

# Parasitoids of the ber fruit fly, *Carpomya vesuviana* Costa (Diptera: Tephritidae) in Iran

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## Research Article

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# Abstract

The ber fruit fly, *Carpomya vesuviana* Costa, 1854 (Diptera: Tephritidae) is an important pest of the jujube, *Ziziphus jujuba* Miller, in Eastern Iran. Here, we add four species to the previously known parasitoid community of *C. vesuviana*, *Pteromalus* sp. (Pteromalidae) and three species of the family Eurytomidae, namely *Aximopsis augasmae* (Zerova, 1977), *Eurytoma pineticola* Zerova, 1981 and *Eurytoma serratulae* (Fabricius, 1798). The last two species being found for the first time in Iran. *Eurytoma pineticola* and *Cyrtoptyx lichtensteini* (Masi, 1921) are the main larval ectoparasitoids of *C. vesuviana*. The parasitoid community of *C. vesuviana* in Iran is reviewed. Ten species of parasitic wasps of the ber fruit fly, *C. vesuviana* are now listed from Iran and we propose an identification key to these species.

# Introduction

With about 135 species, the genus *Ziziphus* (Rhamnaceae) is mostly distributed in the tropical and subtropical regions of Asia and America (Mabberley 2008) and a fewer number of species in the Pacific Islands and Australia (Bhandari and Bhansali 2000; Ara et al. 2008).

Some species in the genus are of tremendous economic and medicinal importance. The fruits of *Ziziphus jujuba* Miller, known as jujube or Chinese date, are employed medicinally to treat human anxiety and insomnia (Chen et al. 2017). The plant is also used to alleviate stress and is also used as an appetite stimulant, a digestive aid as well as for antiarrhythmic and contraceptive medication (Gupta et al. 2004; Jiang et al. 2007; Vahedi et al. 2008).

The greatest part of the Iranian territory has a Mediterranean climate, but Southern and Eastern Iran have a sub-tropical and semi-arid climate (Yarahmadi and Amini 2021). Thus, the country has a favorable climate for tropical fruit crops, such as jujube, *Ziziphus jujuba*. This plant is associated with more than 20 species of arthropod pests (Hashmi 1994; Balikai 2009) including caterpillars, beetles, and mites (Kavitha and Savithri 2002; Nizamani et al. 2015; Haldhar et al. 2016). Among them, the ber fruit fly, *Carpomya vesuviana* Costa, 1854 (Diptera: Tephritidae) is an economically important pest with a high population level and the highest level of infestation of jujube fruits (Sarwar 2006; Vadivelu 2014). The fly infests as a key pest of *Ziziphus* can cause serious damage and yield loss of up to 80% or even up to 100% (Haldhar et al. 2012; Karuppaiah 2014). It is widely distributed in southern European countries and Asia (Guo et al. 2019). In Iran, this species also attacks a few other cultivated *Ziziphus* species (Farrar et al. 2003). *Carpomya vesuviana* is also one of the most destructive pests for *Ziziphus* in adjacent countries (India, Pakistan, China, and the Middle East) (Farrar et al. 2003, 2004; Sarwar 2006; Balikai 2009; Vadivelu 2014; Nizamani et al. 2015). The morphology of the larva and the biological characteristics of *C. vesuviana* were described by Kandybina (1977) and Hu et al. (2013). Until now, only a few parasitoids have been reported from Iran. Among them three braconid species (Singh 1989; Karuppaiah 2014) of which *Fopius carpomyiae* (Silvestri, 1916) is the most studied parasitoid (Farrar et al. 2003, 2004, 2009; Golestaneh et al. 2018). This species was also reported as a parasitoid of *C. vesuviana* infesting *Ziziphus spina-christi*

(L.) Willd in southern Iran (Farrar and Chou 2000). Narayanan and Chawal (1962) reported five braconids and an eulophid species from India. To date, no chalcidoid parasitoids have been reported from *C. vesuviana* (Noyes 2021), but *Eupelmus urozonus* Dalman, 1820 was reported on *Carpomya incompleta* (Becker, 1903), a closely related species (Thompson 1955). Amini et al. (2014a) reported two larval and pupal parasitoids of the ber fruit fly, while in a second report, they added two mutillid species reared from puparia of *C. vesuviana* (Amini et al. 2014b). A recent sampling of ber fruit fly in eastern Iran led to the discovery of several parasitoid species presented in this paper. Furthermore, we present the first review of known parasitoids associated with tephritids infesting jujube in Iran, and provide new information based on a dense survey of fruits infested by *Carpomya vesuviana*.

## Materials and Methods

Ber fruit fly, *Carpomya vesuviana* were collected from *Ziziphus jujuba* during 2012–2013 and 2017, from 8 different localities in South Khorasan province, Eastern Iran. The collection of infested fruits was made from sites not treated with pesticides in Birjand (Birjand, Chahkand, Mood, Noghab, Rakat, Razg, Zini) and Ghaen (Shahrakht). The jujube fruits were brought to the Entomology laboratory of the Department of Plant Protection, Ferdowsi University, Mashhad. These samples were kept separately per collecting batch to rear their parasitoids. About 2150 ( $\approx$  17 kg) fruits of *Z. jujuba* were dissected and infested fruits were placed in plastic rearing jars and were sprayed with water on a weekly basis to maintain moisture. The fruits were kept in room condition. Larvae and puparia of ber fruit fly were conserved at room temperature. Emerging flies and parasitoids were collected and preserved in 70% ethanol. The parasitism rate of the obtained wasps was estimated by considering the number of infested fruits in each batch and the number of emerged parasitoids.

Identification of parasitic wasps was made using available keys and descriptions (Silvestri 1916a, b; Claridge 1961, 1962; Graham 1969; Dzhankmen 1976; Zerova and Khodzhevanishvili 1977; Muesebeck 1980; Nixon 1980; Zerova 1981, 1995; Kozlov 1987; Bouček and Rasplus 1991; Zerova and Seryogina 2006). All morphological terminology follows the Hymenoptera Anatomy Ontology (<http://portal.hymao.org/>). Images were taken with a Keyence digital microscope (VHX-5000). The final illustrations were edited and processed for contrast and brightness in Adobe Photoshop® CS6 software. Voucher specimens were deposited in the HMIM (Hayk Mirzayans Insect Museum, Iranian Research Institute of Plant Protection, Tehran, Iran).

## Results

Our large sampling and previously collected specimens revealed the presence of 10 hymenopterous parasitoid species belonging to five different families (Braconidae, Diapriidae, Eurytomidae, Pteromalidae and Mutillidae) mostly attack the larval and pupal stages of *Carpomya vesuviana* (Figs 1a, b) (Table 1). These species included our reared species and previously reported parasitoids on *C. vesuviana* in Iran such as *Fopius carpomyiae* (Silvestri, 1916) (Braconidae). The most common and abundant parasitoids reared were *Eurytoma pineticola* Zerova, 1981 (Eurytomidae) and *Cyrtotypx lichtensteini* (Masi, 1921)

(Pteromalidae). These are larval ectoparasitoids of *C. vesuviana* with 1.60 and 1.30% parasitism rates, respectively (Table 1).

**Table 1** Hymenopterous parasitoids of *Carpomya vesuviana* (Diptera: Tephritidae) infesting jujube fruit, *Ziziphus jujuba* in Iran and their parasitism rate.

Family	Species	Parasitoid	Activity period	Means Parasitism rate (%) (± SE)
Braconidae	<i>Fopius carpomyiae</i> (Silvestri, 1916)	egg-puparia	-	-
Diapriidae	<i>Coptera</i> nr. <i>silvestrii</i> (Kieffer, 1913)	Puparia	July	0.18 (±0.01)
Eurytomidae	<i>Aximopsis augasmae</i> (Zerova, 1977)	larvae	July	0.82 (±0.11)
	<i>Eurytoma pineticola</i> Zerova, 1981	larvae	June	1.60 (±0.20)
	<i>Eurytoma serratulae</i> (Fabricius, 1798)	larvae	July	0.60 (±0.15)
Pteromalidae	<i>Cyrtoptyx lichtensteini</i> (Masi, 1921)	larvae	July	1.30 (±0.25)
	<i>Pteromalus</i> sp.	larvae	July	0.12 (±0.09)
Mutillidae	<i>Smicromyrme</i> ( <i>Astomyrme</i> ) <i>nikolskajae</i> Lelej, 1985	Puparia	October	0.30 (±0.01)
	<i>S. (Eremotilla) tekensis</i> Skorikov, 1935	Puparia	January & July	0.12 (±0.01)
<b>Sum of the parasitism rate</b>				<b>5.04 (±1.02)</b>

### *Fopius carpomyiae* (Silvestri, 1916) (Hymenoptera: Braconidae)

**Remark.** This Oriental species (Narayana and Batra 1960; Gilstrap and Hart 1987) has been recently introduced to Iran (Farrar and Chou 2000). We did not sample it from our rearing but the species was reported from southern Iran as an egg-pupal endoparasitoid of *C. vesuviana* on *Ziziphus spina-christi* by Farrar and Chou (2000). The percentage parasitism of this wasp was estimated to be 24% (Farrar et al. 2009).

**Diagnosis.** *Fopius carpomyiae* has a pale coloration body; frons densely covered with large punctures; second metasomal tergite striate, with a relatively short ovipositor, and the ovipositor tip is not narrowed apically. The species is closely related to *Fopius arisanus* (Sonan, 1932) and *F. vandenboschi* (Fullaway, 1952) but has a shorter ovipositor. Wharton (1999) provided a table of morphological features that facilitate the comparison of known species of *Fopius*.

***Coptera* nr. *silvestrii* (Kieffer, 1913) (Hymenoptera: Diapriidae)**

**Material examined:** 1 ♀, Iran: South Khorasan province, Mood (59°31'23" E, 32° 42' 31" N), 1851 m, 20.vii.2012, A. Amini, leg. 2 ♀, Birjand (32° 51' 59"N, 59° 13' 55"E), 1465m, 11.vii.2012, A. Amini, leg. 1 ♀, Birjand, Chahkand (32° 50' 49" N, 59° 09' 20"E), 1551 m, 21.vii.2012, A. Amini leg.

**Remark.** This species is distributed in the Nearctic and the Afrotropical regions (Kozlov 1987), and was recently reported from Iran (Amini et al. 2014).

***Aximopsis augasmae* (Zerova, 1977) (Hymenoptera: Eurytomidae)**

(Figs 2-3)

**Material examined:** 15 ♀, 3 ♂, Iran: South Khorasan province, Birjand (32° 51' 59"N, 59°13' 55"E), 1465 m, vii.2017, A. Amini, leg.

**Remark.** *Carpomya vesuviana* infesting *Ziziphus jujuba* represents a new host for *A. augasmae* which develops as a solitary endoparasitoid of the larvae. This species is distributed in the eastern part of the West-Palaearctic (Noyes 2021) and has been previously reared on *Augasma atraphaxidellum* Kuznetz (Lepidoptera: Coleophoridae) on *Atraphaxis spinosa* L. (Polygonaceae) and other moth species on *Zygophillum* (Zerova and Seryogina 2006), as well as *Etiella zinckenella* (Treitschke) (Lepidoptera: Pyralidae) on *Sophora alopecuroides* L. (Leguminosae) (Lotfalizadeh and Hosseini 2014).

**Diagnosis.** The most important characters to distinguish *A. augasmae* from closely related species were discussed by Zerova (1977), Zerova and Seryogina (2006) and Lotfalizadeh and Hosseini (2014).

This species is characterized by the following characters: body generally black, with some parts brown (legs and antenna partly) (Figs 2a, b). Gena distinctly carinate posteriorly, postgenal lamina present and raised, joining genal carina ventrally (Figs 3e, f). Clypeus not delimited dorsally, strigose, truncate on ventral margin (Fig. 3d). All funiculars longer than broad in female (Fig. 3a); often asymmetric, strongly tapering apically and with whorls of long hairs in male (Fig. 3b). Mesepimeron strigose, with horizontal ventral shelf in front of mesocoxal foramina (Fig. 3g). Mesodiscrimen with projecting triangular tooth in front of mesocoxal foramina (Fig. 3g), epicnemium completely delimited. Postmarginal vein distinctly longer than stigmal and marginal veins (1.2 and 1.8 times, respectively) (Figs 3i, j). Procoxa with an oblique carina on front side, delimiting ventrally a depression (Fig. 3c). Gaster as long as mesosoma and head together (Fig. 2a), with a short petiole, shorter than width; ovipositor sheaths horizontal (Fig. 3h).

***Eurytoma pineticola* Zerova, 1981 (Hymenoptera: Eurytomidae)**

(Figs 4-5)

**Material examined:** 25 ♀, 12 ♂, Iran: South Khorasan province, Birjand (32° 51' 59"N, 59°13' 55"E), 1465 m, vi.2017, A. Amini, leg.

**Remark.** This species was reared for the first time on larvae of *Carpomya vesuviana* infesting *Ziziphus jujuba*. However, it was already reported from non-frugivorous tephritid such as *Paratephritis transitoria* (Rohdendorf) on *Cacalia hastata* L. (Asteraceae) (Zerova 1981).

**Diagnosis.** *Eurytoma pineticola* is characterized by a strigose supraclypal area (Fig. 5g), gena as long as eye height; funiculars in female distinctly longer than wide (Fig. 5a), antennae of male with 5 funiculars and 2 clavomeres (Fig. 5b); adscrobal carina of mesopleuron not elbowed and exhibiting a unique tooth in front of mesocoxa, mesepisternal shelf not developed (Fig. 5f); marginal vein 1.5 times as long as stigmal vein (Fig. 5e); metasoma as long as mesosoma (Fig. 4a), slightly compressed laterally and slightly elevated at apex (Fig. 5c); Gt4 is the largest tergite.

*Eurytoma pineticola* is closely related to *Eurytoma serratulae* (Fabricius) and can be separated by the characters mentioned in the key.

### ***Eurytoma serratulae* (Fabricius, 1798) (Hymenoptera: Eurytomidae)**

(Figs 6-8)

**Material examined:** 14 , Iran: South Khorasan province, Birjand (32° 51' 59"N, 59°13' 55"E), 1465 m, vii.2017, A. Amini, leg.

**Remark.** *Eurytoma serratulae* was reared for the first time from larvae of *C. vesuviana*. This species was previously reported as a parasitoid of other fruit flies, *Myopites longirostris* (Loew, 1846) (under *M. frauenfeldi* (Schiner, 1868)) (Herting 1978), *Tephritis stictica* Loew, 1862 (Herting 1978), *Urophora cardui* (L., 1758) (Bouček 1966) and an unknown species of *Urophora* (Claridge 1961). *Eurytoma pineticola* belongs to the *serratulae* species group that occurs in the Holarctic region and parasitizes gall-inducing Cynipidae (Hymenoptera), Tephritidae (Diptera) and Curculionidae (Coleoptera) (Claridge 1961; Lotfalizadeh et al. 2007). Claridge (1962) suggested that *E. serratulae* only parasitized gall-maker tephritids in stems of Compositae, but our finding demonstrated that the species can also parasitize larvae of fruit flies on Rhamnaceae.

**Diagnosis.** *Eurytoma serratulae* is characterized by its punctured supraclypeal area (Figs 6c, d), clypeal margin slightly emarginate (Fig. 6d); gena conspicuously carinate posteriorly, postgena with ventral depression and posterior margin of gena forming a blunt angle and emarginate lateral to edge of oral fossa; postgenal lamina present, ventrally raised, in lateral view appearing as a tooth. In females, funiculars longer than wide (Fig. 6a), with 2 clavomeres that are nearly always fused; notauli complete and not obliterated (Fig. 7b), axillar groves with a pit at mid-length, obliterated by sculpture anteriorly, their bottom thus not clearly visible; epicnemium not entirely delimited, adscrobal carina of mesopleuron not elbowed, forming a single tooth in front of mesocoxa (Fig. 7a); propodeum with a median furrow, not impressed and situated in a broadly concave surface (Fig. 8b); ovipositor sheaths relatively horizontal (Fig. 8a).

This species is close to *Eurytoma compressa* (Fabricius, 1794) and females can be separated by the shape of gaster. While the gaster of *E. serratulae* is elongated, slightly flattened laterally and relatively less raised dorsally with a shorter ovipositor (Fig. 8a), the gaster of *E. compressa* female in lateral view is round, strongly flattened, with a vertically raised Gt7 and a long ovipositor.

### ***Cyrtotypx lichtensteini* (Masi, 1921) (Hymenoptera: Pteromalidae)**

**Material examined:** 24 ♂, 6 ♀, Iran: South Khorasan province, Birjand (32° 51' 59"N, 59°13' 55"E), 1465 m, vii.2017, A. Amini, leg.

**Remark.** This species is an ectoparasitoid of the larval stage and it was reported on Coleoptera, Diptera, Hymenoptera and Lepidoptera (Lotfalizadeh and Hosseini 2014; Mete and Lotfalizadeh 2019) and widely distributed in the Palaearctic (from Europe and North Africa to China) and Nearctic regions (Noyes 2021).

**Diagnosis.** The most important characteristics of *C. lichtensteini* were summarized by Lotfalizadeh and Hosseini (2014) and Mete and Lotfalizadeh (2019). See figure 3 in Mete and Lotfalizadeh (2019) for the morphological details of this species.

The main morphological characters of the species are as follows: Body black with bluish-green reflections on mesosoma, metasoma with reddish-blue reflections laterally and Gt1 with greenish reflections dorsally. Tibiae and tarsi mainly whitish. Antennal formula 11353, scape slightly exceeding the anterior ocellus, all funiculars longer than wide, Fu1 about twice as long as wide, clava 2.5 times as long as wide. Marginal vein longer than postmarginal and stigmal veins, relative measurements: marginal vein: 13; stigmal vein: 10; postmarginal vein: 12. Metasoma about 2.2 times as long as broad and about 1.25 times as long as mesosoma.

### ***Pteromalus* sp. (Hymenoptera: Pteromalidae)**

(Figs 9-10)

**Material examined:** 2 ♂, Iran: South Khorasan province, Birjand (32° 51' 59"N, 59°13' 55"E), 1465 m, vii. 2017, A. Amini, leg.

**Remark.** Several species of the genus *Pteromalus* have been previously reared from fruit flies (Lotfalizadeh and Gharali 2014).

**Diagnosis.** Some of the noticeable morphological characters of this undetermined species are POL about 1.6 times as long as OOL; clypeus bilobed, strigose dorsally (Fig. 10a); antennal toruli located in the center of head (Fig. 10a); antennal formula 11263, all funiculars slightly longer than wide (Fig. 10a); pronotum anteriorly carinate (Fig. 10c); fore wing basally bare, with open large speculum, marginal vein as long as postmarginal vein, 1.5 times as long as stigmal vein (Fig. 9b); propodeum mainly smooth, slightly reticulate anteriorly, without median carina (Fig. 10b).

### ***Smicromyrme (Eremotilla) tekensis* Skorikov, 1935 (Hymenoptera: Mutilidae)**

**Material examined.** 1 , Iran: South Khorasan province, Mood (32°42'N, 59°31'E), 1839 m, Sarbishe, 33 km SE Birjand, vii.2013, A. Amini leg. 1 , Birjand, Razg village (32°53'N, 59°13'E), 1470 m, i.2012, A. Amini, leg.

**Remark.** This species was reported from China, Kazakhstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan (Lelej 2002) and Iran (Amini et al. 2012b). It is a pupal parasitoid of *C. vesuviana*.

**Diagnosis.** The alate male of this species exhibits the following distinctive characters: mandible bidentate with well-developed subventral tooth, separated by excision; clypeus somehow flattened, without preapical teeth; head behind the eyes strongly convergent in dorsal view, without posterolateral angles. Apterous females have a triangular pygidial area, conspicuously widened basally with oblique striae throughout its length, lateral carina not widened apically; mesoscutellar scale well developed.

***Smicromyrme (Astomyrme) nikolskajae* Lelej, 1985 (Hymenoptera: Mutillidae)**

**Material examined.** 1 , Iran: South Khorasan province, Birjand, Razg village (32°53'N, 59°13'E), 1470 m, 14.x.2012, A. Amini, leg. 1 , 2 , Same locality, iix.2013. 1 , 33 Km SE Birjand, Sarbishe, Mood (32°42'N, 59°31'E), 1839 m, A. Amini, leg.

**Remark.** This species is known from Kyrgyzstan and Tajikistan (Lelej 2002) and has been also reported from Iran (Amini et al. 2012b).

**Diagnosis.** The species is recognized by the following characters: mandible without subventral tooth, if an inconspicuous tooth is present then the mandible has no excision; clypeus weakly elevated medially with two apical tubercles; antenna brownish-red, paler ventrally. In female, striae of the pygidial area not reaching the posterior margin, posterior third smooth; mesosoma with well-developed antero- and posterodorsal angles, dorsally more or less flattened (in lateral view); baso-medial pale spot of second metasomal tergum 2.5–3.0 times distance between spot and medial apex of apical pale band of same tergite.

In the subgenus *Astomyrme*, this species is closely related to *Smicromyrme ausonius* Invrea, 1950, but the male of *S. nikolskajae* can be separated by its smaller body size (body size is larger in *S. ausonius*, 6.0–10 mm), the clypeus weakly elevated medially bearing two apical tubercles (concave with three preapical tubercles in *S. ausonius*), and antenna brownish-red, paler beneath (antenna black, rarely reddish-brown beneath in *S. ausonius*).

The female of *S. nikolskajae* is mostly smaller (3.2–4.0 mm) than *S. ausonius* (3.0–6.0 mm); the distance between baso-medial pale spots and apical pale band on Gt2 in *S. nikolskajae* is about 2 times as long as *S. ausonius*; in *S. nikolskajae* apical 1/3 of pygidial area smooth while in *S. ausonius* apical 1/4-1/5 of pygidial area is smooth.

**Key to the hymenopterous parasitoids of *Carpomya vesuviana* in Iran**

1- Fore wing usually with enclosed cell, male apterous (only in Mutillidae)..... 2



- Fore wing without enclosed cell (Figs 3j, 5d, 8c, 9b)..... **4**
  
- 2- Gt1 node-like; pronotum usually indistinctly fused with mesothorax, pronotum medially less than one-third dorsal length of mesonotum-propodeum; Gs1 separated from Gs2 by a deep constriction; body covered with long hairs..... **Mutillidae 3**
  
- Metasoma without node-like segments; pronotum distinctly separated from and larger than mesonotum; Gs1 and Gs2 not separated by a constriction; body without long hairs ..... **Braconidae, *Fopius carpomyiae***
  
- 3- In male, mandible beneath without subventral tooth, if with inconspicuous one then without excision; clypeus medially weakly elevated with two apical tubercles; in female pygidial area with striae not reaching posterior margin, apically smooth; apical 1/3 of pygidial area not sculptured, smooth ..... ***Smicromyrme nikolskajae***
  
- In male, mandible bidentate, beneath with well-developed subventral tooth separated by excision; clypeus flattened, without two preapical teeth; in female pygidial area triangle, conspicuously widened basally with striae throughout; pygidial area with oblique striae ..... ***Smicromyrme tekensis***
  
- 4- Pronotum more or less U-shaped in dorsal view; medial length usually less than one-quarter as long as mesoscutum; Gt1 several times as long as any other tergite and much wider than petiole, petiole cylindrical ..... **Diapriidae, *Coptera nr. silvestrii***
  
- Pronotum rectangular, longer than mesoscutum medially; Gt1 shorter than other tergites and wider; petiole conical..... **5**
  
- 5- Pronotum short and transverse (Fig. 9a); body finely sculptured, with green metallic reflection (Figs 9a, b & 10a) ..... **Pteromalidae 6**
  
- Pronotum long and shoulder-like, body coarsely sculptured (Fig. 7b); body black without metallic reflection (Figs 4a, b & 6a, b) ..... **Eurytomidae 7**
  
- 6- Fu1 distinctly longer than pedicel; clypeus ventrally emarginated; propodeum smooth, with a median carina ..... ***Cyrtotypx lichtensteini***
  
- Fu1 shorter than pedicel (Fig. 10a); clypeus ventrally bilobed (Fig. 10a); propodeum smooth, without median carina (Fig. 10b) ..... ***Pteromalus sp.***
  
- 7- Mesopleuron with horizontal ventral shelf in front of mesocoxal foramen, adscrobal carina of mesopleuron elbowed (Fig. 3g); sublateral prepectus with a deep pit, its bottom not or rarely visible; epicnemium always completely delimited by a carina ..... ***Aximopsis augasmae***

- Mesopleuron without ventral shelf, adscrobal carina of mesopleuron not elbowed forming a single tooth in front of mesocoxa (Fig. 7a); sublateral prepectus sometimes different; epicnemium laterally delimited by epicnemial carina, not ventrally ..... **7**
- 8- Lower face with strigose supraclypeal area (Fig. 5g); pedicel brownish-dark (Fig. 5A); all coxae black, all femora medially black (Fig. 4a) ..... ***Eurytoma pineticola***
- Lower face often with punctured supraclypeal area (Fig. 6c); pedicel yellow (Fig. 6b); fore and mid coxae yellow, all femora mainly yellow (Fig. 6a) ..... ***Eurytoma serratulae***

## Discussion

In this study, we listed ten species of parasitoid wasps belonging to five families, associated with *C. vesuviana* in Iran and provided new biological information. Amini et al. (2014a) reported *Cyrtotypx lichtensteini* as a larval ectoparasitoid and *Coptera* nr. *silvestrii* as a pupal endoparasitoid of *C. vesuviana*. They also reared two mutillid species as pupal parasitoids of *C. vesuviana* in Eastern Iran (Amini et al. 2014b). Our study provides new information about the parasitoids of *C. vesuviana* and increases the number of parasitoids associated with this economically important pest to ten species. New findings of *Eurytoma pineticola* and *E. serratulae* and host-parasitoid association of all species were demonstrated by rearing for the first time. Among these parasitoids, *E. pineticola* and *C. lichtensteini* are the most abundant parasitoids with a relatively high parasitism rate on *C. vesuviana* and after bioecological validation, these species could be recommended for biological control programs. While, five braconid species and *Omphale* sp. (Eulophidae) were reported as parasitoids of the ber fly in India (Narayanan and Chawal 1962). The egg-pupal braconid *Fopius carpomyiae* is the first reported parasitoid of *C. vesuviana* in Iran. We did not rear it from *C. vesuviana* associated with *Z. jujuba*, while the species is known to parasitize this tephritid species on *Ziziphus spina-christi*, an indigenous species in Eastern Iran.

Ten species of parasitic wasps of the ber fruit fly, *C. vesuviana* from four families are now listed from Iran and we propose an identification key to these species. This result suggests that *Fopius carpomyiae* which was introduced from the Oriental region with imported fruits did not yet reach Eastern Iran. We envisage its presence in the near future. Although the parasitism rate of obtained parasitoids is low, it can be evaluated on a larger scale to have an accurate evaluation. Also, including *F. carpomyiae* as an important species on this list can increase the parasitism of *C. vesuviana*. On the other hand, importing populations of this exotic parasitoid to pest-infested areas in eastern Iran can be useful as a practical proposal to reduce pest damage.

## Abbreviations

**C1–3**: first to third clavomere; **Fu1, Fu2, etc.**: first funiculars, second funiculars, etc.; **Gt1-n**: gastral terga 1-n.; **Gs1-n**: gastral sternite 1-n; **OOL**: Oculo-ocellar line; **POL**: Posterior-ocellar line.

# Declarations

## Conflict of interest

All authors declare that they have no conflict of interest.

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## Figures

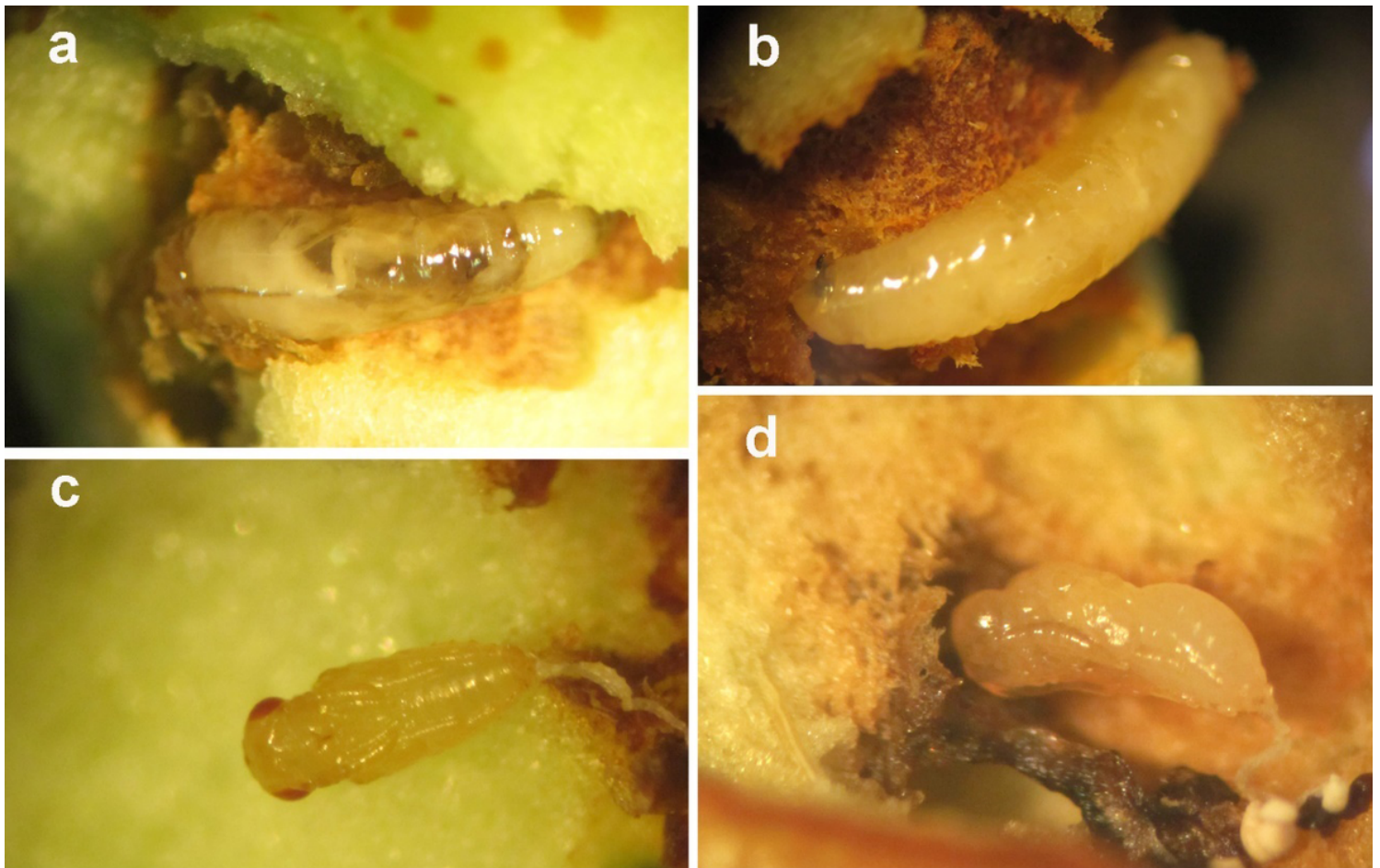


Figure 1

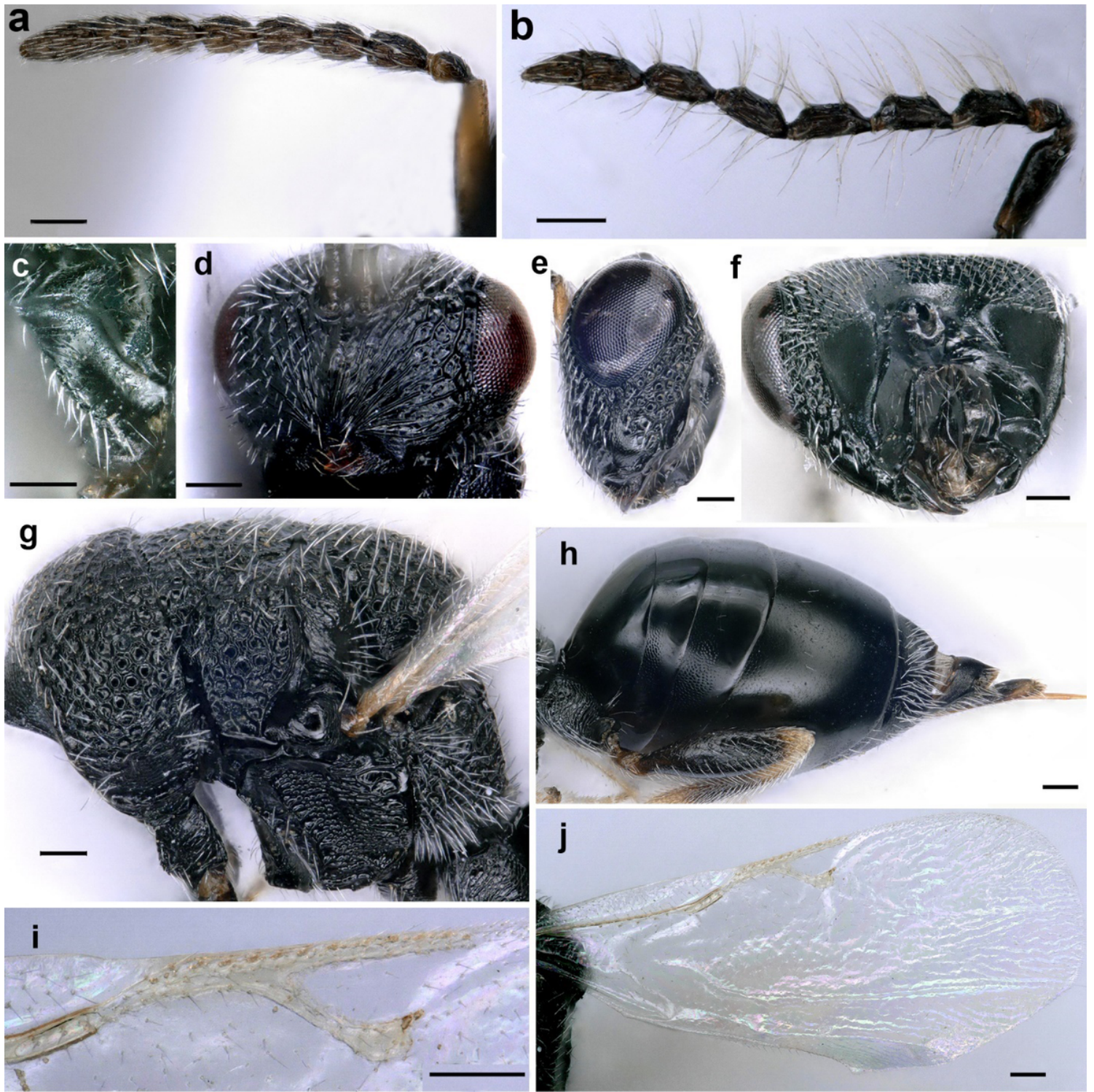
**a & b**, Larvae of *Carpomya vesuviana* on damaged tissue of *Ziziphus jujuba* fruit; **c & d**, Pupae of *C. vesuviana* parasitoids.



**Figure 2**

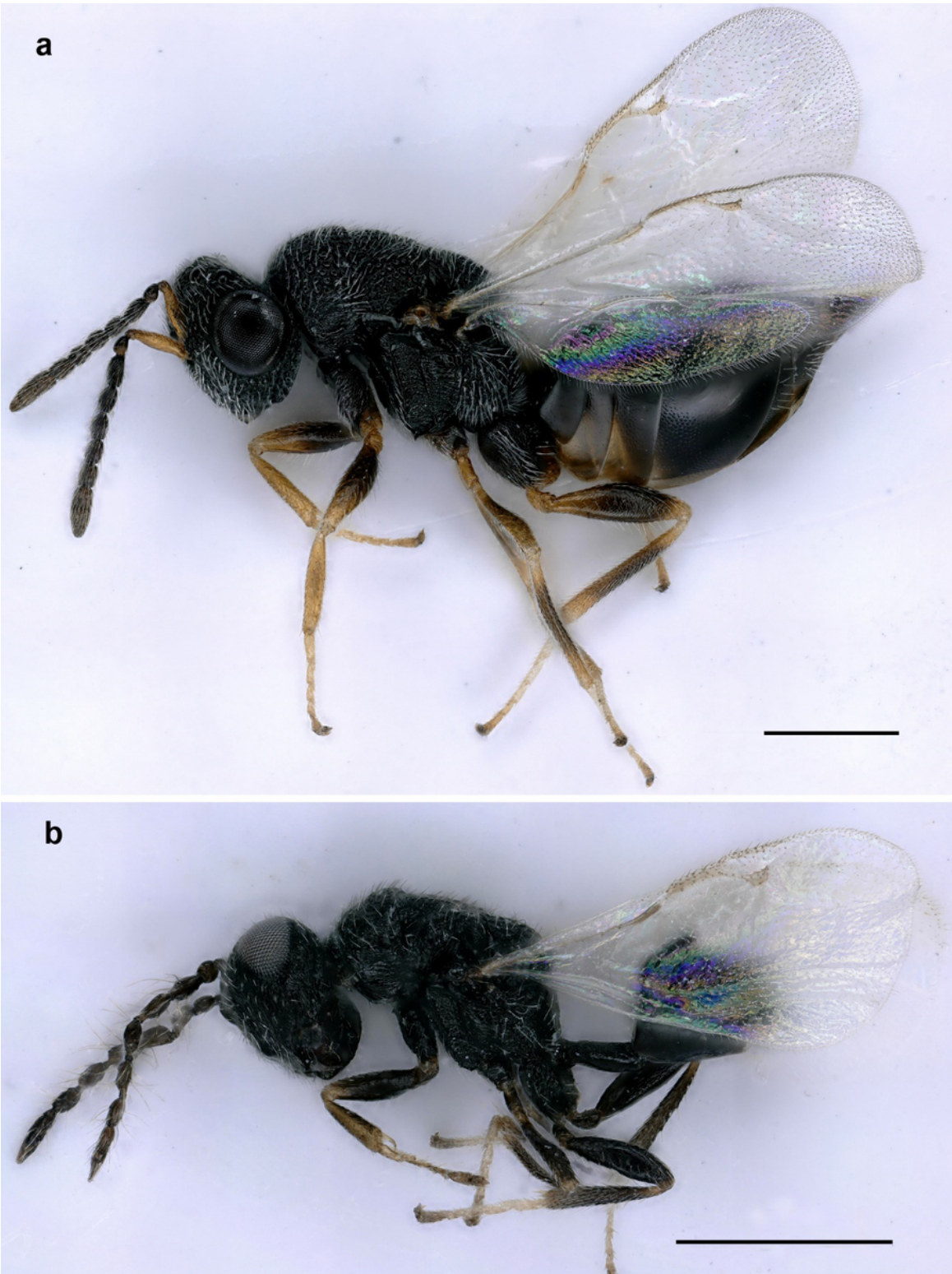
*Aximopsis augasmae*. **a**, Female, lateral habitus; **b**, Male, lateral habitus (scale bare, 500 $\mu$ m).





**Figure 3**

*Aximopsis augasmae*. **a**, Female antenna; **b**, Male antenna; **c**, Fore coxa; **d**, Head, fronto-ventral view; **e**, Head, lateral view; **f**, Head, dorsal view; **g**, Mesosoma, lateral view; **h**, Metasoma, lateral view; **i**, Venation; **j**, Fore wing (scale bare, 100µm).



**Figure 4**

*Eurytoma pineticola*, lateral habitus: **a**, Female; **b**, Male (scale bare, 500 $\mu$ m).



**Figure 5**

*Eurytoma pineticola*: **a**, Female antenna; **b**, Male antenna; **c**, Metasoma, lateral view; **d**, Fore wing; **e**, venation; **f**, Mesosoma, lateral view; **g**, Head, frontal view (scale bare, 100 $\mu$ m).



**Figure 6**

*Eurytoma serratulae*, female: **a**, Lateral habitus; **b**, Antennae; **c**, Head, frontal view; **d**, Lower face and clypeus; **e**, Fore wing venation (scale bare, 100 $\mu$ m).

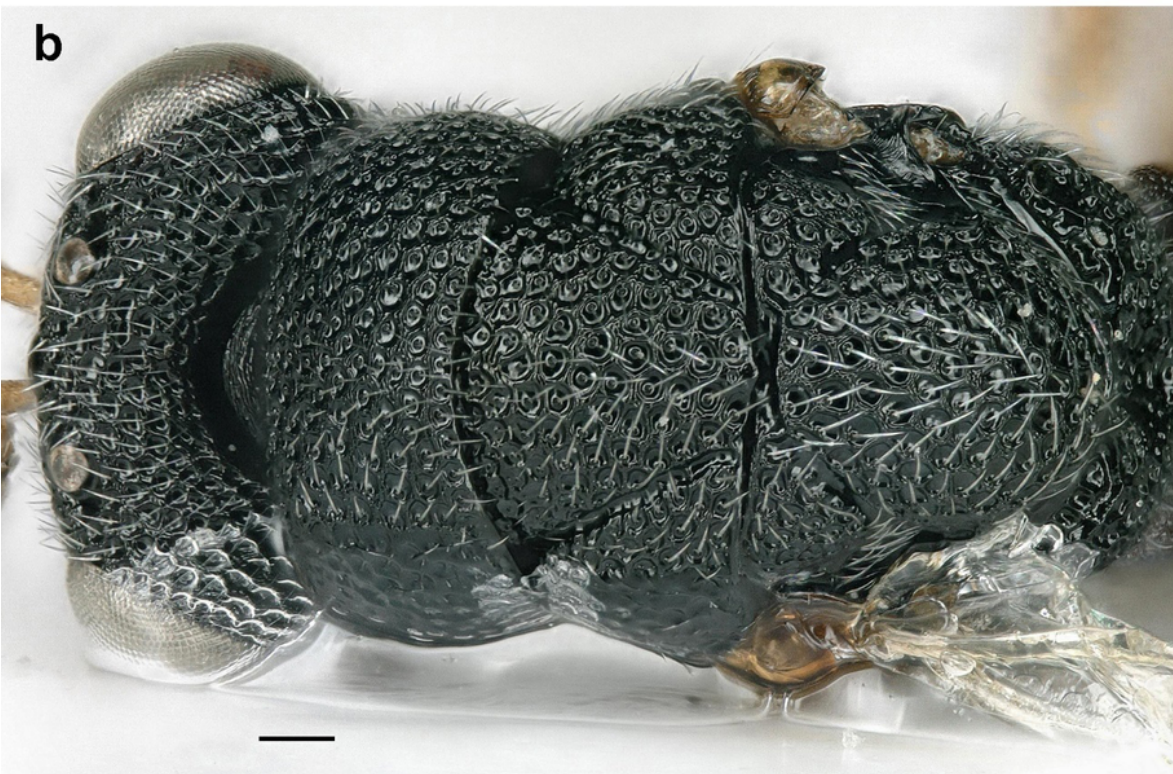
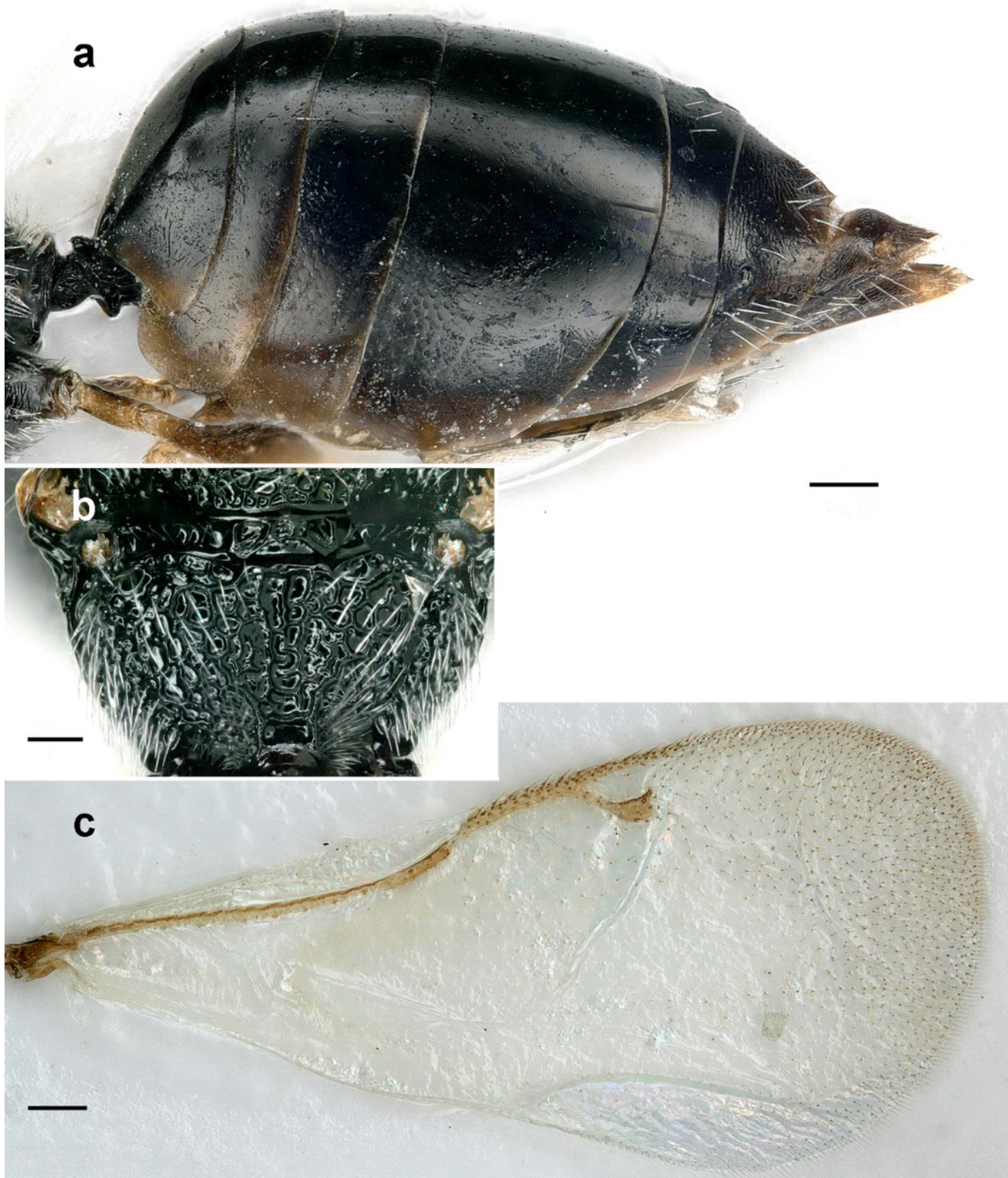


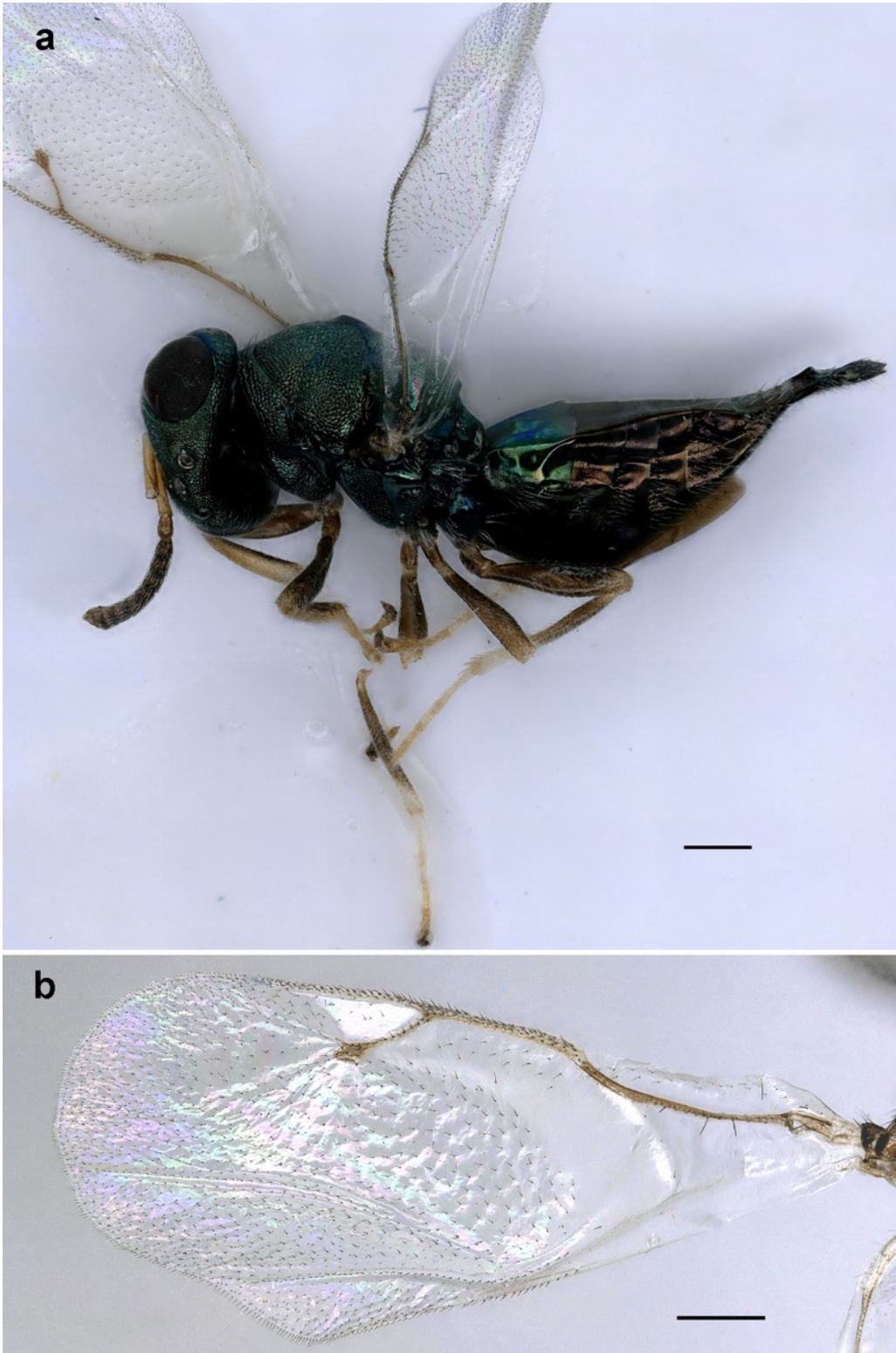
Figure 7

*Eurytoma serratulae*, female, Head and mesosoma: **a**, Lateral view; **b**, Dorsal view (scale bare, 100 $\mu$ m).



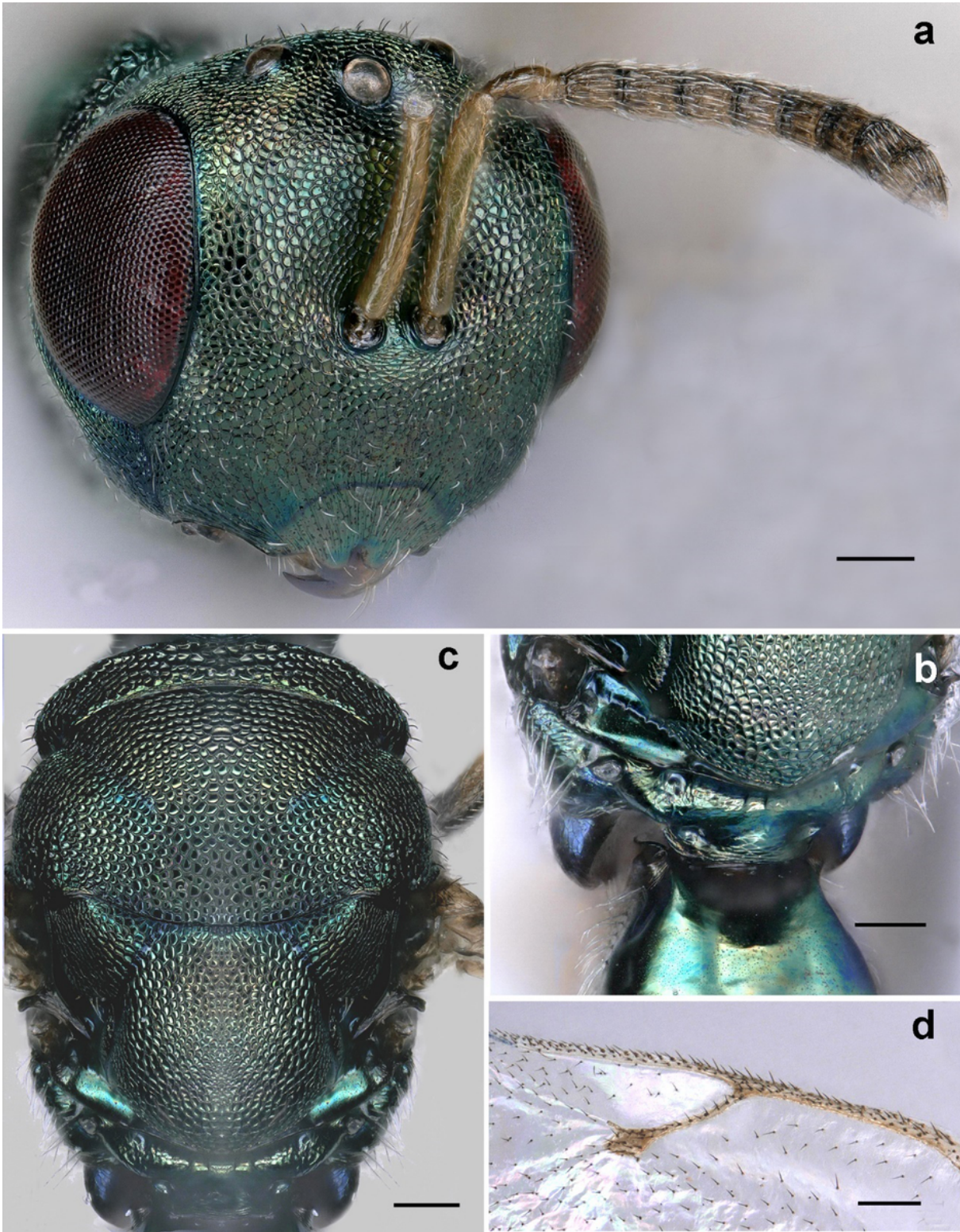
**Figure 8**

*Eurytoma serratulae*, female: **a**, Metasoma, lateral view; **b**, Propodeum, dorsal view; **c**, Fore wing (scale bare, 100 $\mu$ m).



**Figure 9**

*Pteromalus* sp.: **a**, Female, lateral habitus, **b**, Fore wing (scale bare, 200µm).



**Figure 10**

*Pteromalus* sp.: **a**, Head and antenna, laterofrontal view; **b**, Mesoscutellum and propodeum, dorsal view; **c**, Mesosoma, dorsal view; **d**, Venation (scale bare, 100 $\mu$ m).