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Taxonomic studies on external genitalic attributes of two species of genus *Rhagastis* Rothschild and Jordan (Lepidoptera: Hawkmoths)

Sujata Saini
Punjabi University Patiala, Punjab-147001, India
sujatasaini1@gmail.com

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Abstract

Hawkmoths, (family Sphingidae) also known as 'Sphinx' or 'Humming bird' and are economically important. There are 183 species of Sphingidae compiled in volume V of 'Fauna of British India, Moths' and approximately 1000 species found all over the world. During the present studies, Rhagastis hayesi Diehl and Rhagastis aurifera (Butler) have been treated by taking various taxonomic characters, particularly the external genitalia to facilitate their authentic identification, diagnosis and differentiation as genital morphology shows peculiar patterns of variation among insects and both these species are first time reported from North-West India. Traditionally, external genitalic features of insects are considered as highly species specific in general and of high relevance in order Lepidoptera in particular. However, genitalic characters have been ignored by eminent workers. The adult representatives of hawkmoths namely hayesi Diehl and aurifera (Butler) of genus Rhagastis Rothschild & Jordan were collected with help of light trap fitted at different places in North-West India and after proper stretching were finally preserved in air tight wooden boxes containing naphthalene balls. In this research paper, the detailed study of morphological as well as external genitalic features of both the species have been study to update their taxonomic status in family Sphingidae.

Keywords: Lepidoptera, hawkmoths, external genitalia, *Rhagastis* Rothschild and Jordan, *hayesi* Diehl and *aurifera* (Butler).

Introduction

Sphingids are commonly known as "Sphinx" or "Hawk moths" or "Hornworms". Their larvae have a dorsal horn at the tip of the abdomen and when disturbed the larvae will resume a sphinx-like position by tucking the head and holding the legs off the surface; this is most likely why members of the family are known as "Sphinx moths"[1]. 183 species of Sphingidae in volume V of '*Fauna of British India, Moths*'[2]. These are represented by approximately 1000 species all over the world[3]. Sphingids are known to be one of the fastest fliers of order Lepidoptera which can reach 40-50km/hr. Because of their capability to fly far away, these moths are potential long distance pollen dispersers[4] and may be diurnal, crepuscular or nocturnal. The wings are narrow allowing the organism to have a strong rapid wing beat[5]. Family Sphingidae have their close relationship to the superfamily Bombycoidea[6,7,8] and placed in this superfamily rather than treated as a separate superfamily. Other entomologists[9,10] followed the same nomenclature as followed by above authors. Rothschild and Jordan[11] proposed this genus for proper placement of seven species i.e., *velata* (Walker) as the type species; *abdomarginatus* (Rothschild), *acuta* (Walker); *aurifera* (Butler), *gloriosa* Butler; *lunata* (Rothschild) and *olivacea* (Moore). These species are characterized with prominent series of spots on forewings and a large apical tuft on inner side of labial palpi. They also added two new species i.e., *lunata sikhimensis* and *confusa* from India. Chu and Wang[12] reported a new species i.e., *yunnanaria* from China. The genus is diverse in the Oriental tropics and subtropics[13] and represented by twelve species. Hungfu and Linyao[14] dealt with four species from China. Kaur[15] studied two species *viz*., *velata* (Walker) and *olivacea* (Moore) from India. In the present studies two species i.e., *aurifera* (Butler) and *hayesi* Diehl have been studied with detailed accounts on their morphological and genitalic structures. A key to species along with their host plants has also been provided in this research paper and both the species are first time reported from North-West India.

Economic Importance: The members of family Sphingidae play a significant role in pollination and conservation of plant diversity. The length of sucking proboscis (*Agrius convolvuli* (Linnaeus) 125mm-130mm, *Macroglossum stellatarum* Linnaeus 25mm-28mm; *Sphinx ligustri* Linnaeus 37mm-42mm and *Cocytius cluentis* Cramer 250mm) plays a greater role in view of the diversity of the flower structures and position and length of nectary. The long proboscis of hawkmoths and long floral tubes of flowers they pollinate, is often considered to be a classical example of co-evolution. One of the Sphingid species i.e., *Rhagastis olivacea* Moore is even capable of drinking human tears from the eyes and termed as lacryphagous[16]. *Manduca sexta* (common name-Tobacco hawkmoth) is widely used as a "laboratory" and "experimental" species in U.S[17]. The larvae of *Periphoba hircia* (Cramer) defoliate *Acacia mangium* Willdenow in the state of Roraima, Brazil[18].

Materials and methods

The material for the present study i.e., the adult moths of family Sphingidae were collected exclusively from during night hours from different localities of North-West India (2013-2015) by using vertical sheet method[19]. The collected moths were stored with ethyl acetate vapors and were pinned, stretched and finally preserved in air tight wooden boxes with proper care. To study wing venation, the method[20] has been followed.

Study of external genitalia: To study external male and female genitalia, an entire abdomen was detached from thorax of moth and placed in 10% sodium hypochlorite (KOH) to soften the chitin for about overnight. After this, potashed material was cleaned in Distilled water so that all the unwanted traces and excess of KOH removed. The abdomen was dissected by using 50% alcohol for both male and female genitalia. After proper dehydration in different grades of alcohol, the genitalic structures were cleared and preserved in clove oil. The terminology[22] has been followed in the present studies and research paper. The illustration of external genitalia has been done by using image processor and adult moths were also photographed in colour with a digital camera-Canon 300D.

Results and discussion

Sphingidae: Latreille, 1802, *in* Sonnini, *History Natural Genes particuliere Crust. Insects,* 3: 400; Samouelle, 1819, *Entomology Comparision,* 1819: 243.

Diagnosis: Labial palpus long, thickly scaled; third segment minute, generally buried in scaling; first segment with or without a patch of long scales at base; second segment with inner surface scaled or naked, sometimes excavate. Proboscis usually well developed. Antenna filiform, setiform or clavate, rarely bipectinate, tapering towards distal end; males having bands of cilia on undersurface; distal end hooked, end segments long or short, having long bristles; in few cases where distal end is clubbed, flagellum is very thin basally. Thorax strongly build. Forewing elongated, narrow, apically acute in many genera, without ocelli; anal vein 1A+2A forked at base; M_2 from or from near discocellulars (middle); M_1 arises from angle (upper) of discal cell or stalked with R_5 and R_4; R_3 and R_2 totally fused, bifurcating in some Smerinthini. Hindwing shorter than forewing, triangular, frenulum and retinaculum usually present. Legs strong, tibiae simple or spinose; fore-tibia often ending in a thorn or claw; mid leg with one pair of tibial spurs and two pairs of tibial spurs at hindleg; tarsi spinose; pulvillus usually present. Abdomen generally sharply spined, but weaker in many Sphinginae. Male genitalia with well developed, strong uncus and gnathos, may be bifid; socii absent; valva usually simple, well developed, often with a patch of friction scales on exterior side; sacculus with strong saccular projection; aedeagus often with spurs or sclerotized process at distal end; vesica sometimes scobinate. Female genitalia with ductus seminalis arising from ductus bursae; corpus bursae with or without signum; apophyses long.

Genus *Rhagastis* Rothschild and Jordan: Rothschild and Jordan, 1903, *Novit. Zool.*, 9: 791; Bell and Scott 1937, *Fauna British India, Moths*, 5: 465-466; Hungfu and Linyao, 1997, *Fauna Sinica*, 11: 368; Inoue *et al*., 1997, *Sphingidae Thailand*, 2: 119.

Type species: *Pergesa velata* Walker

Distribution: Oriental region

Key to the studied species of genus *Rhagastis* Rothschild and Jordan: i. Hindwing less fuscous; underside without black spot; vein $Sc+R_1$ anastomosing with cell beyond middle; abdomen with lateral sides ochreous without black spots; male genitalia with gnathos spatulate; juxta cone-shaped; valva with five friction scales……*hayesi* Diehl,
ii. Hindwing more fuscous; underside with distinct black spot; vein $Sc+R_1$ anastomosing with cell just before middle; abdomen with lateral sides pale orange having black segmental spots; male genitalia with gnathos clasper-like; juxta shield-like; valva with seven friction scales……*aurifera* (Butler)

***Rhagastis hayesi* Diehl:** *Rhagastis hayesi* Diehl, 1982, *Heterocera Sumatrana*, 1:71; Inoue *et al*., 1997, *Sphingidae Thailand*, 2: 120.

Diagnosis: Head with vertex and frons dressed with olive-brown scales, laterally edged with white scales. Labial palpus with brown scales. Antenna with scape furnished with white scales and shaft brown. Thorax having olive-brown scales, lower portion paler. Legs clothed with brown scales. Abdomen covered with olive-brown scales, dense towards distal end, paired dark dorsal specks on each segment; sub lateral sides ochreous without black spots; underside creamish white.

Wing maculation: Forewing with ground colour olive-brown; indistinct antemedial line; a black spot end of cell; three distinct postmedial dotted lines; submarginal dotted line prominent; marginal area with faint wavy fuscous band; cilia fuscous brown; underside fuscous suffused with orange scales, marginal area fuscous. Hind wing olive-brown, slightly tinged fuscous; postmedial and submarginal lines indistinct; submarginal band distinct; cilia fuscous brown; underside with orange scales, black spot paler, marginal area fuscous.

Wing venation: Forewing with discal cell less than half the length of wing; 1A+2A basal forked, basal less than one-fourth portion forked; Cu_2 from middle of discal cell (beyond); Cu_1 from before lower angle of cell; M_2 arises at below middle of discocellulars; M_3 originated at angle (lower) of discal cell; M_1 from upper angle of cell; R_5 and R_4 stalked; $R_{(3+2)}$ from before upper angle of cell; R_1 from beyond two-thirds of cell. Hindwing with discal cell less than half the length of wing; 2A forming a basal fork; Cu_2 from middle (beyond) of discal cell; Cu_1 arises lower angle (well before) of discal cell; M_3 from

lower angle of cell; M_2 from above middle of discocellulars; M_1 and Radial sector (RS) stalked from upper angle of discal cell; SC+R1arising originates through wing (base) forming bar beyond middle of discal cell.

Wing Expanse: Male: 76mm; Female genitalia: Not examined

Body Length: Male: 34mm; Female genitalia: Not examined

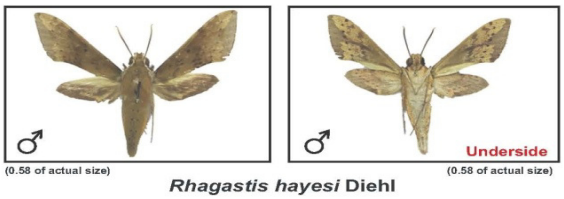
Male genitalia: Uncus of moderate size, narrow, setosed, well sclerotized, ending with blunt apex; gnathos spatulate, tip slightly notched, edges well sclerotized, slightly dentate; tegumen broad, semi-sclerotized, almost 2X length of vinculum; vinculum short with prominent 'U' shaped saccus; juxta small, cone-shaped. Valva simple, semi-sclerotized; extending above the level of uncus and having five long friction scales; sacculus with small falcate saccular projection with blunt tip; distal half of valva setosed with rounded tip. Aedeagus of moderate size, moderately sclerotized; proximal end produced, rounded; ductus ejaculatorius entering directly from proximal end; distal end armed with a curved, hood-like projection with dentate margins, distal end with a semi lunulate sclerotized plate with serrated margin.

Samplings done from: H.P (Himachal Pradesh): Chhitkul, 23 June, 2014, two ♂♂; Uttarakhand: Dobhighat, 24.v.2014, 1♂.

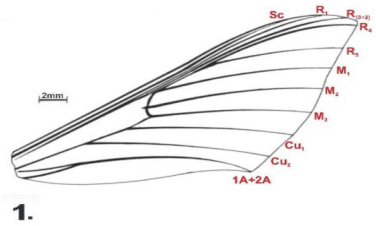
Distribution: Assam, H.P (Himachal Pradesh), Dehradun; Burma; Sundaland (Java & Sumatra); Thailand.

Remarks: The collection of this species from Chitkul and Dobhighat is its first report from North-West India.

***Rhagastis aurifera* (Butler):** *Pergasa aurifera* Butler, 1875, *Proc. Zool. Soc. London*, 1875: 7.
Rhagastis aurifera Butler: Hungfu and Linyao, 1997, *Fauna Sinica*, 11: 375-376; Inoue *et al*. 1997, *Sphingidae Thailand*, 2: 120.



Rhagastis hayesi Diehl



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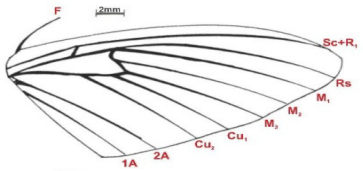

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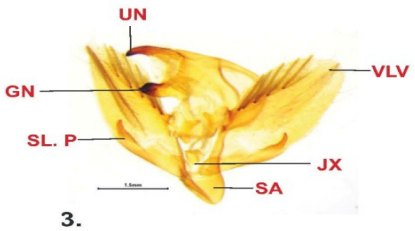

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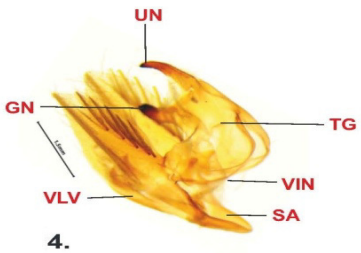

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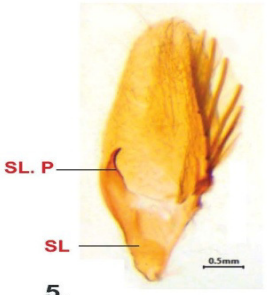

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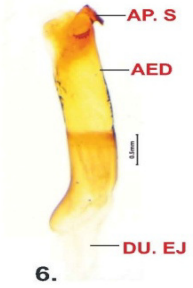

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Figure-1: Rhagastis hayesi Diehl: 1. Forewing, 2. Hindwing, 3. Male Genitalia-ventral view, 4. Male Genitalia-lateral view, 5. Right Valva, 6. Aedeagus, 7. Aedeagus-distal end.

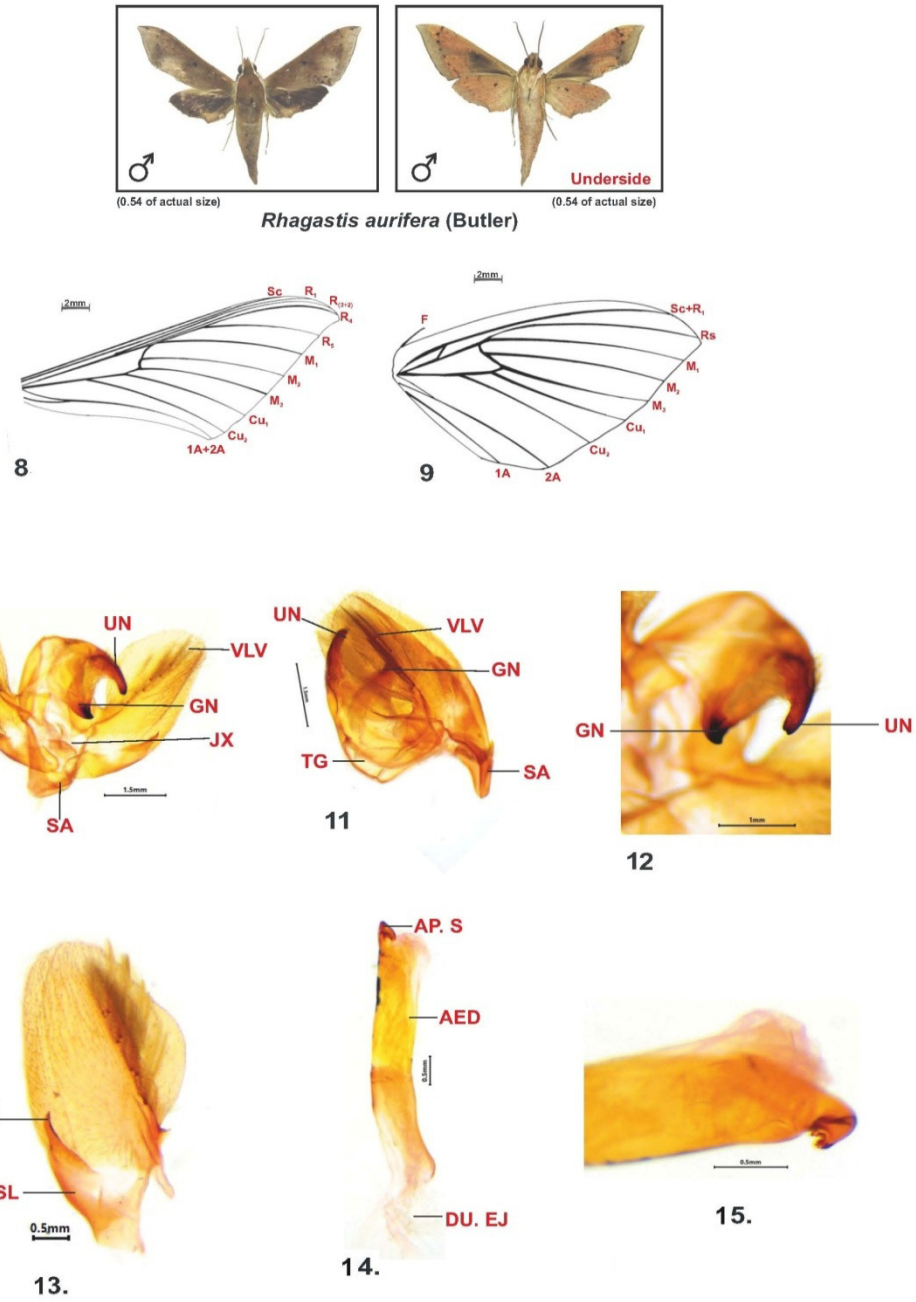

Figure-2: Rhagastis aurifera (Butler): 8. Forewing, 9. Hindwing, 10. Male Genitalia-ventral view, 11. Male Genitalia-lateral view, 12. Uncus & Gnathos Enlarged, 13. Right Valva, 14. Aedeagus, 15. Aedeagus-distal end.

Diagnosis: Head with vertex and frons clothed with olive-brown scales, laterally edged with white scales. Labial palpus with brown scales. Antenna with scape furnished with white scales and shaft brown. Thorax dressed with olive-brown scales, collar and tegula edged with white scales; lower side paler; sub lateral sides with orange scales. Legs clothed with brown scales. Abdomen covered with olive-brown scales, dense towards distal end, paired dark dorsal specks on each segment; lateral sides pale orange having black segmental specks; underside white.

Wing maculation: Forewing with ground colour olive-brown; a basal patch below costa; indistinct antemedial line; a black spot at end of cell; three indistinct postmedial dotted lines; submarginal dotted line distinct; marginal area with faint wavy fuscous band; cilia brown; underside fuscous suffused with

orange scales, marginal area fuscous. Hindwing with ground colour olive-brown suffused with more fuscous scales; postmedial and submarginal lines indistinct; cilia fuscous brown; underside fuscous with orange scales, black spot prominent, marginal area fuscous.

Wing venation: Forewing with discal cell less than half the length of wing; 1A+2A basally forked, basal less than one-fourth portion forked; Cu_2 through centre (beyond) of discal cell; Cu_1 arises lower angle (well before) of discal cell; M_2 from just below middle discocellulars; M_1 through angle (upper) of discal cell; R_5 and R_4 stalked from upper angle of cell; $R_{(3+2)}$ from before upper angle of cell; R_1 from beyond three-fourths of cell. Hindwing with discal cell less than half the length of wing; 2A forming a basal fork; Cu_2 from beyond middle of cell; Cu_1 from well before lower angle of cell; M_2 from just above middle of discocellulars; M_1 and Rs shortly stalked through angle (upper) of discal cell; SC+R1 from wing (base) with bar just before centre of discal cell.

Wing Expanse: Male 78mm; Female: Not examined

Body Length: Male 38mm; Female: Not examined

Male External Genitalia: Uncus narrow, well sclerotized, curved, setosed with blunt apex; gnathos curved with narrow apex, both uncus and gnathos giving clasper-like appearance in lateral view, dorsal margin of gnathos highly sclerotized; tegumen broad, semi-sclerotized, longer than vinculum; vinculum narrow, ending with distinct saccus; juxta shield-like, moderately sclerotized. Valva petiolate, semi-sclerotized; broad in middle with seven friction scales; sacculus distinct with short falcate saccular projection; distal half setosed with rounded apex. Aedeagus short, semi-sclerotized; ductus ejaculatorius entering directly from proximal end; distal end armed with hood like, bent well dark projection with prominent tooth like margins and having dentations at base.

Samplings done from: H.P (Himachal Pradesh): Deoli, 8 May, 2014, Three ♂♂.

Distribution: India: Assam, H.P (Himachal Pradesh); Nepal; Thailand; Vietnam.

Remarks: The present species is being first time recorded from North-West India. The host plants of this species are *Amorphophallus* (Araceae) and *Vitis* (Vitaceae)[23].

Conclusion

The sexual dimorphism characters namely general coloration, wing diagnosis along with venation and particularly the species external genitalic illustrations proved to be the vital for distinguished between these two closely allied species namely *hayesi* and *aurifera* of the same genus.

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Abbreviations: 1A- First anal vein; 2A-Second anal vein; AED-Aedeagus; AP.S-Apical Spur; CU_1-First cubital vein; CU_2-Second cubital vein; DU.EJ-Ductus Ejaculatorius; JX-Juxta; GN-Gnathos M_1-First median vein; M_2-Second median vein; M_3-Third median vein; R_1-First radial vein; R_2-Second radial vein; R_3-Third radial vein; R_4-Fourth radial vein; R_5-Fifth radial vein; RS-Radial Sector; SA-Saccus; SC-Subcosta; $SC+R_1$-Subcosta+ First Radial vein; SL-sacculus; SL. P-saccular projection of sacculus (valva); TG-Tegumen; VIN-Vinculum; VLV-Valva.

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