing and hindwing, vein M_3 stalked with vein CuA_1 and separate from vein M_2 in the hindwing, a cluster of long hair-pencils from the base of the frenulum in the male, and the divided halves of the female seventh sternum bearing a dense cluster of sex scales.

Taxonomic Placement. Kyrki (1984, 1990) demonstrated the monophyly of the Yponomeutoidea with two synapomorphies: the presence of pleural lobes on the eighth abdominal segment in males and a transverse ridge on the second abdominal sternite in both sexes. In addition, yponomeutoids have a naked proboscis, a female frenulum with two acanthae, and abdominal terga with sparse spinelike setae on the abdominal terga. Whereas, the Gelechioidea are united by a scaled proboscis, with most species having a female frenulum with 3 acanthae, and abdominal terga with or without sparse spinelike setae (Hodges 1999). These contrasting adult features convincingly exclude *Metharmostis* from Yponomeutoidea and placed it in Gelechioidea. Pupal characters also support the placement. The antennae meet at the meson in *Metharmostis*: this character is considered unique to the Gelechiidae by Kaila (2004) and a probable apomorphy for the superfamily by Hodges (1999).

Meyrick (1921) placed *Metharmostis* in Hyponomeutidae (= Yponomeutidae) without explanation. Clarke (1955) suggested that *Metharmostis asaphaula* should be assigned to Cosmopterigidae on the basis of the similarity of its female genitalia to those of *Stilbosis devoluta* Meyrick. We agree with Clarke (1955) and hereby transfer *Metharmostis* from Yponomeutidae to Cosmopterigidae (Antequerinae). We base our decision on the evidence from several sources detailed below.

Hodges (1978, 1999) characterized Cosmopterigidae, comprised of three subfamilies, primarily on features of the adult. One of the subfamilies, Antequerinae, has male genitalia with paired lobes on the dorsolateral surface of the tegumen (part of the uncus or gnathos?) a free phallus, and a female ostium bursae that is associated with the seventh segment. Hodges (1978) also showed that cosmopterigids have a hindwing with a



FIGS. 9–10. Wing venation and female genitalia of *Metharmostis asaphaula*, Lectotype. **9**, Forewing and hindwing, female, J.F.G. Clarke slide no. 7494. **10**, Female genitalia, J.F.G. Clarke slide no. 7494.

frenulum with 3 acanthae in the female, a 4-branched cubitus, and a cell that is usually open. *Metharmostis multilineata* possesses all of the above features. Scoble (1992) stated that the cosmopterigid forewing lacks a pterostigma, although this feature is found in *M. asaphaula*, it is absent in *M. multilineata*, suggesting that this feature is more variable than Scoble realized.

Pupal features do not contradict placement of *Metharmostis* in the Cosmopterigidae. Although many pupal Cosmopterigidae have wings that extend almost to the end of the abdomen, this is not unique to the family (Patočka and Turčáni 2005: plates 81–83). Hidden labial palpi are also common to Cosmopterigidae and relatives (Passoa, pers. comm.).

These features of the wing and labial palpi are present in *Metharmostis*, and are consistent with other known cosmopterigids. The most striking feature of the *Metharmostis* pupa is the leglike structure of the 10th segment (Fig. 34–35). Similar structures are illustrated by Common (1990: Fig. 1) and Patočka and Turčáni (2005: Pl. 65, Figs. 22, 31, 34, 41; Pl. 76, Figs. 30, 34, 36–37, 41, 43) for species of Agonoxenidae and *Ethmia* (Elachistidae). Undoubtedly these structures have evolved independently several times within Gelechioidea, and may have limited phylogenetic value at higher levels.

The larva of Cosmopterigidae is characterized by Stehr (1987) as lacking a hairlike SD1 seta on A9, the presence of which is characteristic of many Gelechioidea. *Metharmostis multilineata* lacks this feature as well, SD1 on A9 is setaform (not hairlike). The presence of secondary setae in the SV-V1-group of A9 is unusual.

Metharmostis asaphaula Meyrick, 1921
(Figs. 9–10)

Diagnosis. *Metharmostis asaphaula* is most similar to *M. multilineata* by sharing a similar forewing pattern and a cluster of long hair-pencils from the base of the frenulum in the male. *Metharmostis asaphaula* differs from *M. multilineata* by having a pterostigma between Sc and R_1 of the forewing, a narrower eighth sternum in the female, paired lateral flanges fused from the inner margin of the seventh sternum to the anterior part of the ductus bursae to near the enlarged base of the ductus seminalis, and a signum with two pairs of larger denticles on the same side.

Redescription. *Head*: Vertex and frontoclypeus naked; labial palpus recurved; outer and inner surfaces of labial palpus naked; scape of antenna and most of flagellum naked. Proboscis scaled. *Thorax*: Tegula and mesoscutum naked. Legs pale yellow [faded]. Forewing length 3.5 mm (n=1), pale yellow [badly faded and many scales missing]; lanceolate; venation (Fig. 9) with pterostigma between Sc-R1; cell open; M_2-M_3 fused. Hindwing pale yellow [badly faded]; male with a long pencil of ochreous-whitish hairs lying along costa from base to 4/5 according to Meyrick (1921); frenulum with three acanthae in female; venation (Fig. 9) with cell open; M_1-M_2 stalked, separate from M_3; cubitus 3-branched. *Abdomen*: Male genitalia unknown. *Female genitalia* (Fig. 10) with papillae anales setose throughout, longer setae on basal 1/3. Apophysis posterioris about 1.6X longer than apophysis anterioris; eighth sternum narrow, semicircular, apically fused with apophyses posteriores. Ostium within membrane between divided seventh sternum; divided parts broadly rounded and ridged along inner margin, slightly recessed medially, bearing a dense cluster of sex scales. Ductus bursae smooth from ostium to slightly beyond anterior margin near swollen base of ductus seminalis, denticulate anteriorly, including corpus bursae; signum rounded, spinulate, with two large denticles along margin of one side.

Type (examined). Lectotype ♀, "Lectotype" [round label with a red circle in middle]; "[India], Nasik, Bombay, CB, 10[October] [19] 19"; Lectotype, *Metharmostis asaphaula* Meyrick, [designated by] JFGC Clarke, 1948"; "♀ genitalia on slide 25, 1948, JFGC 7494" [right wings slide mounted separately with same number], "*Metharmostis asaphaula* Meyr. 1/1, E. Meyrick det., in Meyrick Coll[ection]"; "Meyrick Coll[ection], BM 1938-290"; "*asaphaula* Meyr." [hand-written label]; "*Metharmostis* Meyr."

Remarks. *Metharmostis asaphaula* was described from three specimens (Meyrick 1921) including both sexes. Clarke (1965) found a single female specimen, concluded that the other two specimens were lost, and designated the female as the lectotype. A search for the remaining two specimens in the collections of the British Museum was unsuccessful.

Meyrick (1921) described *Metharmostis* as having a forewing with "faint brassy-ochrous longitudinal streaks of pale brassy-ochreous suffusion above fold." His description of the forewing pattern is similar to that of *M. multilineata*, and this pattern is considered a synapomorphy for the genus. In addition, Meyrick (1921) described *Metharmostis* as having posterior ocelli and lacking pecten on the scape; however, he was in error or based these details of the description on the two missing specimens which possibly represented a different species.

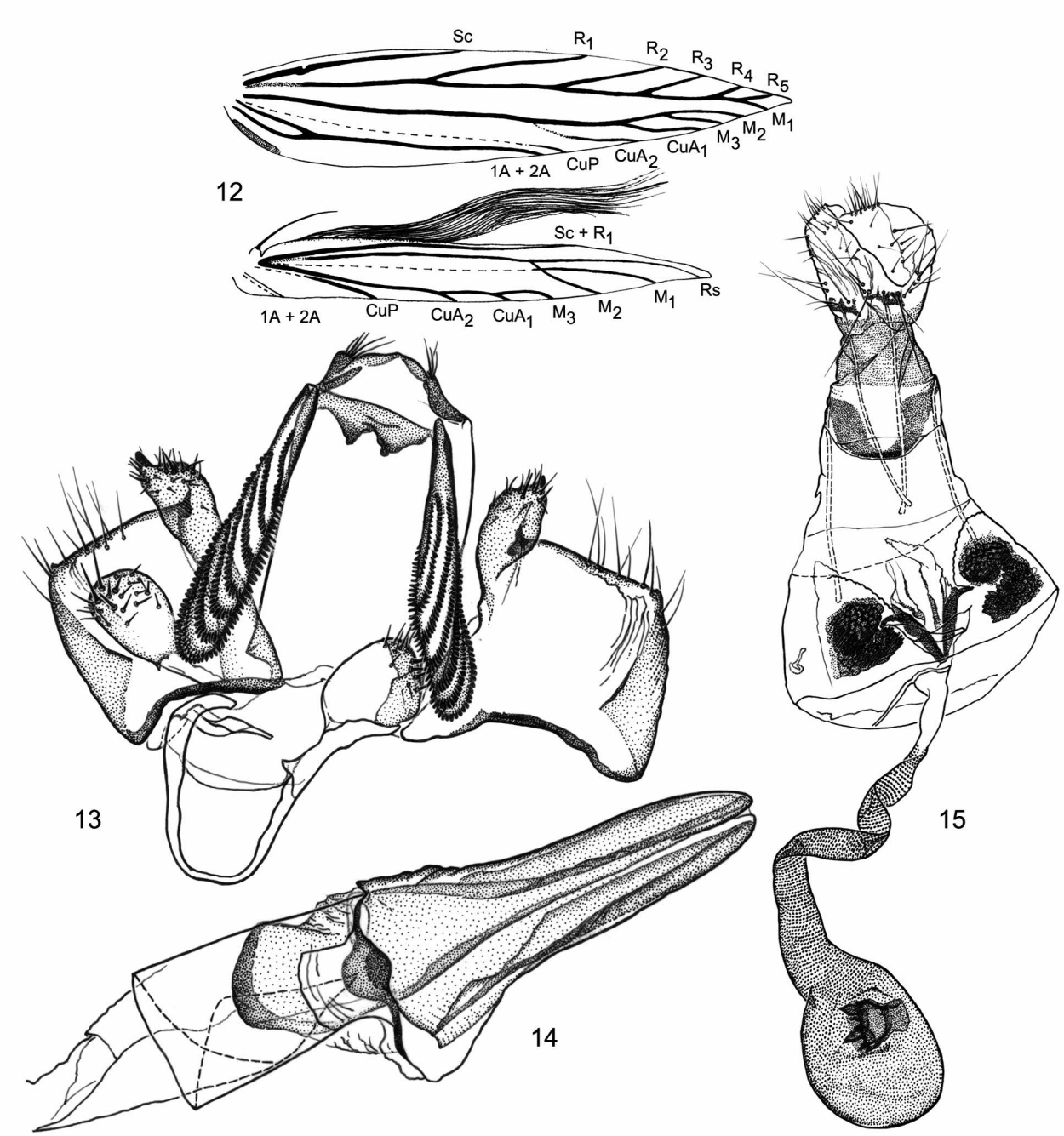
Clarke (1965) illustrated the forewing venation of *M. asaphaula* with five radial veins, but it has only four (Fig. 9).

Metharmostis multilineata Adamski, **new species**
(Figs. 11–41)

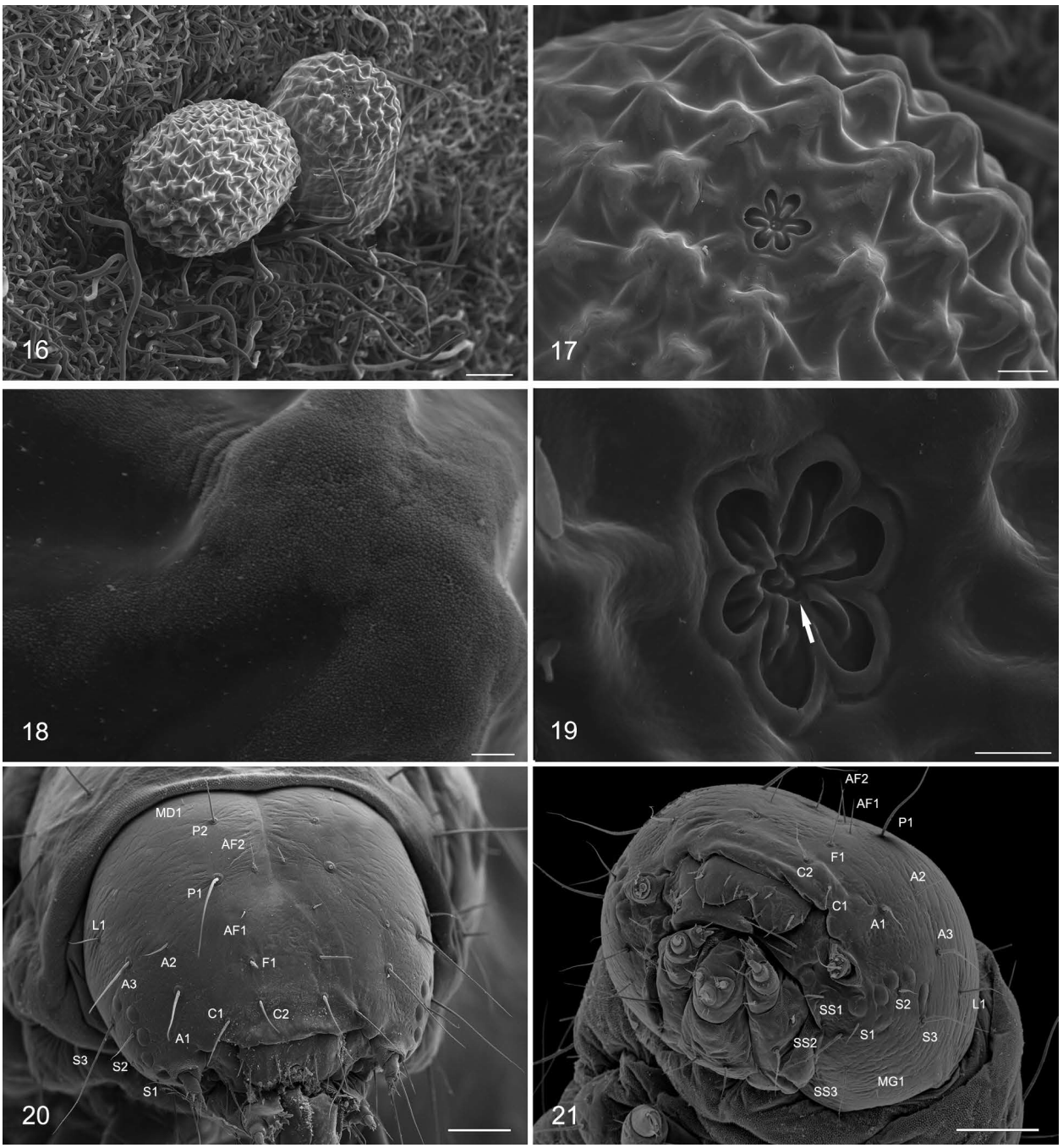
Diagnosis. *M. multilineata* is most similar to *M. asaphaula*: the two share a similar forewing pattern and a cluster of long hair-pencils from the base of the frenulum in the male. *M. multilineata* can be distinguished from *M. asaphaula* by the absence of a pterostigma between Rs and R_1 of the forewing, its wider eighth sternum, and its signum with one pair of smaller denticles on the same side.

Description. *Head*: Vertex and frontoclypeus with scales with transverse, irregular, and alternating bands of white and gray or pale gray. Labial palpus three segmented, curved in parallel with frontoclypeus, extending beyond vertex; basal segment very short, second segment slightly longer than terminal segment; second

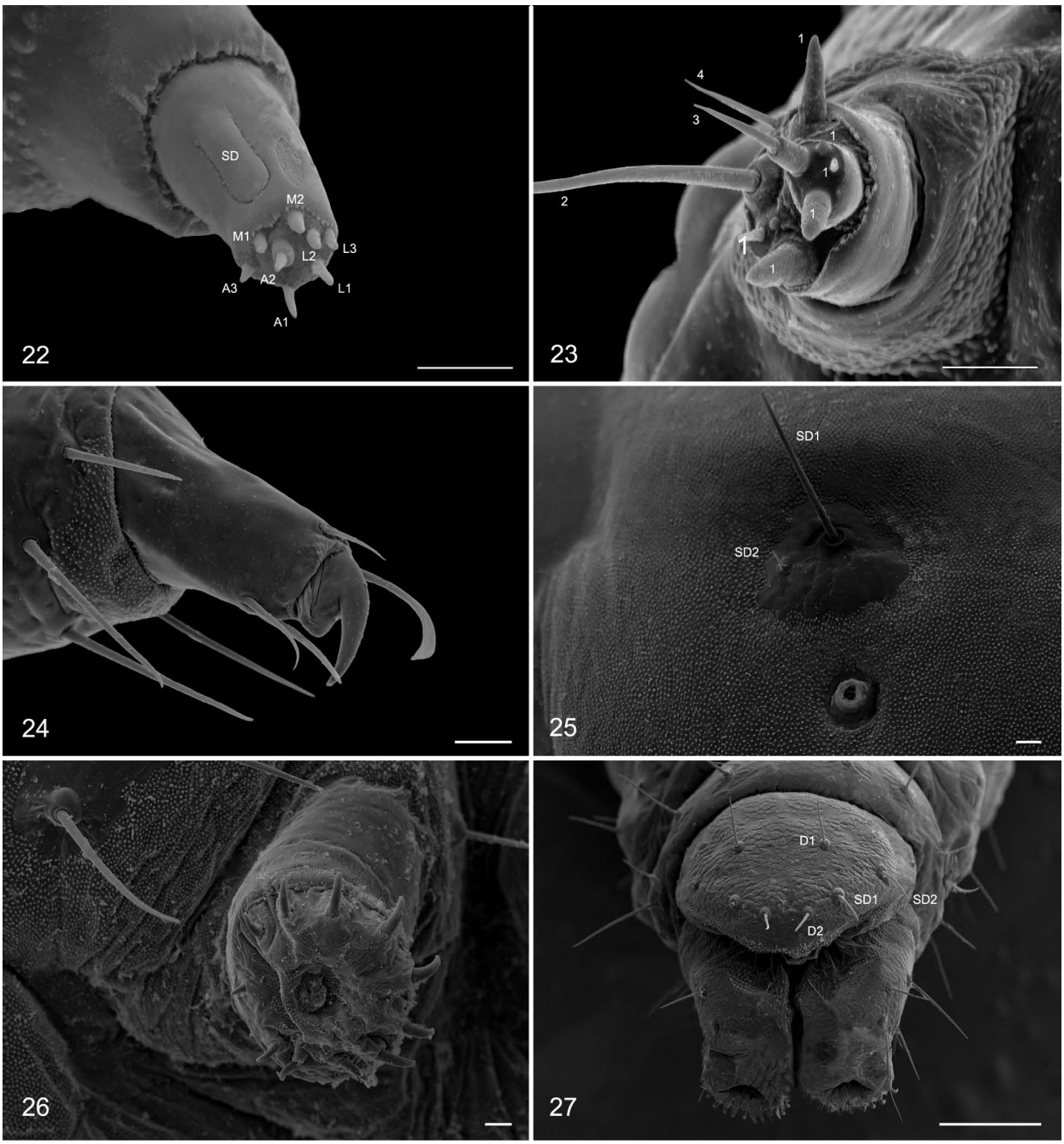
FIG. 11. Adult of *Metharmostis multilineata*, male, paratype, Hong Kong, China.



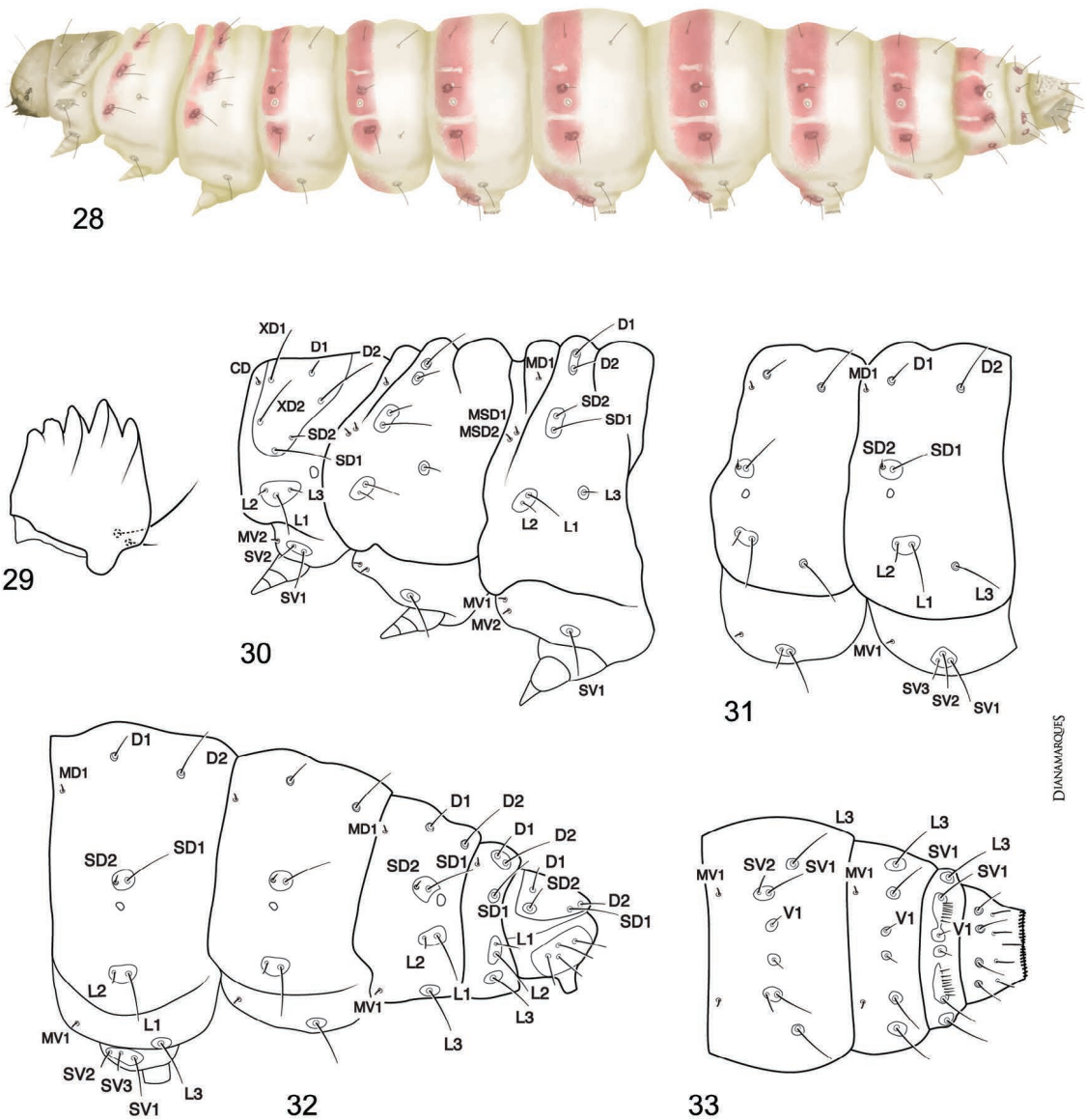
FIGS. 12–15. Wing venation, male genitalia, and female genitalia of *Metharmostis multilineata*.**12**, Forewing and hindwing, male voucher slide. **13**, Genital capsule, holotype, USNM slide 84156. **14**, Phallus, holotype, USNM slide 84156. **15**, Female genitalia, paratype, USNM slide 84163.



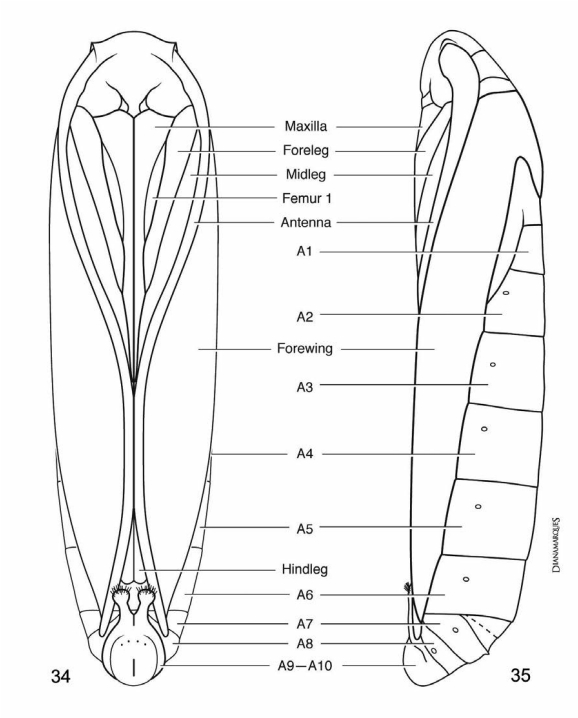
FIGS. 16–21. Scanning electron micrographs of egg and larval head capsule of *Metharmostis multilineata*. **16**, Two eggs on leaf of host. Scale = 100 µm. **17**, Apical end of egg showing micropylar rosette and chorionic relief radiating from rosette. Scale = 20 µm. **18**, Fine structure of chorionic relief. Scale = 2 µm. **19**, Micropylar rosette with arrow pointing to entrance to micropyle. Scale = 10 µm. **20**, Head capsule, frontal view. Scale = 100 µm. **21**, Head capsule, ventrolateral view. Scale = 100 µm.



FIGS. 22–27. Scanning electron micrographs of larval maxillary palpus and antenna, and thoracic and abdominal appendages and regions of *Metharmostis multilineata*. **22**, Left maxillary palpus and associated sensilla, frontoapical view; A2 = sensillum styloconicum, A1, A3, M1, M2, L1, L2, and L3 = sensilla digitiform. Scale = 10 µm. **23**, Right antenna and associated sensilla, apical view; 1 = sensilla basiconica, 2, = sensilla chaetica, 3 = sensillum styloconicum, 4 = sensillum trichodeum. Scale = 10 µm. **24**, Left mesotarsus, inner view. Scale = 10 µm. **25**, Spiracular area of A4, lateral view. Scale = 10 µm. **26**, Right proleg on A5. Scale = 10 µm. **27**, Anal plate on A10, caudal view. Scale = 100 µm.



FIGS. 28–33. Mandible and larval chaetotaxy of *Metharmostis multilineata*. **28**, Illustration of entire larva showing color pattern. **29**, Right mandible, inner surface. **30**, Thorax, lateral view. **31**, A1–A2, lateral view. **32**, A6–A10, lateral view. **33**, A7–A10, ventral view.



FIGS. 34–35. Pupa of *Metharmostis multilineata*. **34**, Ventral view. **35**, Lateral view.

segment elongate, alternating tufted, white narrow bands with wider, dark-gray bands ventrally, with a large, white apical tuft; terminal segment with alternating tufted, narrow white bands with wider, dark-gray bands. Antennal scape with basal and apical 1/4 gray or dark gray, middle 1/2 pale gray; pecten dark gray or dark gray tipped with white; flagellomeres basally gray or dark gray, apically pale gray or white. Proboscis white-scaled. *Thorax*: Tegula dark gray on basal 1/2, pale gray on apical 1/2. Mesonotum pale gray intermixed with few gray scales. Legs dark gray with narrow white bands along apical margins of all segments and tarsomeres. *Forewing* (Fig. 11) length 3.9–5.1 mm (n = 8); pale gray intermixed with gray scales, patterned with two rows of grayish-yellow streaks from base of cell to crossvein; streaks interrupted by narrow, pale gray or white scale tufts, partially demarcated by distinct or suffuse dark-gray streaks from above veins; basal region with a single grayish yellow streak; area posterior to CuP with two wide grayish-yellow patches; area from crossvein to apical margin gray intermixed with few pale-gray scales, marginal spots grayish yellow; venation (Fig. 12) with pterostigma absent between Sc and R_1; cell open; R_5-M_1 stalked; M_1 separate from a stalked M_2-M_3; cubitus 4-branched. Undersurface pale gray except, dark gray within distal 2/3 area of cell. Hindwing pale gray with gray fringe; male with an elongate, medially crooked, cluster of hair pencils originating from slightly beyond base of frenulum to 4/5, with a narrow dark-gray streak extending from base of Rs to 1/5, and a dark-gray margin to posterior margin; venation (Fig. 12) with Rs arched apically; M_1-M_2 stalked, separate from M_3; cubitus 3-branched. *Abdomen*: Male genitalia (Figs. 13–14) with uncus rudimentary, basally fused with short, apicolateral arms of tegumen, each arm bearing a small setal cluster near apical margin. Gnathos narrow laterally, widening towards a broadly rounded medial emargination, forming two angular teeth pointed ventroposteriorly; two decumbant, oblanceolate, and slightly asymmetrical processes originating from dorsolateral apices of tegumen, each process with deeply crenulate outer margins and deeply crenulate, curved struts within. Vinculum U-shaped, narrower than valval length. Juxta quadrate. Valva subquadrate, with basiventral margin extending to dorsal apex of vinculum, inwardly-curved outer margin, a stalked setose and bulbous structure near middle, and a stout digitate, setose process arising from basidorsal margin; process also bearing a short apical spine. Phallus free and not ankylosed, elongate, widened near 1/3, apical part parallel-sided throughout most of length, gradually narrowed apically; apical 2/3 divided along median longitudinal axis. *Female genitalia* (Fig. 15) with papillae anales setose throughout, longer setae on basal 1/3. Apophysis posterioris about equal in length to apophysis anterioris; eighth sternum wide, semicircular, apically fused with apophyses posteriores. Ostium within membrane between divided seventh sternum; divided parts broadly rounded and ridged along inner margin, slightly recessed medially, bearing a dense cluster of sex scales; two narrow flanges divergent from lateral walls of anterior part of antrum to inner margin of seventh sternum. Corpus bursae smooth from ostium to slightly beyond anterior margin near swollen base of ductus seminalis, denticulate anteriorly, including corpus bursae; signum rounded, spinulate, with two large subequal denticles along margin of one side.

Holotype ♂, "THAILAND: Nakhon Si Thammarat Province: Muang District: Tambol Pak Poon, Ban Pak Poon School; Coll. A. Winotai, 15.IV.2001; 08°31.28N, 99°58.56E; Reared from striped larva boring flower bud & fruit of *Rhodomyrtus tomentosa*", "♂ genitalia slide by D. Adamski, USNM 84156." [USNM]

Paratypes (2 ♂, 5 ♀): 1 ♀, Same label data as holotype except, "♀ genitalia slide by D. Adamski, USNM 84157": 1 ♂, 1 ♀, same label data as holotype except, "Ban Yang Tia, 31.V.2003, Ex. *Rhodomyrtus tomentosa*", "♂ genitalia slide by D. Adamski, USNM 84158": "♀ genitalia slide by D. Adamski, USNM 84159": 1 ♂, 1 ♀, Same label data as above except, "Trat Province: Klong Yai District: nr. Haad Sai Kaew; 3.IV.2001; 11°54.83N, 102°48.59E", "♂ genitalia slide by D. Adamski, USNM 84160", "♀ genitalia slide by D. Adamski, USNM 84161": 1 ♀, "CHINA: Hong Kong: New Territories, Ngau Liu, 20 July 2009; 22°21.255'N, 114°13.854'E; [Coll.] J. Makinson, ABCL 2009942.P001", "Adult reared from fruit of *Rhodomyrtus tomentosa*. Larva pupates on leaf vein", "♀ genitalia slide by D. Adamski, USNM 84162": 1 ♀, "ABCL Quarantine Colony, ex. [CHINA] HONG KONG, Nov. 2009, [Coll.] J. Makinson, ABCL Idiophantes from *Rhodomyrtus tomentosa*", "♀ genitalia slide by D. Adamski, USNM 84163." [USNM]

Etymology. The species epithet, *multilineata*, is a compound word formed from the Latin *multi* meaning many and *linea* meaning line, together referring to the many streaks on the forewing of the adult moth.

Early Stages. Egg (Figs. 16 – 19): About twice as long as wide, apically domelike (Fig. 16). Chorionic relief with longitudinal rows of stellate projections radiating from perimeter of micropylar rossette (Fig. 17), each connected by 5–6 struts; dorsal surfaces of raised projections and struts granulate, giving a velvety appearance to their dorsal surface (Fig. 18). Micropylar rossette on exposed end, with six petal-like depressions radiating from a small central circle; each depression with a longitudinal ridge extending from outer margin of central circle to 2/3; inner circle with 2–3 shallowly pointed projections; entrance to micropyles appear on proximal end of fused, adjacent, outer ridges of each pair of petal-like depressions (Fig. 19).

Larva (Figs. 20–33). Length 4.1–4.7 mm; body cylindrical, slightly dorsoventrally flattened from A7–A10 (n = 4 preserved larvae). Head capsule, prothoracic shield, thoracic legs, and anal shield pale brown or brownish yellow; pinacula small, brown. Body pale gray to white interrupted with transverse pale-red patches encompassing D-group, SD-group, and L-group pinacula on T2-T3 (Fig. 28); T3 with a narrow, transverse pale red stripe near dorsoanterior margin; A1-A8 with wide, transverse, pale-red stripes, interrupted by a small, linear, pale-gray patch of tonofibrillary platelets between D-group and SD-group pinacula, a circular, pale-gray spot encompassing the spiracle, areas above and below L-group pinaculum, and anteriorventral to L3 pinaculum and SV-group setae. Spiracles on T1 and A8 slightly above and slightly larger than those on A1-A7.

Head (Figs. 20–23, 29): Hypognathous; epicranial suture extending to epicranial notch, beyond apex of frons, dividing head

into two hemispheres (Figs. 20–21); adfrontal sclerites delimiting frons; frons wide basally, abruptly narrowed at 1/3 length from base, gradually narrowing to apex; AF2s slightly above or at same level of apex of frons; AF2 and AF1 about same length, slightly shorter than F1; distance between AF1 and AF2 about 3× distance between AF1 and F1; distance between F1 and AF1 about 3× distance between F1 and C2; C1 slightly longer than C2; P1 and A1 longest cranial setae; P1 about 4× length of P2, both below AF2, P2 slightly dorsal to P1; P2 in straight diagonal line with MD1, MD2, MD3 (not shown); L1 about ¼ length of and posteroventral to A3; A3 above and between stemmata 1–2; A1 about 1/3 longer than A2, in near straight line with C2, both perpendicular to median longitudinal axis; five stemmata (1–4 and 6) in a semicircle, stemmata 3–4 approximate; stemma 5 beneath antenna (Fig. 21); S3 beneath stemma 1, about 3× longer than S1 and S3; S3 on lower aspect of gena, and posterolateral of SS3; S2 slightly beneath and between stemmata 2–3; SS1 beneath antenna; SS2 between stemmata 5–6; SS3 posterior to and closer to midline than SS2; clypeus with six pairs of setae, two subequal pairs medially; two subequal pairs along proximolateral margin, and two pairs of equal length along margin lateral to notch; mandible with two large dentitions flanked by two smaller dentitions, and bearing two subequal setae dorsally (Fig. 29); sensilla of maxillary palpus (Fig. 22) sensilla of antenna (Fig. 23); posterior part of labium with two divergent setae slightly anterior to submental pit; spinneret cylindrical and elongate. Dorsal cervical seta ventroposterior to epicranial notch (Fig. 20, partially shown).

Thorax: (Figs. 24, 28, 30): T1 shield pale brown or brown along posterior and lateral margins; XD1 and XD2 equal in length, along anterior margin; SD1 slightly longer and slightly posterior to XD1 and XD2 (Fig. 30); SD2 about 1/5 length of and slightly dorsoposterior to SD1; D2 about equal in length to SD1, along posterior margin, equidistant to XD1 and XD2, forming a large triangle; D1 about equal in length to SD2, slightly anterior to D2 and close to median longitudinal axis; L-group trisetose, L1 about 5–6× longer than L2; L2 slightly shorter than L3; SV1 about 2× longer than SV2, both setae on same pinaculum; MV2 anterior to SV-pinaculum; coxae approximate, about 1/4–1/5 closer than on T2–T3 (not shown); V1s approximately about 1/4 closer than on T2-T3 (not shown); pretarsus with two setae above claw and two setae beneath claw, dorsal seta on outer surface flattened distally (Fig. 24). T2-T3 (Figs. 28, 30): D1 about 2–2 1/2× longer than D2, each on separate pinaculum on T2, same pinaculum on T3; MD1 anterioventral to SD1; SD1 about 2–2 1/2× longer than SD2, each on same pinaculum; SD-pinaculum ventroanterior to D2 pinaculum; MSD1 and MSD2 anterioventral to SD-pinaculum; L1 about 2–2 1/2× longer than L2, each on same pinaculum ventroanterior to SD-pinaculum; L3 same length as L2, slightly dorsal to, and posterior to L1-L2 pinaculum, and above and slightly posterior to SV1; MV1 and MV2 anterior to SV1.

Abdomen: A1–A2 (Figs. 25, 28, 31) with D2 ventral to and about 2–2 1/2× longer than D1; MD; MD1 on anterior margin ventral to D2; SD setae on same pinaculum dorsoanterior to spiracle (more so in A1); SD1 about equal in length to L1, SD2 minute (Fig. 25, 31–32, enlarged); L1 about 2–2 1/2× longer than L2, on same pinaculum; L3 about equal in length to L1, in line with or slightly anterior to D2; SV-group bisetose on A1, each seta on same pinaculum, with SV1 about 2–2 1/2× longer than SV1; SV-group trisetose on A2, in a triangular pattern on same pinaculum, SV1 about 2 1/2–3× longer than SV3 and slightly longer than SV2; MV1 along anterior margin in line with SV-pinaculum; V1s about equidistant apart to V1s on A8 (not shown); A3-A6 (Figs. 28, 32) as above except, SD1 dorsal and slightly posterior to spiracle, planta of prolegs bearing uniserial and uniordinal crochets in a lateral penellipse (Fig. 26); A7 as above except, SV-group bisetose, with SV1 about 2× length of SV2 (Figs. 28, 32–33); A8 as above except, spiracle on posterior half of segment, SD-group pinaculum dorsoanterior to spiracle, L1–L2 pinaculun ventroanterior to spiracle, and L3, SV1, and V1 in a straight line; V1s about 2× farther apart than V1s on A9; A9 (Figs. 28, 32–33) with D2 about 2× longer than D1, both on same pinaculum; SD1 about equal in length to D2; L2 about 2× longer than L1, each on same pinaculum; L3 about as long as L2; SV-pinaculum transversely elongate with SV1 on dorsolateral end and 6–8 hairlike setae on posterior margin (enlarged); some specimens with pinaculum bearing V1 fused with elongate SV-pinaculum (Figs. 28, 32–33); A10 with shield bearing four pairs of setae (Figs. 27-28, 32-33); SD1 slightly longer than SD2; SD2 slightly longer than D1 and D2; SD1 about 3X distance from SD2 than distance from D2; D2 and D1 in straight line parallel with median longitudinal axis; planta of prolegs with 10–11 uniserial and uniordinal crochets, crochets on each end about 1/2 length of middle crochets.

Pupa (Figs. 34–35): Length 3.4–3.7 mm (n = 6). Slightly flattened dorsoventrally; smooth; golden yellow, with thin brown lines demarcating sclerites; vertex rounded; frontoclypeus convergent, broadly rounded distally; antennae broadly rounded from vertex, encircling sclerites of maxillae, forelegs and midlegs, meeting medially near 2/3, extending in parallel, diverging distally beyond apices of forewings, exposing sclerites of hindlegs; maxillae and sclerites of midlegs extending to a common point with convergent antennae posterior to sclerites of midlegs; segments A7–10 movable from proximal end, decumbent; cremaster with two anteriorly-directed, slightly-divergent, spatulate processes, extending to near apices of hindlegs; each process with many hooked spinules on distal end.

Biology. Eggs of *Metharmostis multilineata* are typically laid singly or in small clutches at the junction of the basal part of the terminal twig and the lateral leaf-buds or at the junction of the midvein and lateral veins on the undersurface of the terminal or subterminal leaves (Figs. 36–37). Newly hatched larvae usually migrate to a flower bud (Fig. 38) or leaf bud (Fig. 39) and mine into it. The mature larva tunnels proximally out of the flower bud or leaf stalk, leaving a drooping terminal part (Fig. 40), and makes a silken cocoon on a new bud, a stem beneath the previously mined portion (Fig. 40), or on the undersurface of a nearby leaf parallel to the midvein or lateral veins or at the leaf's edge (Fig. 41). In the laboratory, development from oviposition to adult stage takes about 45–48 days; 3–6 days for the egg, 30 days for the larva, and 12 days for the pupa at 27°C. The total number of instars for larval development was not determined. Six generations were maintained in the laboratory from March 2011 to March 2012. Although larvae were found in stems and in old fruits of *Rhodomyrtus tomentosa* throughout the year, the number of generations could not be determined from field observations in Hong Kong and in Thailand. In quarantine, adults lived from 6–8 wks: one female lived 22 wks. Females have a preovipositional period of about 2 weeks or slightly longer.

Distribution. *Metharmostis multilineata* was collected in Thailand and Hong Kong, China. It probably occurs throughout the tropical Indo-Asian region.

Parasitoids. Eighteen specimens of *Apanteles* sp. and 20 specimens of *Cotesia* sp. (Braconidae) were reared from pupae of *Metharmostis multilineata* collected from Hong Kong.

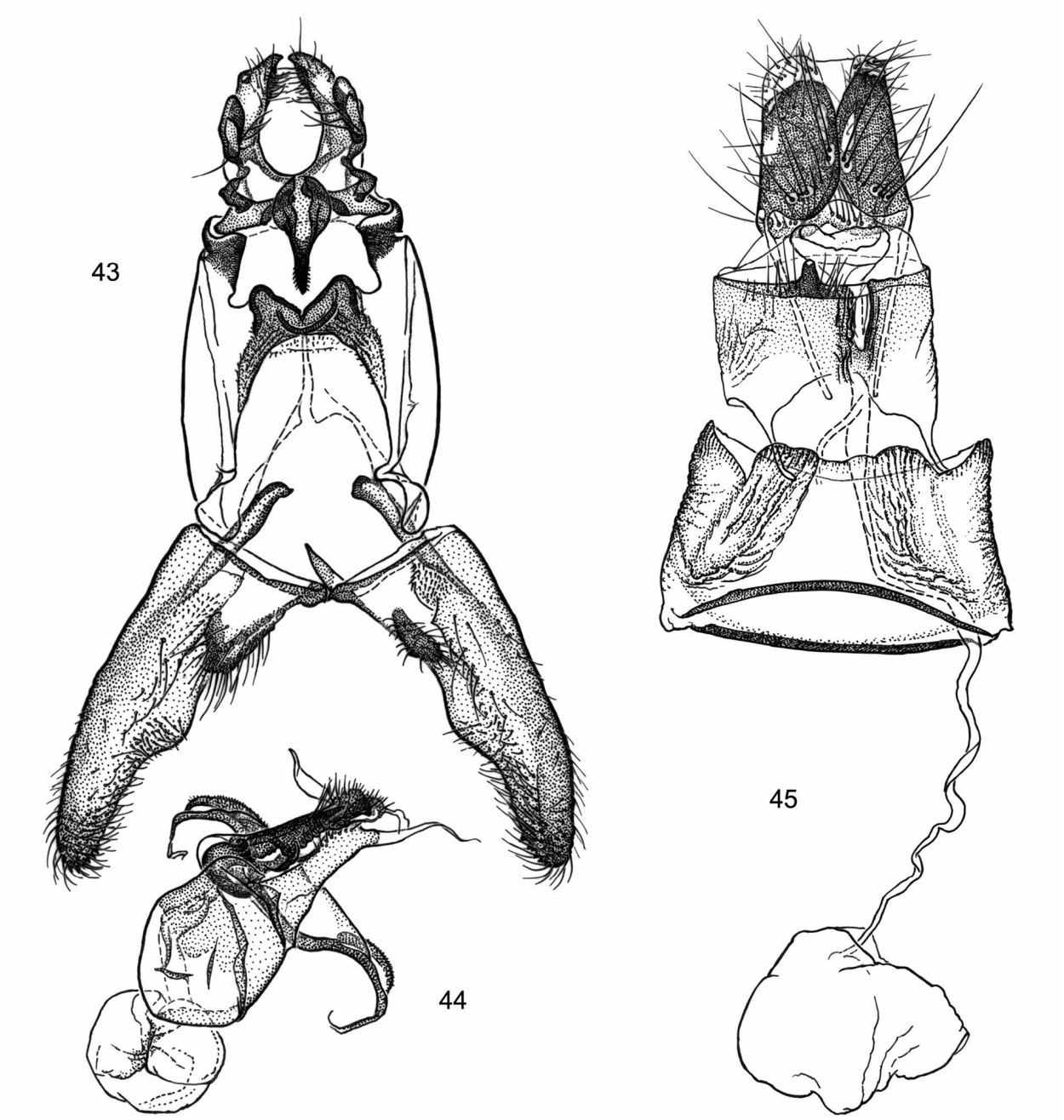
Idiophantis soreuta Meyrick, 1906
(Figs. 42–45)

Redescription. *Head*: Vertex and frontoclypeus pale grayish orange. Labial palpus sickle-shaped, long, extending beyond vertex; outer surface gray basally, gradually darkening to dark brown apically, inner surface pale grayish brown. Antennae with scape and pecten brown, flagellum grayish orange. Proboscis with pale grayish orange scales.

Thorax: Tegula and mesonotum grayish orange. Legs gray. *Forewing* (Fig. 42) length 5.0 mm (n = 2) grayish orange with area from base of costa to CuP apically to near crossvein of cell dark brown, continuing as a series of alternating pale grayish-orange and pale-gray strigulae to apex; subapical margin deeply and broadly excised, forming a posteriorly-curved, apical digitus and a larger, more broadly-rounded, apicoposterior margin; cell with a dark-brown

FIGS. 36–41. Oviposition sites, larval damage, and pupation sites of *Metharmostis multilineata*. **36**, Arrow indicating egg between small bud and base of petiole of lateral leaf. **37**, Arrows indicating eggs on undersurface of leaf at junction of midvein and lateral veins. **38**, Arrow pointing to frass indicating larva feeding within flower bud. **39**, Arrow pointing to frass indicating larva feeding within terminal part of stem. **40**, Larval feeding causing drooping of apical part of stem. Arrow pointing to cocoon. **41**, Pupa teased from cocoon on undersurface of leaf.

FIG. 42. Adult of *Idiophantis soreuta*, male, voucher specimen, Thailand.



FIGS. 43–45. Male genitalia and female genetalia of *Idiophantis soreuta*. **43**, Genital capsule, USNM slide 84164. **44**, Phallus with juxta attached, USNM slide 84164. **45**, Female genitalia, USNM slide 84165.

streak near middle, a minute dot near 2/3, and a larger, crescent-shaped marking demarking border of excised area. Undersurface yellow brown. Hindwing translucent pale gray, gradually darkening to apex.

Abdomen: *Male genitalia* (Figs. 43–44) with uncus widened basally, extending dorsally, with two crescent-shaped processes; base with a large, Y-shaped median process, connected apically from its arms by two lateral arms, each fused onto an apically excavated part of a dilated lateral process of tegumen. Gnathos emarginate medially, forming two dorsolaterally projecting angular processes juxtaposed laterad to a ventrally projecting base of median process of uncus. Tegumen near parallel-sided. Valva elongate, nearly 3× longer than basal width, gradually narrowing and more densely setose apically; dorsal articulations elongate, separate; ventral articulation fused; ventral margin with a swollen medial lobe; base with a darkly pigmented shallow, setose, lobe. Vinculum narrow medially, bifurcate laterally, fusing with juxta. Juxta elongate and setose apically, supporting phallus. Phallus bulbous basally, narrowed apically, with a lanceolate membranous projection on one apicolateral side. *Female genitalia* (Fig. 45) with papillae anales large, darkly-pigmented, setose lobes; longer setae on ventral margin; apophyses posteriores about 3× longer than apophysis anterioris; apophysis anterioris extending from a widened eighth sternum; eighth sternum widely emarginate anteriorly, deeply and narrowly notched mediolaterally on posterior end, juxtaposed to a median, posteriorly-pointed tooth-like projection. Ostium wide, within membrane posterior to eighth sternum. Ductus bursae long, about 4× longer than apophysis posterioris, narrowed from a widened, membranous antrum, narrowing gradually from region anterior to inception of ductus seminalis near posterior margin of seventh sternum. Seventh sternum divided medially, deeply wrinkled from inner margin to a broadened emargination on posterior end. Corpus bursae subspherical and membranous.

Type (examined). Lectotype ♂, [round label with a red circle in middle]; "[Sri Lanka] Ceylon, Puttalam, 12 [December] [19]04, Pole [Coll.]"; "Lectotype, *Idiophantis soreuta* Meyrick, [designated by] JFGC Clarke, 1948"; "♂ genitalia on slide 17.x.1948, JFGC 8391", "*Idiophantis soreuta* Meyr., 4/1 E. Meyrick det., in Meyrick Coll[ection]"; "Meyrick Coll[ection]", "*soreuta* Meyr." [handwritten label]; "Meyrick Coll[ection], BM 1938-290."

Other Specimens Examined (1 ♂, 1 ♀). "THAILAND: Trat Province: Klong Yai District; Mai Root Trat; 11°50.03'N, 102°50.51'E; A. Winotai [Coll.]; 18.VI.2001; ABCL 2001431; Reared from striped larva boring fruit of *Rhodomyrtus tomentosa*", "♂ genitalia slide by D. Adamski, USNM 84164", ♀ genitalia slide by D. Adamski, USNM 84165." [USNM]

Biology. *Idiophantis soreuta* Meyrick was reared from fruits of *Rhodomyrtus tomentosa* in Thailand. Other host records for *Idiophantis* were reported by Meyrick (1914, 1931), Gater (1926), and Bradley (1968). Meyrick (1931) reported that *Idiophantis acanthopa* Meyrick was reared from *Eugenia jambolana* Lam. (Myrtaceae) from India, and that *I. chirodota*, which occurs in India, Sri Lanka, Java, and Malaya, was reared from psyllid galls on *Eugenia* sp. (Meyrick 1914). Gater (1926) also reported *I. chirodota* from galls on *Durio zibethinu*s Murray (Malvaceae). Finally, Bradley (1968) reported that *I. eugeniae*, a closely allied species to *I. chirodota*, was reared from galls on leaves of *Eugenia* sp. on New Ireland in Papua New Guinea.

Distribution. *Idiophantis* inhabits principally the Indo-Australian region, but extends eastward to the Seychelles Islands, Madagascar, and South Africa.

Remarks. *Idiophantis soreuta* was previously misidentified as *Agriothera* sp. (Roeslerstamiidae) by Winotai et al. (2005). This species is similarly patterned with red stripes on the body as *Metharmostis multilineata*. Unfortunately, only two larvae were collected and reared to the adult stage, and no larval pelts are available for examination.

DISCUSSSION

A range of herbivores were found feeding on *R. tomentosa* in Hong Kong, but as with surveys in Thailand, *M. multilineata*, was the most common. Larvae had been collected from almost every field site surveyed. In 2009 *M. multilineata* was selected as the first candidate for evaluation at the IPRL Gainesville Quarantine Laboratory. Six generations of *M. multilineata* were successfully obtained during the quarantine trials. When a viable colony was established, host range-tests were initiated. Trials using an ornamental, *M. communis*, and two threatened species native to Florida, *C. pallens* and *M. fragrans*, exhibited positive rearing results; hence, all further plans to test *M. multilineata* as a biocontrol agent against *R. tomentosa* in Florida were aborted. *I. soreuta* was not found in suitable numbers in Asia and was never considered for quarantine rearing trials on *R. tomentosa*.

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