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On the parasitoid complex of butterflies with descriptions of two new species of parasitic wasps (Hymenoptera: Eulophidae) from Goa, India

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Abstract In comprehensive rearing of butterflies from Goa, India, an interesting parasitoid complex of wasps and tachinid flies was found. Two new species of parasitic wasps are described and illustrated: *Tetrastichus thetisae* n. sp. (Hymenoptera: Eulophidae), a gregarious parasitoid reared from the pupa of *Curetis thetis* (Drury) (Lepidoptera: Lycaenidae) on the host plant *Derris* sp., and *Sympiesis thyrsisae* n. sp. (Hymenoptera: Eulophidae), a gregarious parasitoid reared from the caterpillar of *Gangara thyrsis* (Fabricius) (Lepidoptera: Hesperidae) on the host plant *Cocos nucifera* L. Additionally, the following host-parasitoid associations are recorded: *Amblypodia anita* Hewitson (Lepidoptera: Lycaenidae) with *Parapanteles* sp. (Hymenoptera: Braconidae); *Coladenia indrani* (Moore) (Lepidoptera: Hesperidae) with *Sympiesis* sp. (Hymenoptera: Eulophidae); *Danaus chrysippus* L. (Lepidoptera: Nymphalidae) with

Sturmia convergens (Wiedemann) (Diptera: Tachinidae); *Idea malabarica* Moore (Lepidoptera: Nymphalidae) with *Brachymeria* sp. (Hymenoptera: Chalcididae) and *Palexorista* sp. (Diptera: Tachinidae); *Notocrypta curvifascia* Felder & Felder (Lepidoptera: Hesperidae) with *Cotesia erionotae* (Wilkinson) (Hymenoptera: Braconidae); and *Rapala* sp. (Lepidoptera: Lycaenidae) with an in nominate species close to *Aplomya* spp. (Diptera: Tachinidae). This discovery is the first record of *Tetrastichus* as parasitoid of *Curetis thetis*, *Sympiesis* as parasitoid of *Gangara thyrsis* and *Coladenia indrani*, *Brachymeria* and *Palexorista* as parasitoids of *Idea malabarica*, and *Cotesia erionotae* as parasitoid of *Notocrypta curvifascia*. Data on habitat, brief diagnoses and host records for all parasitoids are provided.

Introduction

The genus *Tetrastichus* Haliday, 1844 is known from almost all the continents. This genus is highly speciose and includes 519 species worldwide (Noyes, 2015). Narendran (2007) provided a key to the Indian subcontinent wherein 82 species were included. The wide host range of this genus includes species of Lepidoptera, Diptera, Coleoptera, and Hymenoptera. Amongst all of the recorded hosts, only three lycaenid species are known to act as hosts of *Tetrastichus* worldwide: *Mimacraea krausei* Dewitz, *Thecla echion* (Godart) and *Thecla ericusa* Hewitson. None of these lycaenids occur in India (Noyes, 2015).

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The genus *Sympiesis* Förster, 1856 is widely distributed in the Nearctic, Palearctic, Oriental Region to Australia, New Zealand and various Pacific islands (Bouček, 1988). Narendran (2011) provided a key to the species of Indian subcontinent wherein 13 species were included. The majority of *Sympiesis* spp. larvae are parasitic on lepidopterous larvae mining leaves of plants, but few others have found to be associated with species of Coleoptera, Diptera, and Hemiptera as well (Noyes, 2015). A few have also been recorded as hyperparasitoids, attacking the larvae of other parasitic wasps and flies. They are mainly found to be associated with vegetative habitats either mining in leaves, or in retreats formed by rolling or tying leaves or even sometimes boring in stems. Depending on species, *Sympiesis* larvae may be either ectoparasites or endoparasites: those species feeding on leaf-rolling hosts tend to be ectoparasites, while those targeting leaf-miners are endoparasites (Miller, 1970).

Altogether 254 species of butterfly have been recorded from Goa (Rangnekar & Dharwadkar, 2009). Despite of the species richness, much obvious from the known butterfly fauna, the associated parasitoids have received disproportionally little attention from researchers. Hitherto only a single species of parasitic wasp attacking one butterfly species has been reported from Goa, i.e. *Elasmus brevicornis* Gahan parasitic on *Erionota thrax* (L.) (Lepidoptera: Hesperidae) (Verma et al., 2002; Noyes, 2015). In this paper, the parasitoid complex (wasps and flies) associated with butterflies from Goa, India is illustrated along with their respective hosts and two new species of parasitic wasps are described: *Tetrastichus thetisae* n. sp. and *Sympiesis thyrsisae* n. sp. This study adds first host-parasitoid association records of *Tetrastichus* as parasitoid of *Curetis thetis* (Drury), *Sympiesis* as parasitoid of *Gangara thyrsis* (Fabricius) and *Coladenia indrani* (Moore), *Brachymeria* and *Palloxorista* as parasitoids of *Idea malabarica* Moore, and *Cotesia erionotae* (Wilkinson) as parasitoid of *Notocrypta curvifascia* Felder & Felder.

Materials and methods

The collection locality, Dharbandora taluka in South Goa district, is situated between 15.1655–15.2936°N and 74.0615–74.2026°E. The elevation ranges from 50 meters to more than 700 metres above mean sea

level (MSL) with a tropical monsoon type of climate. The vegetation in this region comprises west coast tropical evergreen forests, west coast semi-evergreen forests, and moist deciduous forests. Parasitoids were reared from the wild-caught caterpillars on the natural host plant on which they were initially found. The parasitised caterpillars were kept in cages awaiting parasitoid eclosion. Alcohol-preserved specimens were processed using hexamethyldisilazane and later point-mounted. Few specimens were treated with KOH, dehydrated, dissected and slide-mounted in natural Canada balsam.

Photographs of the wasps were taken using Leica M 205 A stereozoom microscope with Leica DC 420 inbuilt camera using automontage software (version 3.8). The slide-mounted specimens were photographed using Leica DFC 425 camera attached to Leica DMLB compound microscope. Macro images of the various life stages of lepidopterous hosts were taken using either of the following cameras: Nikon D3100 with 18–55 mm and 55–300 mm Nikkor lens, Canon 60D with Canon 100 mm macro lens. Wasp specimens were identified consulting Narendran (1989, 2007, 2011), Valerio et al. (2009) and Wilkinson (1928). Measurements are in millimetres and are taken from the holotype, unless specified otherwise. Types are deposited in the ICAR-National Bureau of Agricultural Insect Resources (NBARI), Bangalore, India. The terminology and abbreviations used for wasps are as follows: OOL, ocular-ocellar line; POL, post-ocellar line; F1–F3, funicular segments 1–3; T1–T6, metasomal/ abdominal tergites; fore wing veins: CC, costal cell, SMV, submarginal vein, MV, marginal vein, STV, stigmal vein; PMV, postmarginal vein.

Results

A total of 57 individuals was reared and 24 species from five families of Lepidoptera (Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae) were identified between 2014 and 2015 (see Table 1 for a list of the butterfly species reared, the number of reared individuals and their host plants from Goa, India). Altogether 12 individuals were found parasitised. These hosts belong to eight species of three families (Hesperiidae, Lycaenidae and Nymphalidae; see Table 2 for details). Species descriptions and host details of parasitoids are presented below.

Table 1 List of reared butterfly species, the number of reared individuals (N) and their host plants from Goa, India

Family	Species	N	Host plant
Hesperiidae	<i>Celaenorrhinus putra</i> (Moore)	1	<i>Strobilanthes</i> sp.
	<i>Hasora taminatus</i> (Hübner)	8	<i>Derris scandens</i> Benth
	<i>Coladenia indrani</i> (Moore)	3	<i>Grewia</i> sp.
	<i>Tagiades litigiosa</i> Möschler	1	<i>Dioscorea</i> sp.
	<i>Gangara thyrsis</i> (Fabricius)	1	<i>Cocos nucifera</i> L.
	<i>Notocrypta curvifascia</i> Felder & Felder	1	<i>Zingiber</i> sp.
Lycaenidae	<i>Curetis thetis</i> (Drury)	2	<i>Derris</i> sp.
	<i>Rathinda amor</i> (Fabricius)	1	<i>Ixora</i> sp
	<i>Cheritra freja</i> (Fabricius)	5	<i>Mangifera</i> sp.
	<i>Rapala manea</i> (Hewitson)	2	<i>Moullava spicata</i> (Dalzell)
	<i>Rapala varuna</i> (Horsfield)	2	<i>Zizyphus</i> sp.
	<i>Rapala</i> sp.	1	<i>Lantana camara</i> L.
	<i>Talicauda nyseus</i> (Guérin-Meneville)	3	<i>Bryophyllum</i> sp.
	<i>Chilades pandava</i> (Horsfield)	1	<i>Acacia</i> sp.
	<i>Amblypodia anita</i> Hewitson	3	<i>Olex</i> sp.
Nymphalidae	<i>Euploea core</i> (Cramer)	2	<i>Ficus</i> sp.
	<i>Idea malabarica</i> Moore	4	<i>Agonosma</i> sp.
	<i>Acraea violae</i> (Fabricius)	1	<i>Passiflora</i> sp.
	<i>Cupha erymanthis</i> (Drury)	2	<i>Flacourtia</i> sp.
	<i>Neptis hylas</i> L.	3	<i>Dalbergia</i> sp.
	<i>Rohana parisatis</i> Westwood	4	<i>Celtis</i> sp.
	<i>Danaus chrysippus</i> L.	4	<i>Calotropis gigantea</i> (L.)
Papilionidae	<i>Papilio demoleus</i> L.	1	<i>Glycosmis</i> sp.
Pieridae	<i>Cepora nerissa</i> Fabricius	1	<i>Capparis</i> sp.

Order Hymenoptera Linnaeus, 1758

Family Eulophidae Westwood, 1829

Tetrastichus thetisae n. sp.

Type-host: Pupa of *Curetis thetis* (Drury) (Lepidoptera: Lycaenidae) (Fig. 5B) on the host plant *Derris* sp.

Type-locality: Goa, Tambdi Surla, (15.261°N, 74.1528°E; altitude 154 m above MSL), India.

Type-material: Holotype, one female on card (Fig. 1A), 31.i.2015, coll. Ravindra Bhambure and Sandesh Gawas (NBAIR/Eulo/Tetra/31115-A). Paratypes, four females and one male on card, with same data as for the holotype (NBAIR/Eulo/Tetra/31115-B).

Etymology: The specific name ‘thetisae’ is derived from the host species.

Other material examined: Four females and two males, Karnataka, Hessarghatta, 20.v.15, ex pupa of *Curetis* sp. (Lepidoptera: Lycaenidae), coll. Umesh (NBAIR/Eulo/Tetra/20515).

Description (Fig. 1A–H)

Female [Measurements based on the holotype.] Body length 1.39 mm (Fig. 1A); paratypes 1.29–1.36 mm. **Colour** (Fig. 1A, B, D, F–H). Head black with metallic shine, occiput black, eyes grey; ocelli pale brown. Antenna with scape yellow, remaining dark brown. Mesosoma black. All coxae concolourous with mesosoma, fore and mid femora dark brown except extreme apices, remaining yellow; hind femur yellowish-brown, remaining yellow. Gaster black. Wings hyaline with veins and pilosity brown. Ovipositor sheaths yellow. **Head** (Fig. 1B). Head finely and shallowly reticulate; ocellar triangle faintly rugose. POL 1.79–1.83× OOL;

Table 2 List of host species, associated parasitoids, stage of parasitism, nature of cocoon, and associated host plant

Host	Parasitoid	Stage	Nature of cocoon	Host plant
<i>Amblypodia anita</i> Hewitson (Lepidoptera: Lycaenidae)	<i>Parapanteles</i> sp. (Hymenoptera: Braconidae)	Larva	Gregarious	<i>Olex</i> sp.
<i>Coladenia indrani</i> Moore (Lepidoptera: Hesperidae)	<i>Sympiesis</i> sp. (Hymenoptera: Eulophidae)	Larva	Solitary	<i>Grewia</i> sp.
<i>Curetis thetis</i> (Drury) (Lepidoptera: Lycaenidae)	<i>Tetrastichus thetisae</i> n. sp. (Hymenoptera: Eulophidae)	Pupa	Gregarious	<i>Derris</i> sp.
<i>Danaus chrysippus</i> Linnaeus (Lepidoptera: Nymphalidae)	<i>Sturmia convergens</i> (Wiedemann) (Diptera: Tachinidae)	Pupa	Solitary	<i>Calotropis gigantea</i> (L.)
<i>Gangara thyrsis</i> (Fabricius) (Lepidoptera: Hesperidae)	<i>Sympiesis thyrsisae</i> n. sp. (Hymenoptera: Eulophidae)	Larva	Gregarious	<i>Cocos nucifera</i> L.
<i>Idea malabarica</i> Moore (Lepidoptera: Nymphalidae)	<i>Palexorista</i> sp. (Diptera: Tachinidae) (primary parasitoid)	Pre pupa	Gregarious	<i>Agonosma</i> sp.
<i>Idea malabarica</i> Moore (Lepidoptera: Nymphalidae)	<i>Brachymeria</i> sp. (Hymenoptera: Chalcididae) (secondary parasitoid)	Pre pupa	Solitary	<i>Agonosma</i> sp.
<i>Notocrypta curvifascia</i> Felder & Felder (Lepidoptera: Hesperidae)	<i>Cotesia erionotae</i> (Wilkinson) (Hymenoptera: Braconidae)	Larva	Gregarious	<i>Zingiber</i> sp.
<i>Rapala</i> sp. (Lepidoptera: Lycaenidae)	Genus. indet. near <i>Aplomya</i> sp. (Diptera: Tachinidae)	Larva	Gregarious	<i>Lantana camara</i> L.

OOL 1.60× OD. Vertex without occipital carina. Clava with spicule at apex. Scrobal area reticulate and without median carina. Torulus placed above level of ventral margin of eye. Malar sulcus straight without a basal fovea. Mandibles bidentate. *Antenna* (Fig. 1C, D). Antenna with 3 funicular segments and 1 anellus. First and second funicular segments longer than wide, third subquadrate. Clava 2.57× longer than wide. C3 short, with small terminal spine. Scape 5.78× longer than wide, not reaching front ocellus. Scape 1.14× as long as clava. Pedicel 1.68× longer than wide. Clava 1.03× as long as combined length of F2 and F3. Measurements (ratio of length/width of each funicular segment): F1, 1.37; F2, 1.38; F3, 1.05. *Mesosoma* (Fig. 1E, F). Mesosoma 1.24× as long as gaster, with 2 submedian longitudinal ridges reaching posterior margin of mesoscutum, entire mesosoma with distinct longitudinal carinae; 5 adnotaular setae on each side. Scutellum with submedian grooves and lateral grooves along with additional carinae; scutellum with 2 setae, anterior pair of setae located near middle. Propodeum with inverted Y-shaped carina; paraspiracular carinae split posteriorly; spiracle distinctly separated from posterior margin

of metanotum. Callus with 2–3 setae. Hind femur 6.15× as long as wide. Midtibial spur 1.17× midmetatarsus. Second midtarsal segment shorter than first. *Fore wing* (Fig. 1G). Hyaline. Submarginal vein usually with one dorsal setae. Marginal vein 3.85× as long as stigmal vein. Postmarginal vein absent. Speculum small and closed behind by cubital line of setae. Wing disc beyond speculum densely pilose, speculum not extending below marginal vein. Measurements (relative length of wing veins): costal cell : marginal vein : stigmal vein, 4.0 : 3.85 : 1.0. *Metasoma* (Fig. 1H). Gaster sessile. Hypopygium reaching about half length of gaster. Ovipositor sheath slightly protruding, not visible in dorsal view.

Male [Measurements based on the paratype.] Body length 1.25 mm. Similar to female in general body colouration.

Biology. Caterpillar of *Curetis thetis* (Drury) was field collected in Tambdi Surla, Goa and later reared in cage on the host plant *Derris* sp. Gradually the green coloured pupa turned brown and later within 4–5 days wasps of *T. thetisae* n. sp. emerged. Also a single

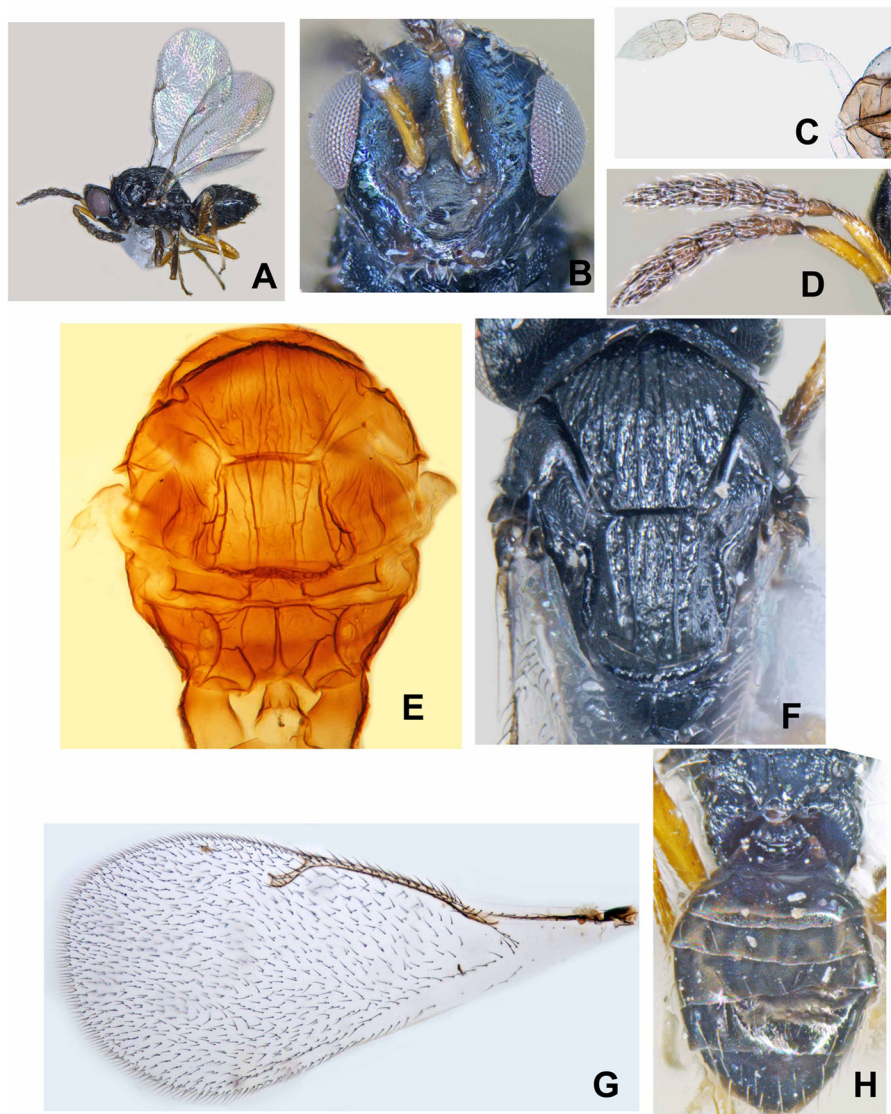


Fig. 1 *Tetrastichus thetisae* n. sp. (A–H, female). A, Habitus; B, Head in frontal view; C, Antenna (KOH treated); D, Antenna (untreated); E, Mesosoma (KOH treated); F, Mesosoma (untreated); G, Fore wing; H, Metasoma

parasitised pupa of *Curetis* sp. was field collected in Bangalore, Karnataka from which parasitoids emerged within 2–3 days. *Curetis thetis* (Drury) is the first lycaenid to be recorded as the host of a species of *Tetrastichus* in India.

Remarks

Tetrastichus thetisae n. sp. is unique and different from the remaining species of this genus in the following combination of characters: (i) mesosoma with distinct longitudinal carinae along with two

submedian longitudinal ridges; (ii) antenna with one anellus; (iii) mesoscutum with five adnotaular setae; (iv) mesoscutum without median line; (v) pedicel shorter than F1; and (vi) marginal vein $3.85\times$ as long as stigmal vein.

Sympiesis thyrsisae n. sp.

Type-host: Caterpillar of *Gangara thyrsis* (Fabricius) (Lepidoptera: Hesperidae) (Fig. 7B) on the host plant *Cocos nucifera* L.

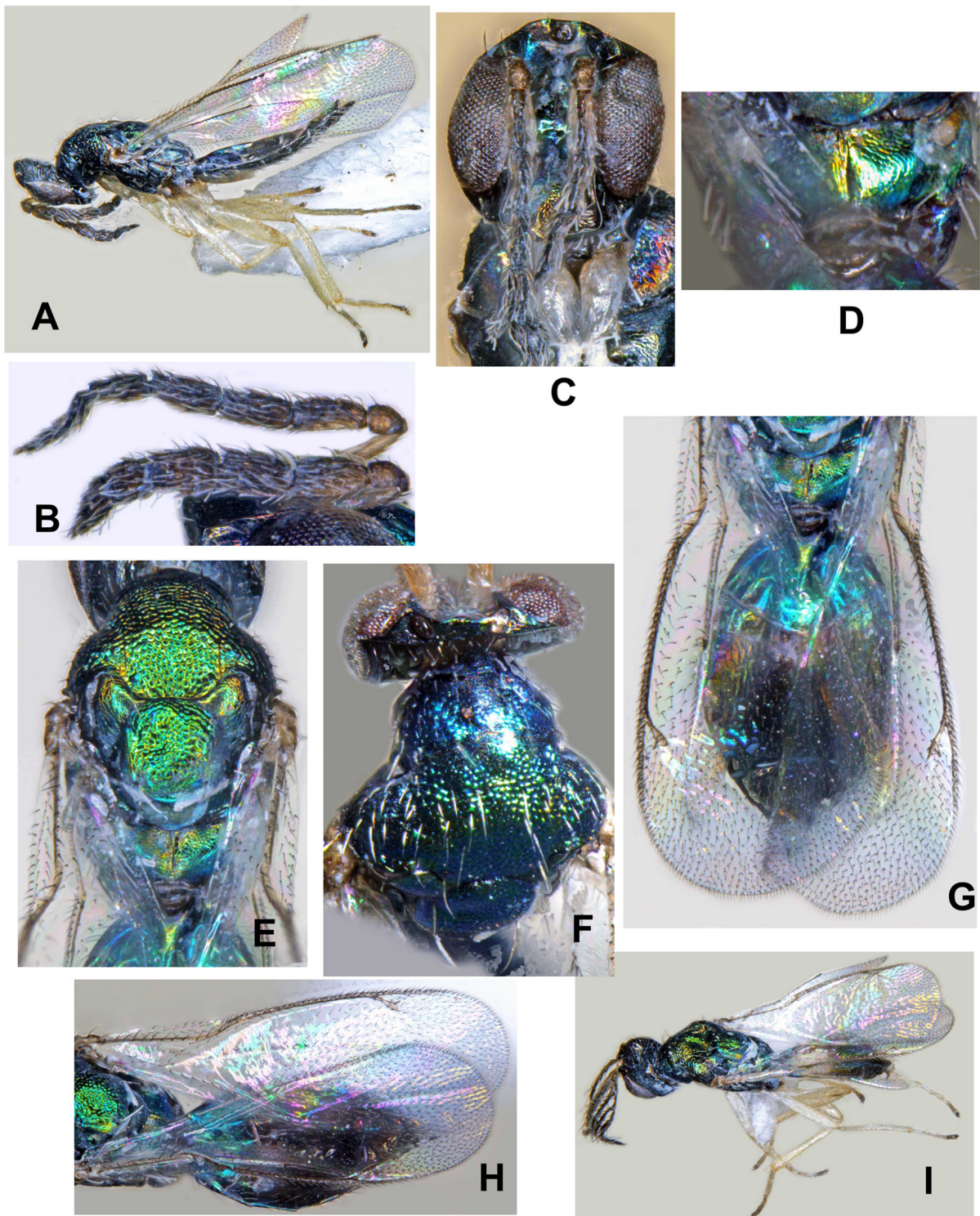


Fig. 2 *Sympiesis thyrsisae* n. sp. (A–H, female; I, male). A, Habitus; B, Antenna; C, Head in frontal view; D, Propodeum; E, Mesosoma; F, Mesosoma in part; G, Metasoma covered with wings; H, Wings; I, Habitus, male

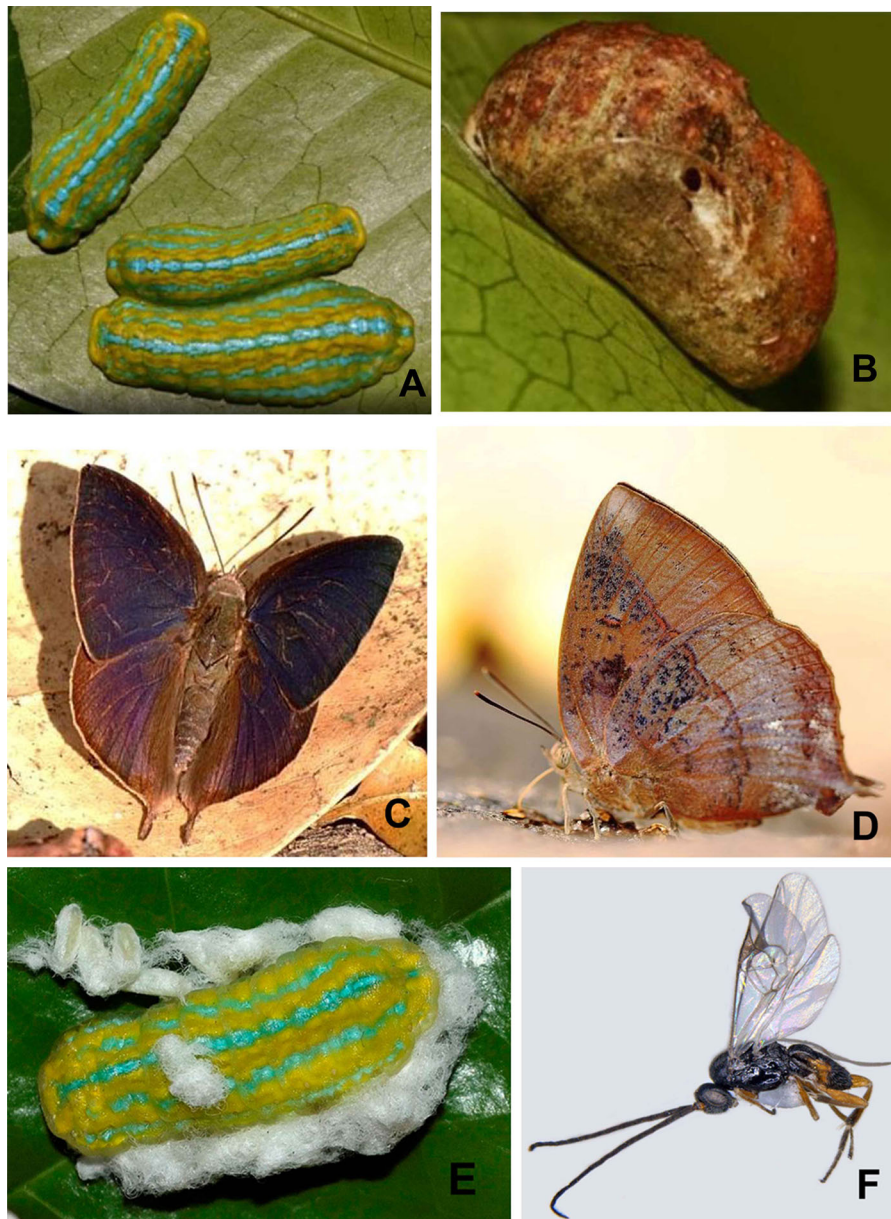


Fig. 3 *Amblypodia anita* Hewitson (Lepidoptera: Lycaenidae) (A–E) and its larval parasitoid (F) . A, Healthy caterpillar; B, Pupa; C, Adult butterfly, dorsal view; D, Adult butterfly, lateral view; E, Parasitised caterpillar with cocoons; F, Parasitoid *Parapanteles* sp. (Hymenoptera: Braconidae)

Type-locality: Goa, Bonumal-Mollem, (15.2154°N, 74.1254°E; altitude 64 m above MSL), India.

Type-material: Holotype, one female on card (Fig. 2A), 29.iii.2015, coll. Sandesh Gawas, (NBAIR/Eulo/Symp/29315–A). Paratype, one male on card, with same data as for the holotype (NBAIR/Eulo/Symp/29315–B).

Etymology: The specific name ‘thyrsisae’ is derived from the host species.

Description (Fig. 2A–H)

Female [Measurements based on the holotype.] Body length 2.01 mm (Fig. 2A). **Colour.** Body dark bright metallic green, pronotum metallic blue, legs pale whitish yellow including fore coxa, mid coxa and hind coxa brownish-black except apex. Eyes brown, ocelli yellowish-brown. Antenna with scape yellow, pedicel

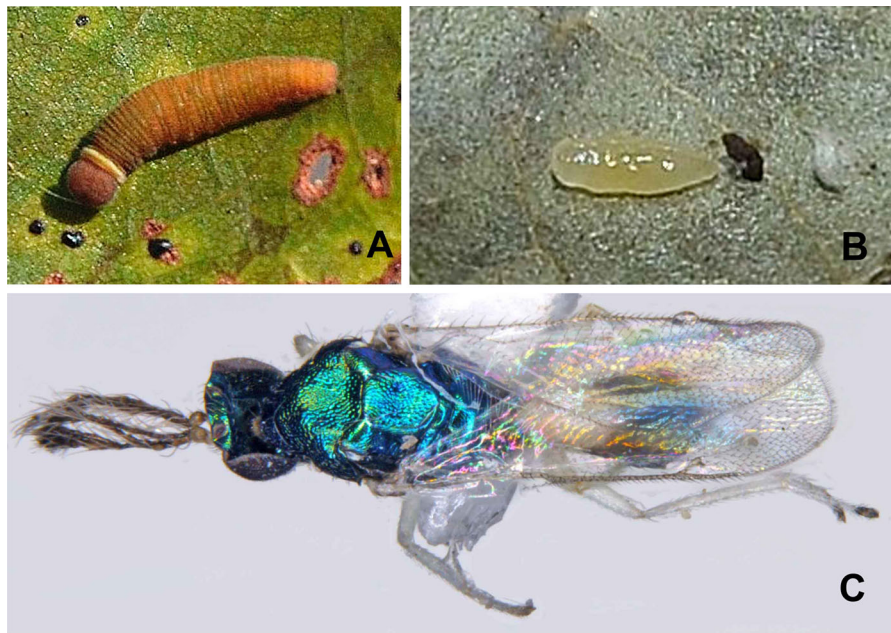


Fig. 4 *Coladenia indrani* (Moore) (Lepidoptera: HesperIIDae) (A–B) and its larval parasitoid (C). A, Caterpillar; B, Cocoon of parasitoid; C, Parasitoid *Sympiesis* sp. (Hymenoptera: Eulophidae)

brown, remaining dark brown (Fig. 2B). Wings hyaline, setae and veins brown. Tegula dark brown. Metasoma metallic green. *Head* (Fig. 2C). $1.02\times$ as wide as long in dorsal view; occiput concave; occipital carina absent; POL $4.5\times$ OOL; hind ocellus distance 0.05 ; width of interocular space 0.38 ; width of interocular space $3.17\times$ as wide as POL; malar sulcus distinct; malar space $0.21\times$ as long as eye height; eyes bare; frons without reticulations and mostly bare except few setae near eye margin; frontal fork absent; face with median carina; vertex and gena moderately setose. *Antenna* (Fig. 2B). Antenna inserted little above ventral margin of eyes; scape not reaching level of vertex. Measurements (length $\times$ width): scape 0.23×0.04 ; pedicel 0.06×0.05 ; F1, 0.11×0.05 ; F2, 0.11×0.05 ; F3, 0.11×0.05 ; F4, 0.10×0.06 ; clava 0.08×0.15 . *Mesosoma* (Fig. 2E). Lateral panel of pronotum finely reticulate. Mesosoma $1.13\times$ as wide as head, $1.01\times$ as wide as metasoma; notauli complete, fine, reaching axilla; mesosoma strongly reticulate; midlobe of mesoscutum with 4 pairs of setae (Fig. 2F); scutellum strongly reticulate with 2 pairs of setae; axilla with reticulate sculpture, reticulations not as strong as scutellum; dorsellum smooth, shiny, with fine delicate sculpture.

Propodeum reticulate with distinct median carina, plicae absent; spiracle round and not touching metanotum, slightly separated from metanotum by distance shorter than diameter of spiracle (Fig. 2D). Prepectus, mesepimeron and mesepisternum smooth. *Fore wing* (Fig. 2H). $2.93\times$ as long as wide; speculum closed behind by cubital line of setae; basal cell bare. Costal cell $8.50\times$ as long as wide; MV $2.26\times$ as long as PMV and PMV $2.55\times$ as long as STV. Measurements: costal cell (length $\times$ width) 0.51×0.06 . Length of veins: SMV, 0.48 ; MV, 0.52 ; STV, 0.09 ; PMV, 0.23 . *Metasoma* (Fig. 2G). Gaster sessile; $1.23\times$ as long as mesosoma (in profile); about $1.79\times$ as long as its own width; posterior margin of T1 convex.

Male (Fig. 2I). Similar to female except basal half of metasoma yellow excluding lateral margins. Male antenna with 3 branches, longer than wide; clava 2-segmented.

Biology. *Sympiesis thyrsisae* n. sp. was reared from a caterpillar of *Gangara thyrsis* (Fabricius) (Lepidoptera: HesperIIDae) on the host plant *Cocos nucifera* L. This single parasitised caterpillar of *G. thyrsis*,

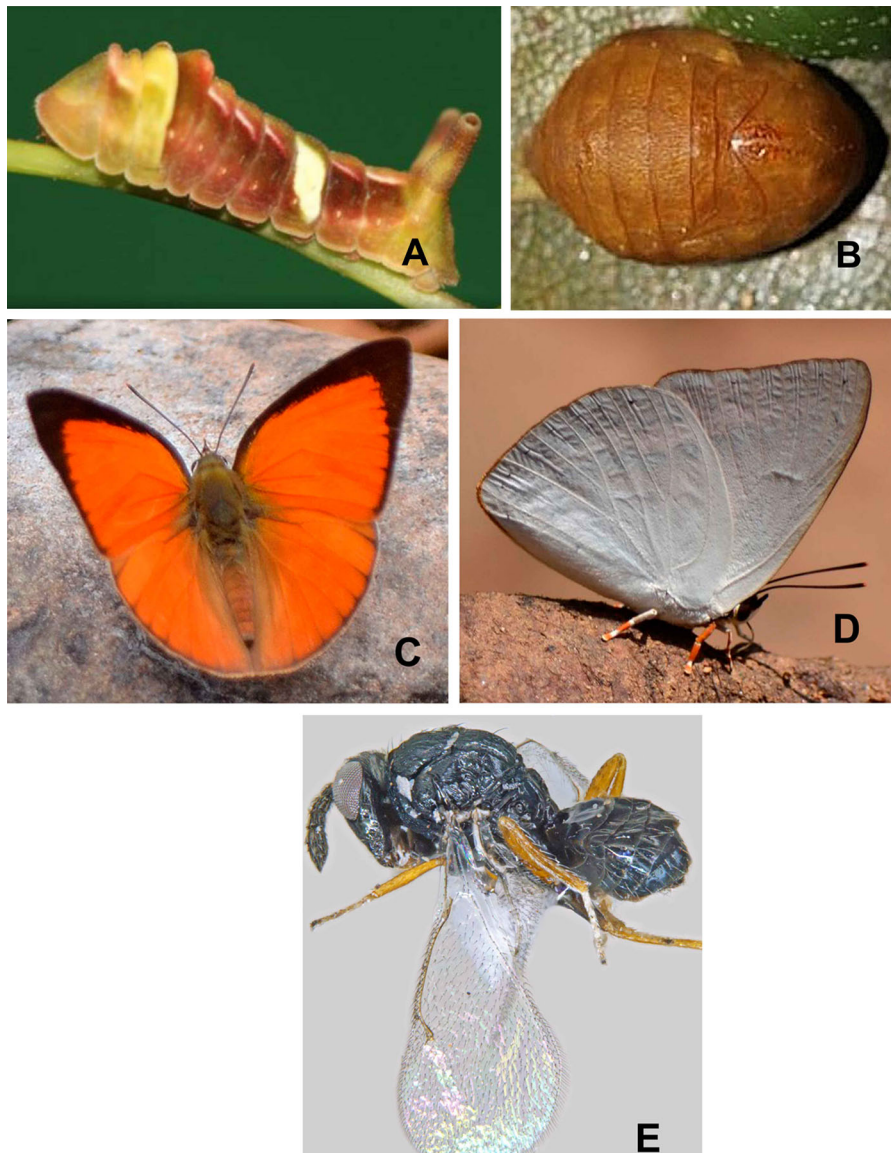


Fig. 5 *Curetis thetis* (Drury) (Lepidoptera: Lycaenidae) (A–D) and its pupal parasitoid (E). A, Healthy caterpillar; B, Parasitised pupa; C, Adult butterfly, dorsal view; D, Adult butterfly, lateral view; E, Pupal parasitoid *Tetrastichus thetisae* n. sp. (Hymenoptera: Eulophidae)

almost transparent in appearance and less than 1 cm in body length, contained three cocoons within (Fig. 7B). Two wasps of *S. thyrsisae* n. sp. eclosed within a week, one from each cocoon, and one cocoon remained intact. Considering the hyperparasitoid nature of the Eulophidae, *S. thyrsisae* n. sp. may or may not be a hyperparasitoid in this case, as there is no way to know if the wild-caught caterpillar had primary parasitoids in it.

Remarks

This new species is placed in the genus *Sympiesis* because of the following characters: (i) axillae distinctly advanced; (ii) mid lobe of mesoscutum with four paired setae; (iii) scutellar grooves absent; and (iv) male antennae with three branches. It does show some similarity with *Diaulomorpha* spp. in having mesoscutum with regular raised reticulation and

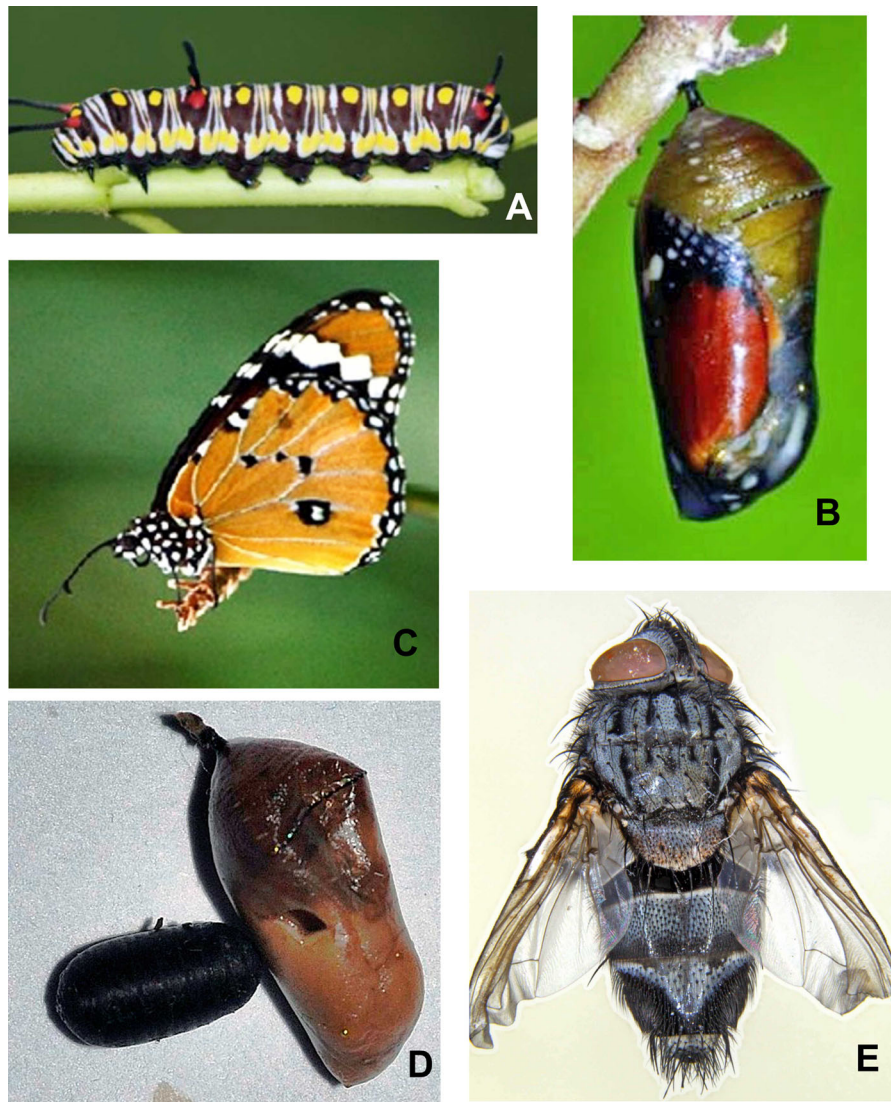


Fig. 6 *Danaus chrysippus* Linnaeus (Lepidoptera: Nymphalidae) (A–D) and its pupal parasitoid (E). A, Healthy caterpillar; B, Pupa; C, Adult butterfly, lateral view; D, Parasitised pupa; E, Pupal parasitoid *Sturmia convergens* (Diptera: Tachinidae)

complete notauli but differs in the structure of the male antenna and the presence of scutellum grooves (in *Diaulomorpha* spp. male antenna is unbranched and lateral grooves of scutellum are present).

The combination of the following characters of *Sympiesis thyrissae* n. sp. separates this species from the remaining congeners: (i) legs pale whitish-yellow including fore coxa; (ii) mid coxa and hind coxa brownish-black except apex; (iii) notauli complete; (iv) midlobe of mesoscutum with four pairs of setae; (v) MV $2.26\times$ as long as PMV; (vi) costal cell $8.50\times$ as long as wide; (vii) F1 as long as F2; (viii)

propodeum reticulate with distinct median carina, plicae absent, spiracle round and not touching metanotum, spiracle slightly separated from metanotum by a distance shorter than diameter of spiracle.

Sympiesis sp.

Host: *Coladenia indrani* (Moore) (Lepidoptera: Hesperiiidae) (Fig. 4A) on the host plant *Grewia* sp.

Locality: Goa, Barabhumi-Sacorda (15.2610°N , 74.1146°E ; altitude, 85 m above MSL), India.

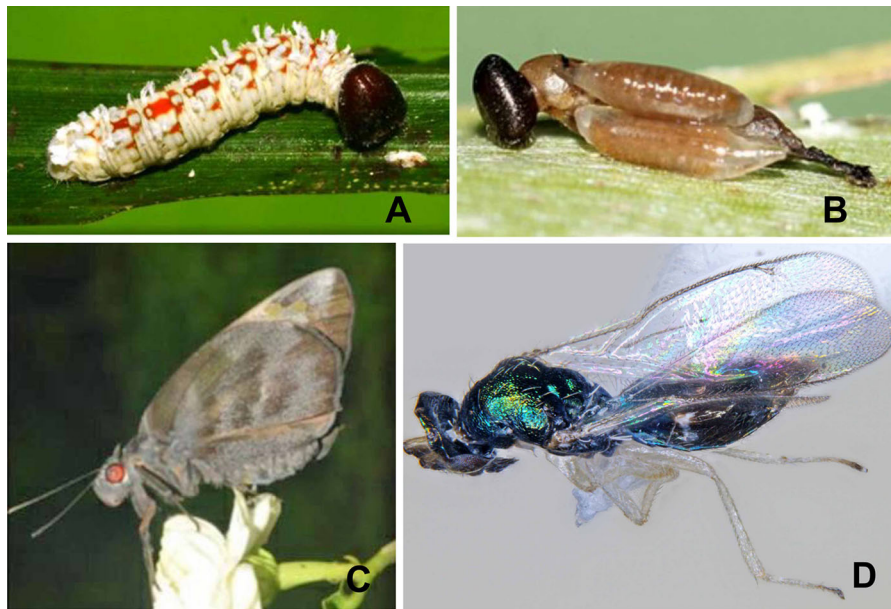


Fig. 7 *Gangara thyrsis* (Fabricius) (Lepidoptera: Hesperiiidae) (A–C) and its larval parasitoid (D).. A, Healthy caterpillar; B, Parasitised caterpillar; C, Adult butterfly, lateral view; D, Parasitoid *Sympiesis thyrsisae* n. sp. (Hymenoptera: Eulophidae)

Voucher material: One male, 8.ii.2015, coll. Sandesh Gawas, NBAIR/Eulo/Symp/08215.

Brief diagnosis (Fig. 4C)

Male with 3 branched antennae. Remaining characters as in female.

Remark

A single male specimen was obtained hence could not be identified to species level.

Family Braconidae Nees, 1811

Cotesia erionotae (Wilkinson, 1928)

Host: Caterpillar of *Notocrypta curvifascia* Felder & Felder (Lepidoptera: Hesperiiidae) (Fig. 9C) on the host plant *Zingiber* sp.

Locality: Goa, Tambdi Surla (15.2611°N, 74.1527°E), India.

Voucher material: Six females, 4.i.2015, coll. Sandesh Gawas, NBAIR/Brac/Micro/Cotesia/erio/4115.

Brief diagnosis (Fig. 9D)

Head and mesosoma black. Scape and pedicel yellow brown; flagellomeres dark brown. Fore and mid coxa red testaceous. First metasomal tergite deep red-black; second tergite brown with yellow infuscation in middle; apex of hind femur and apical half of hind tibia darkened; pterostigma and wing veins brown. Propodeum with well-marked median longitudinal carina. Oblique carinae run upwards on each side of median carina and join to strong transverse basal carina.

Parapanteles sp.

Host: Caterpillar of *Amblypodia anita* Hewitson (Lepidoptera: Lycaenidae) (Fig. 3E) on the host plant *Olex* sp.

Locality: Goa, Satpal-Sacorda (15.2343°N, 74.1231°E; altitude 83 m above MSL), India.

Voucher material: Six females, 28.ii.2015, coll. Sandesh Gawas, NBAIR/Brac/Micro/Para/28215.

Brief diagnosis (Fig. 3F)

Basal antennal placodes 2-ranked and with same pattern of arrangement ventrally and dorsally on midapical segments; propodeum areola present; first

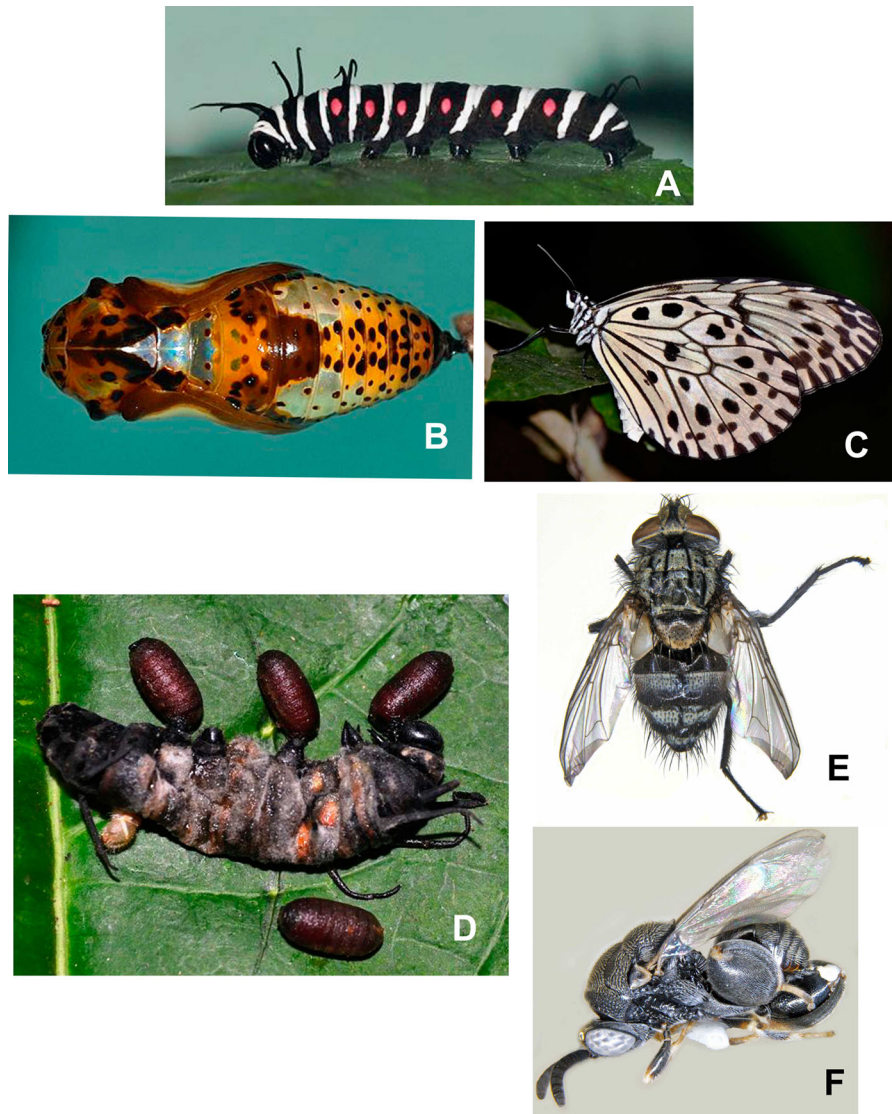


Fig. 8 *Idea malabarica* Moore (Lepidoptera: Nymphalidae) (A–D) and its pupal parasitoid (E) along with the hyperparasitoid (F). A, Healthy caterpillar; B, Pupa; C, Adult butterfly, lateral view; D, Pre-pupa; E, *Palexorista* sp. (Diptera: Tachinidae); F, *Brachymeria* sp. (Hymenoptera: Chalcididae)

metasomal tergum rugose, broad; hypopygium sharply folded medially; ovipositor usually short, thick in lateral view; hind wing with vannal lobe evenly convex; fore wing areolet open distally (Valerio et al., 2009).

Remarks

This material does not match completely with any of the known Indian species of *Parapanteles*. Detailed

studies are required and Indian *Parapanteles* spp. needs to be revised in order to achieve its identification.

Family Chalcididae Latreille, 1817

Brachymeria sp.

Host: Pre-pupa of *Idea malabarica* Moore (Lepidoptera: Nymphalidae) (Fig. 8D) on the host plant *Agonosma* sp.



Fig. 9 *Notocrypta curvifascia* Felder & Felder (Lepidoptera: Hesperidae) (A–C) and its larval parasitoid (D). A, Healthy caterpillar; B, Adult butterfly, dorsal view; C, Parasitised caterpillar with cocoons; D, Parasitoid *Cotesia erionotae* (Wilkinson) (Hymenoptera: Braconidae)

Locality: Goa, Collem (15.1951°N, 74.1553°E; altitude, 108 m above MSL), India.

Voucher material: One female, 21.ii.2015, coll. Sandesh Gawas, NBAIR/Chal/Brachy/21215.

Brief diagnosis (Fig. 8F)

Body length 7 mm. Body colour black; tegula pale yellow on edges, black in middle; coxa and trochanter black; femur shiny black with apical region yellow

testaceous; fore and mid tibia yellow; hind tibia black except yellow testaceous apex. Pubescence silvery white. First tergite smooth; second tergite punctured.

Remarks

This species of *Brachymeria* does not match any of the known Indian species. However, based on the single reared specimen decision of new species could not be made as this genus is highly speciose.

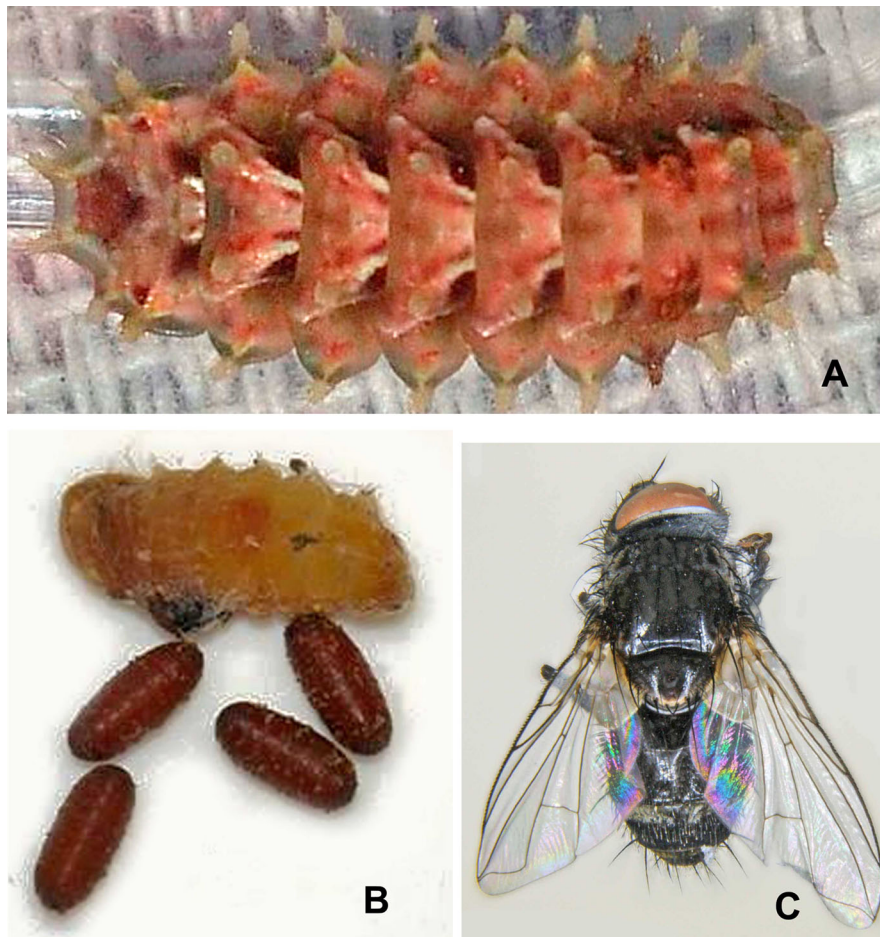


Fig. 10 *Rapala* sp. (Lepidoptera: Lycaenidae) (A–B) and its larval parasitoid (C). A, Healthy caterpillar; B, Parasitised caterpillar; C, *Aplomya* sp. (Diptera: Tachinidae)

Order Diptera Linnaeus, 1758
Family Tachinidae Bigot, 1853

***Sturmia convergens* (Wiedemann, 1824)**

Host: Pupa of *Danaus chrysippus* L. (Lepidoptera: Nymphalidae) (Fig. 6D) on the host plant *Calotropis gigantea* (L.).

Locality: Goa, Bonumal-Mollem (15.2156°N, 74.1255°E; altitude 64 m above MSL), India.

Voucher material: One male, 4.iii.2015, coll. Ravindra Bhambure and Sandesh Gawas, NBAIR/Dip/Tach/Sturm/4315.

Brief diagnosis (Figs. 6E, 11A–C)

Subapical scutellae setae exceptionally widely separated, distance between their bases much greater than that between a subapical seta and its corresponding basal seta. One pair of lateral scutellar setae present. Apical scutellar setae extremely strong, as long as

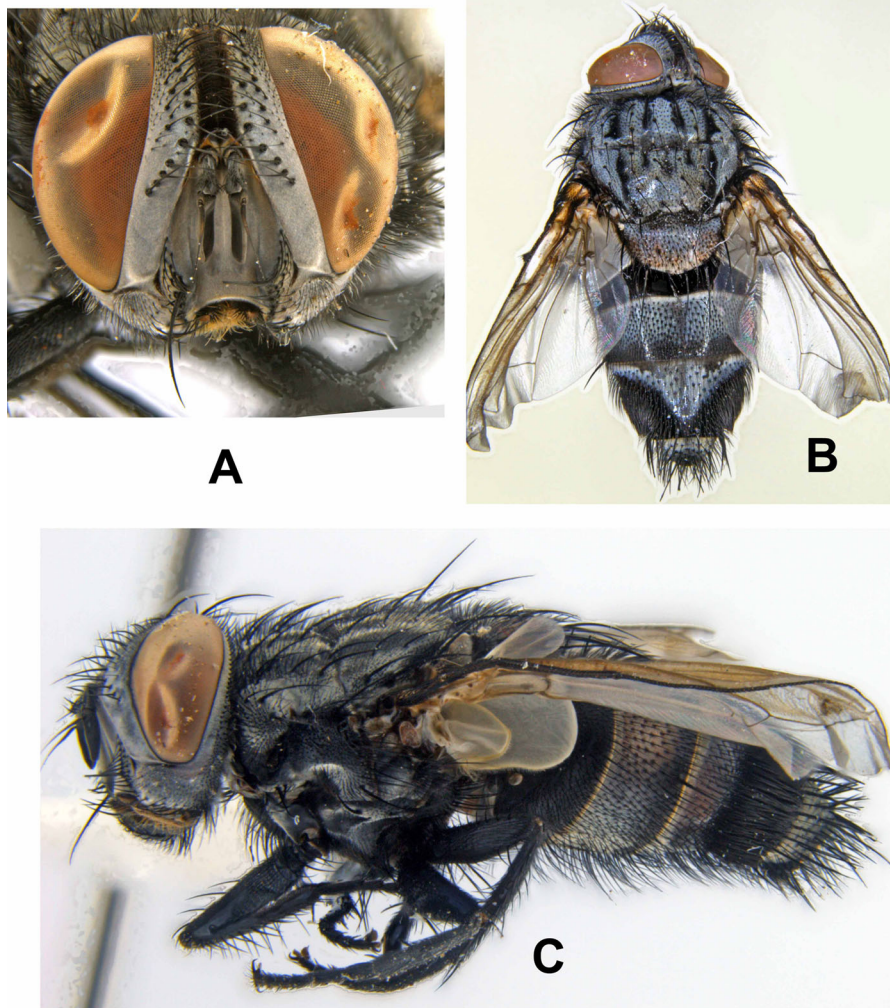


Fig. 11 *Sturmia convergens* (Diptera: Tachinidae) (A–C). A, Head, frontal view; B, Body, dorsal view; C, Body, lateral view

scutellum. Four sternopleural setae present. Sides of fourth abdominal tergite with long dense hair-fascicles (in male) (Crosskey, 1976).

***Palexorista* sp.**

Host: Pre pupa of *Idea malabarica* Moore (Lepidoptera: Nymphalidae) (Fig. 8D) on the host plant *Agonosma* sp.

Locality: Goa, Collem (15.1951°N, 74.1553°E; altitude), India.

Voucher material: One female, 21.ii.2015, coll. Sandesh Gawas, NBAIR/Dip/Tach/Palexo/21215.

Brief diagnosis (Figs. 8E, 12A–C)

Parafacials finely haired on upper parts, hair sometimes extending on to lower parts. Parafacials never entirely bare. Ocellar setae present (Crosskey, 1976).

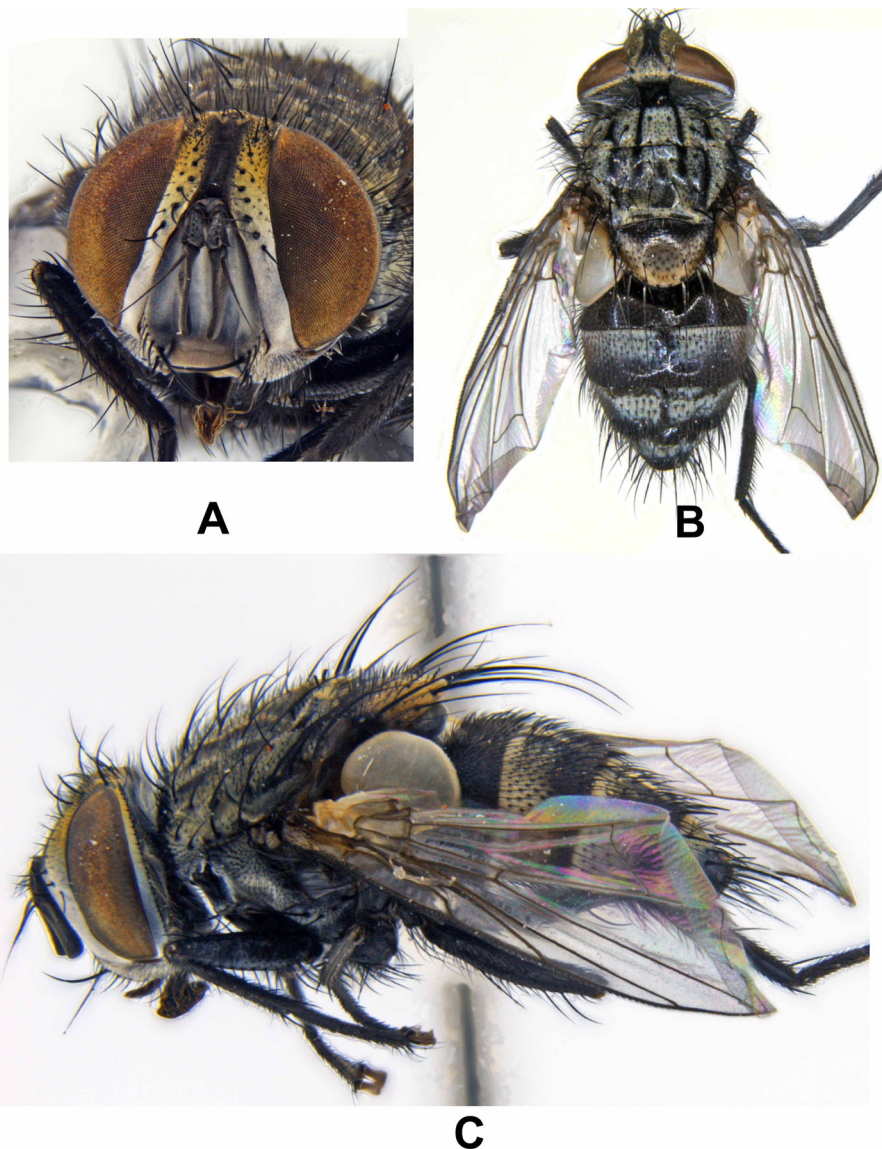


Fig. 12 *Palearxista* sp. (Diptera: Tachinidae) (A–C). A, Head, frontal view; B, Body, dorsal view; C, Body, lateral view

Innominate species close to *Aplomya* spp.

Host: Caterpillar of *Rapala* sp. (Lepidoptera: Lycaenidae) (Fig. 10A) on the host plant *Lantana camara* L.
Locality: Goa, Barabhum-Sacorda (15.2610°N, 74.1145°E), India.

Voucher material: Four females, 27.xii.2014, coll. Ravindra Bhambure and Sandesh Gawas, NBAIR/ Dip/Tach/Aplom/271214.

Remarks (Figs. 10C, 13A–C)

This very distinctive species looks most like *Aplomya*, which is the only tachinid genus known to parasitise Lycaenidae in India. However, this specimen shows one or two characters which exclude it from this genus e.g. bare eyes (pers. comm. Dr. Nigel Wyatt).

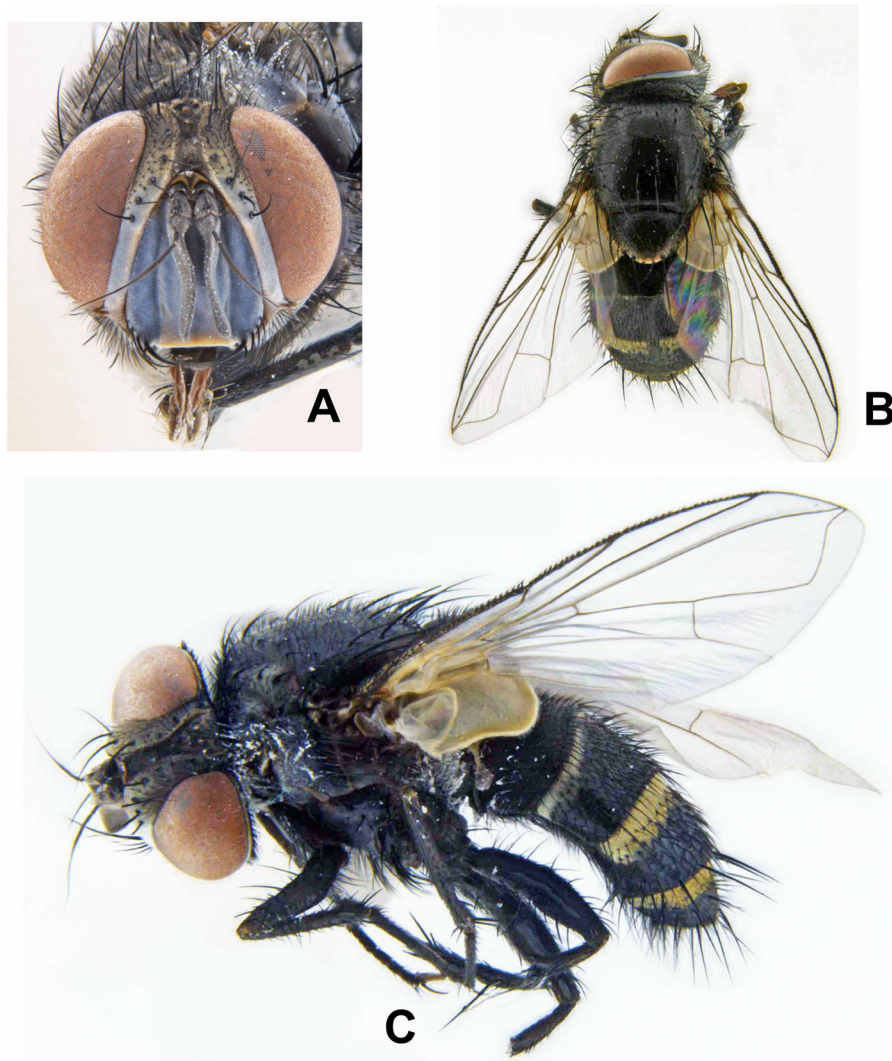


Fig. 13 Innominate species close to *Aplomya* spp. (Diptera: Tachinidae) (A–C). A, Head, frontal view; B, Body, dorsal view; C, Body, lateral view

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable institutional, national and international guidelines for the care and use of animals were followed.

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