Bonn zoological Bulletin 66 (2): 95–106 December 2017

First record of *Chrysotoxum baphyrum* Walker from West Palaearctic (Diptera: Syrphidae), with key to species of *Chrysotoxum* Meigen from Iran

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Abstract. A new species of Syrphidae is recorded from Iran, *Chrysotoxum baphyrum* Walker. This record represents a new species for the Western Palaearctic Region, as *C. baphyrum* is predominantly distributed in India and Southeast Asia. An identification key to the recorded species of *Chrysotoxum* from Iran is provided, as well as newly obtained DNA sequences for *C. baphyrum*.

Key words. Iran, taxonomy, identification key, new record, DNA barcode.

INTRODUCTION

Flies of the genus *Chrysotoxum* Meigen, 1803 are excellent wasp mimics, with long antennae (usually as long as or longer than face), a broad convex abdomen, and a very distinct black and yellow colour pattern. There are many observations on habitat and visited flowers by adults (Speight 2016) and on oviposition (Reemer & Goudsmits 2004), but the precise prey of larvae of *Chrysotoxum* remains unclear. Some previous authors have reported immature stages of *Chrysotoxum* near or in ant nests (Dixon 1960; Speight 1976; Rotheray et al. 1996), suggesting that immatures may live in ant nests and feed on aphids. Other observations reported a similar behaviour (Inouye 1958; Luciano et al. 1989), but the truth is that developmental stages for the majority of species are unknown. Recently, Patil et al. (2013) reported the species, *Chrysotoxum baphyrum* Walker, 1849 feeding on the sugarcane root aphid from northern Karnataka State, peninsular India.

Chrysotoxum species are so distinct from other genera that previous workers have given different ranks, i.e. as a subfamily (Newman 1834; Schiner 1864; Brunetti 1923, or Hull 1949 among other), as a tribe under Syrphinae (Vockeroth 1969), or a subtribe due to its 'aberration' (Shatalkin 1975). Currently, *Chrysotoxum* is placed within the tribe Syrphini (Vockeroth 1992; Mengual et al. 2008) without a clear sister group (Rotheray & Gilbert 1999; Mengual 2015; Mengual et al. 2015). Shannon (1926) divided the genus into two subgenera based on the ratio of the antennal segments, but subsequent authors have not followed his subdivision.

In the Palaearctic Region, there are 87 recognized species of *Chrysotoxum* at present, from a total of 143 published names (Peck 1988; Ghorpadé 2012; Nedeljković et al. 2013, 2015; Thompson 2013; Vujić et al. 2017). There is currently great need for a revision of the species belonging to this genus. Speight (2016) pointed out a fact already mentioned by Coe (1953) and Sommaggio (2001), that "*the male genitalia of many European 'species' of* Chrysotoxum *are equally indistinguishable*". As a consequence, new techniques, molecular data and integrative approaches are being applied to separate species (Masetti et al. 2006; Nedeljković et al. 2013, 2015) and new species are described, mostly from China (Huo & Zheng 2004; Huo et al. 2006; Zhang et al. 2010; Yuan et al. 2011). But a sound taxonomic background is still needed. The Palaearctic species were last revised by Violovitsh (1974), but he did not include all the recognized species at the time and separated females and males in different keys as both sexes were not known for all species.

The syrphid fauna of Iran has been actively studied during the last years (Dousti & Hayat 2006; Gilasian 2007; Naderloo et al. 2013; Naderloo & Pashaei Rad 2014), and as a result some new species (Gilasian & Sorokina 2011; Gilasian et al. 2015) and multiple new records (Gharali & Reemer 2008, 2010; Khaganinia 2010, 2011; Bedoreh & Ansari 2012; Kazerani et al. 2013, 2014a, 2014b; Khaganinia & Hosseini 2013; Vosughian et al. 2013; Khaganinia & Kazerani 2014; Khosravian et al. 2015) have been reported. In Iran, Dousti & Hayat (2006) reported 12 species of *Chrysotoxum* in their catalogue, and more recently, Kazerani et al. (2013) added three more species.

Received: 05.02.2017
Accepted: 13.07.2017
Corresponding editor: B. Sinclair

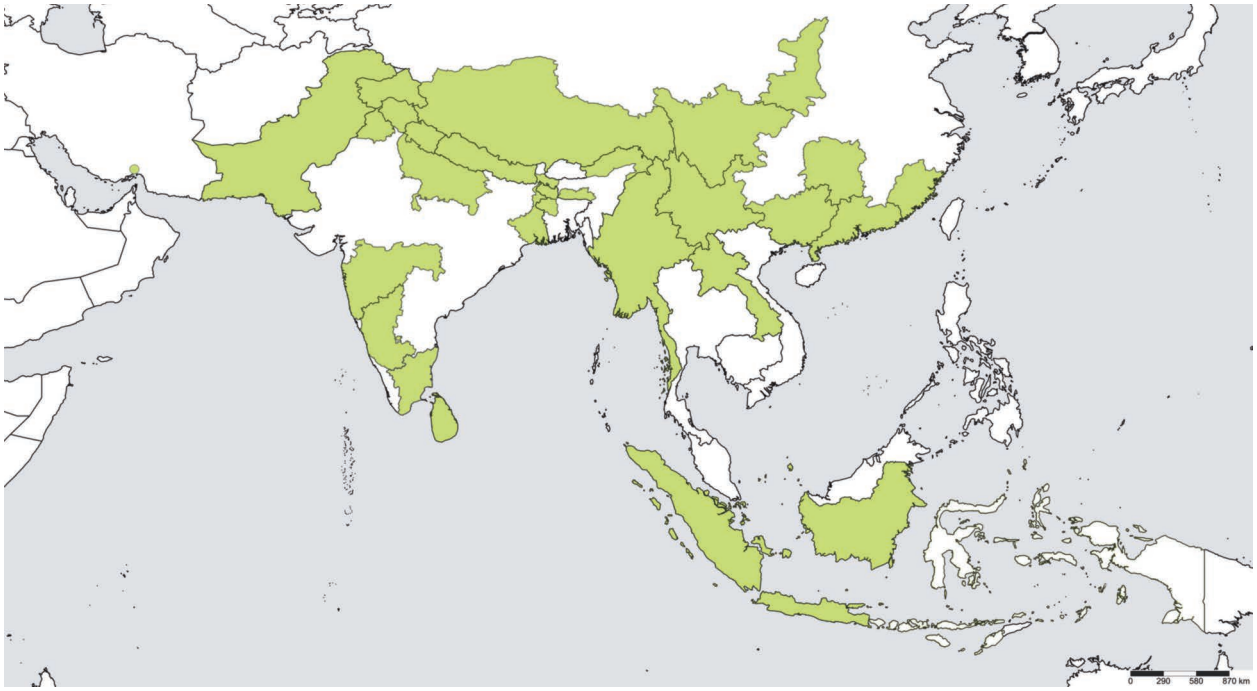


Fig. 1. Map the known geographical distribution of *Chrysotoxum baphyrum*.

Vujić et al. (2017) described a new species from the Middle East, *Chrysotoxum persicum* Vujić, Nedeljković & Hayat, 2017, which is also present in Iran. The present study reports a new species record of this genus for West Palaearctic, *Chrysotoxum baphyrum*. In addition, an identification key is provided for the recorded Iranian species of this genus.

MATERIALS & METHODS

Morphological terminology follows Violovitsh (1974) and Thompson (1999a). In the material examined section, the use of ellipses follows standard English practice and merely indicates that the missing information is the same as that in the preceding record. At the end of each record, between square brackets ([]) and separated by commas, the number of specimens and sex, the holding institution, and the unique identifier or number are given. The abbreviations used for collections and their equivalents are given below:

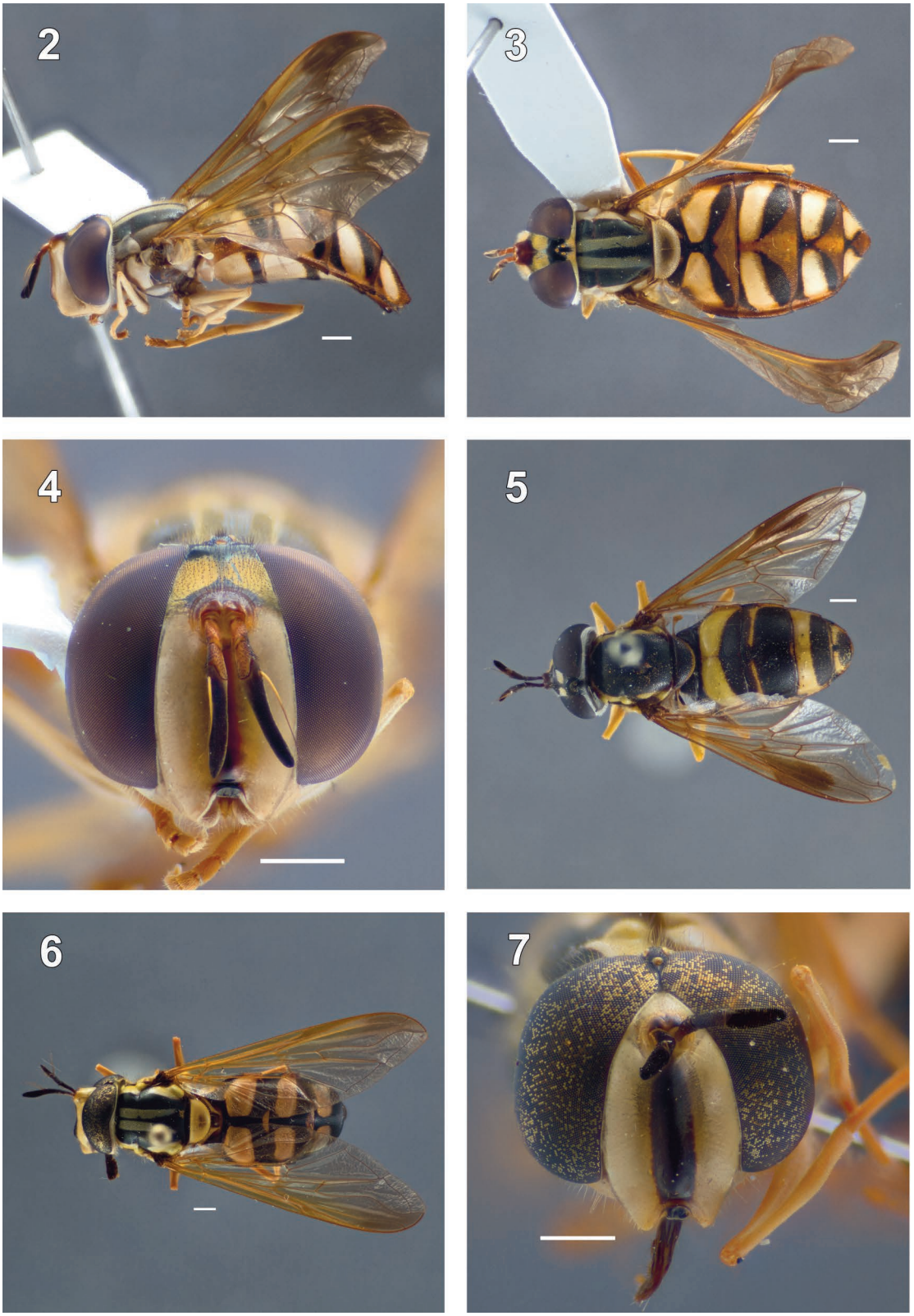
TMUI Department of Entomology, Tarbiat Modares University, Tehran, Iran
ZFMK Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany

Photographs were composed using the software Zerene Stacker® 1.04 (Richland, Washington, USA), based on images of pinned specimens taken with a Canon EOS 7D® mounted on a P–51 Cam-Lift (Dun Inc., VA, USA) and with the help of Adobe Lightroom® (version 5.6). Figure 1 was created with the help of SimpleMappr (Shorthouse 2010).

The identification key is based on previous works; i.e., Becker (1921), Sack (1932), Violovitsh (1974), Sommaggio (2001), van Veen (2006), and Speight (2016), with the help of the original descriptions and species checklist. The collected material has been compared with the collections at TMUI, ZFMK and other major natural history museums (USNM: National Museum of Natural History, Washington DC; BMNH: The Natural History Museum, London; RMNH: Naturalis Biodiversity Center, Leiden), and all the recorded species from the literature have been included.

RESULTS

During the course of the survey to provide an initial taxonomic insight on the genus *Chrysotoxum* for Iran, Malaise traps were used during 2010–2012 to collect specimens from different habitats in several Iranian provinces. Among the available material, five female specimens collected in the southern Hormozgan province were studied (Fig. 1). They were identified as *Chrysotoxum baphyrum* (see Ghorpadé 2012 for the justified emendation of the original name *baphyrus*), a widespread species on the In-



Figs 2–7. *Chrysotoxum baphyrum* Walker, female ZFMK-DIP-00018044. 2 – lateral view. 3 – dorsal view. 4 – frontal view. *Chrysotoxum bicinctum* (Linnaeus), female ZFMK-DIP-00018047. 5 – dorsal view. *Chrysotoxum parmense* Rondani, male ZFMK-DIP-00017469. 6 – dorsal view. 7 – frontal view. Scale bars = 1 mm.

dian subcontinent, representing the first record of this Indomalayan species in the West Palaearctic Region. Brunetti (1923), Ghorpadé (1994) and Huo et al. (2007) were used to key out these specimens, which agreed with the original description and cannot be keyed out using current Palaearctic identification keys. The type material of *C. baphyrum* was not studied. The material of *C. baphyrum* was then compared with specimens at the ZFMK collected in India and Pakistan. Although only five females were collected, these can be without doubt determined as *C. baphyrum* by some morphological characteristics unique to this taxon, such as basoflagellomere long (longer than scape and pedicel together), gena yellow, scutum with a complete lateral yellow vitta from postpronotum to scutellum, and abdominal pattern reduced, less dark than other species (see Differential diagnosis below).

Chrysotoxum baphyrum Walker, 1849

Chrysotoxum baphyrus Walker, 1849: 542. Type locality: North Bengal, between India and Bangladesh.
Figs 2–4

Differential diagnosis. Scape and pedicel light brown to orange with black hairs dorsally, basoflagellomere darker, black, about 1.5 times as long as scape and pedicel together (Figs 2, 4). Scutum with two dorsomedial, long yellowish pollinose vittae almost reaching the posterior margin (Fig. 3), with a complete lateral yellow vitta. Abdomen mostly orange, dark markings reduced; lateral margin of abdomen yellow; terga 2–5 each with a pair of medial, broad, paler maculae, with traces of black fasciate maculae on posterior margin of the pale maculae (Fig. 3).

Material examined. IRAN: Hormozgan province, Bandar Abbas, Zakin, 27˚49′37″ N 56˚18′24″ E, 1122 m, 12.ii.2012, A. Ameri [1 ♀, TMUI]; …, 25.iv.2012, … [2 ♀, TMUI] ..., vi.2011, ... [2 ♀, ZFMK, ZFMK-DIP-00018044, ...18045].

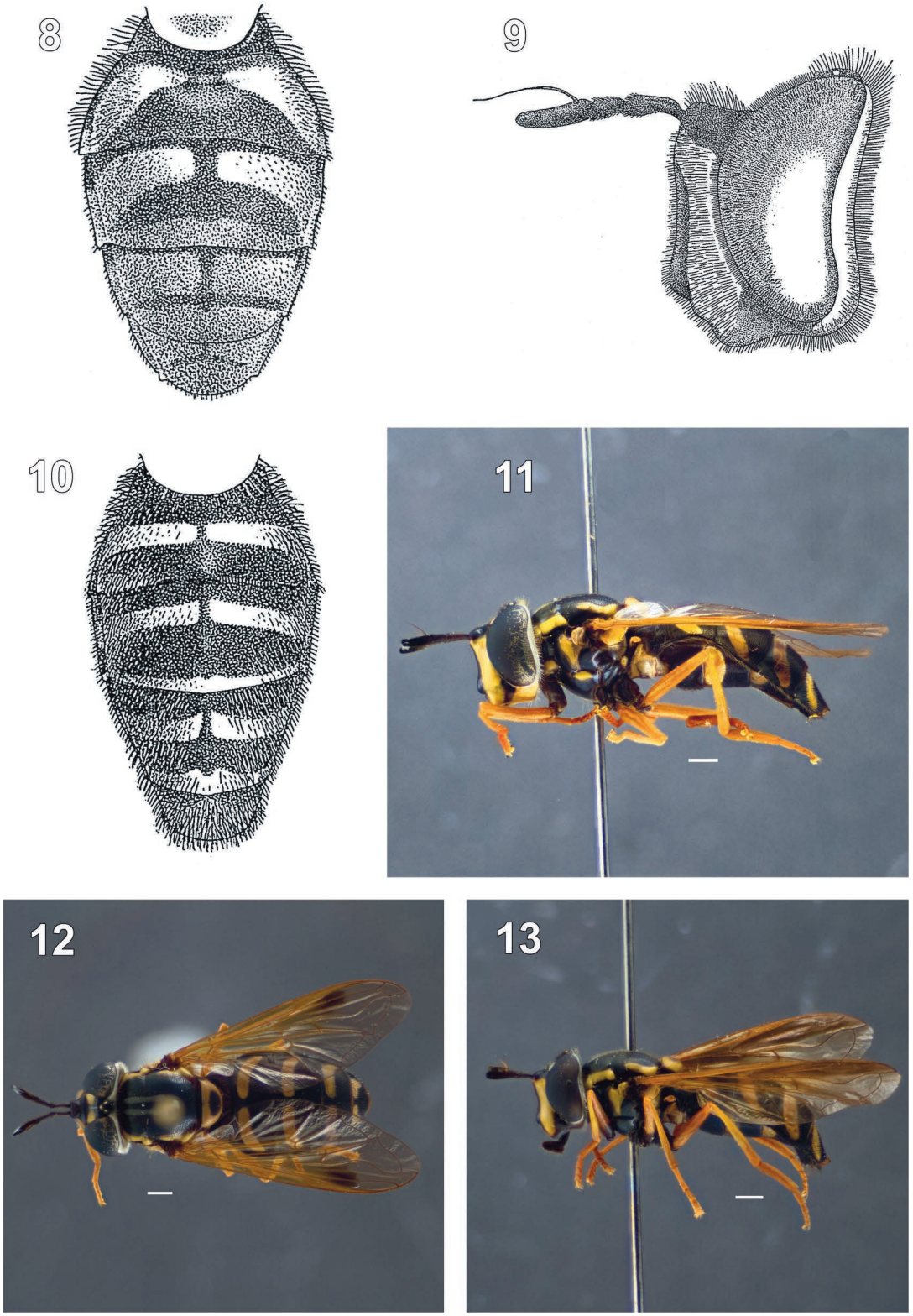
Genetics. The GenBank accession numbers for the specimen ZFMK-DIP-00018045 (Lab code ZFMK_D278) are: 28S gene (KY315697), 18S gene (KY315696), and COI gene (KY315698). This is the first time that *C. baphyrum* is barcoded, but we hope that more barcodes become available (especially from near the type locality) in the near future and further analyses and comparisons can be done.

Distribution. The type locality of *C. baphyrum* is North Bengal, a term used for the north-western part of Bangladesh and northern part of West Bengal in India. The Bangladesh part denotes the Rajshahi Division and Rangpur Division. This species has been previously recorded from China (Huo et al. 2007), Pakistan, Sri Lanka, India (Arunachal Pradesh, Chandigarh, Himachal Pradesh, Jammu & Kashmir, Karnataka, Maharastra, Meghalaya, Punjab, Tamil Nadu, Uttarakhand, North Bengal, West Bengal, Uttar Pradesh), Bangladesh, Nepal, Myanmar, Laos, and Indonesia (Java is mentioned in the literature but might be present in other regions, although not recorded eastwards of the Wallace line) (Ghorpadé 1994, 2012, 2014; Huo et al. 2007; Thompson 2013; Mitra et al. 2015).

Key to *Chrysotoxum* species in Iran

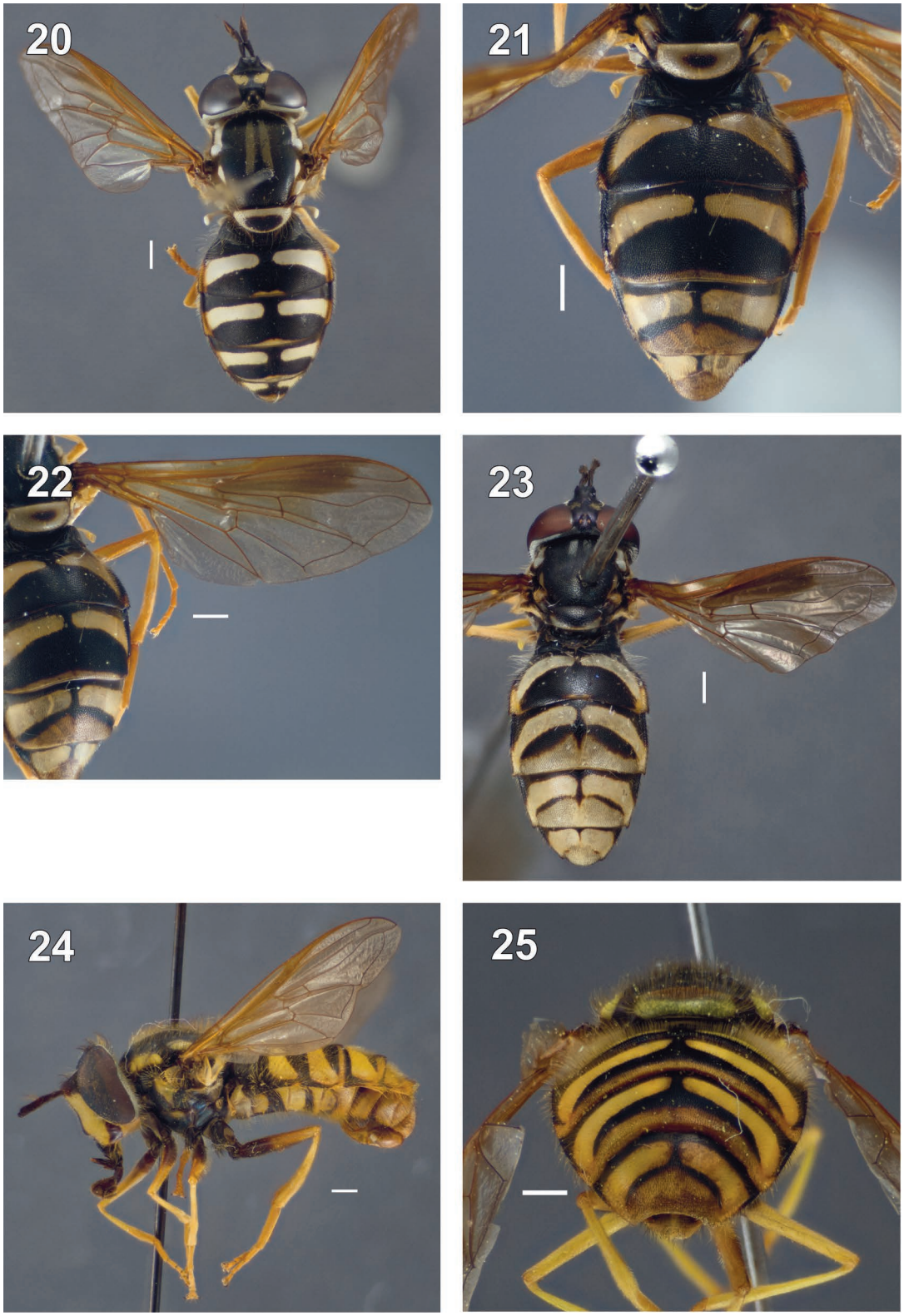
This identification key is based on recorded species from Iran in the literature plus our new records. The images to illustrate the key may not be from Iranian specimens.

1 Antennal basoflagellomere long, as long as or longer than scape and pedicel combined (Figs 2, 4) …… 13
– Antennal basoflagellomere short, distinctly shorter than scape and pedicel combined (Figs 5, 7, 9, 11) …….. 2
2 Median black facial vitta incomplete, not reaching antennal bases; only basal 2/3 of face length occupied by black vitta, not present on dorsal 1/3 (abdomen as in Fig. 8) …… ***C. robustum*** Portschinsky
– Median black facial vitta complete, reaching or nearly reaching base of antennae (Fig. 7) …….. 3
3 Abdomen with distinct yellow fasciate maculae on terga 2 and 4 only; tergum 3 entirely black or with narrow yellow markings (less than half width of those on tergum 4) (Fig. 5) …… ***C. bicinctum*** (Linnaeus)
– Abdominal terga 2–5 with yellow, usually interrupted, fasciate maculae of equal width; tergum 3 with yellow markings as wide as those on tergum 4 (Figs 12, 14) …… 4
4 Frons yellow (Figs 6, 7); scutum shiny black with two dorsomedial broad pale pollinose vittae that almost reach scutellum (Fig. 6) …… ***C. parmense*** Rondani
– Frons black (Figs 11, 13); scutum shiny black with two dorsomedial narrow pale pollinose vittae, usually ending at transverse suture or after, but never beyond anterior 2/3 of scutum (Figs 12, 14) …… 5
5 Anterior part of frons projecting prominently upwards (Fig. 9); yellow markings on terga 2–4 very similar, not arcuate, with anterior margin of fasciate vittae parallel to anterior margin of tergum (Fig. 10) …….. ***C. coreanum*** Shiraki
– Frons of usual shape, anterior part of frons not projecting upwards (Fig. 11); yellow markings on terga 2–4 somehow arcuate (Figs 12, 14) …… 6
6 Lateral margin of abdomen alternately black and yellow (Figs 14, 19) …….. 8
– Lateral margin of abdomen black, yellow fasciate vittae not reaching margin (Figs 11, 12) …….. 7

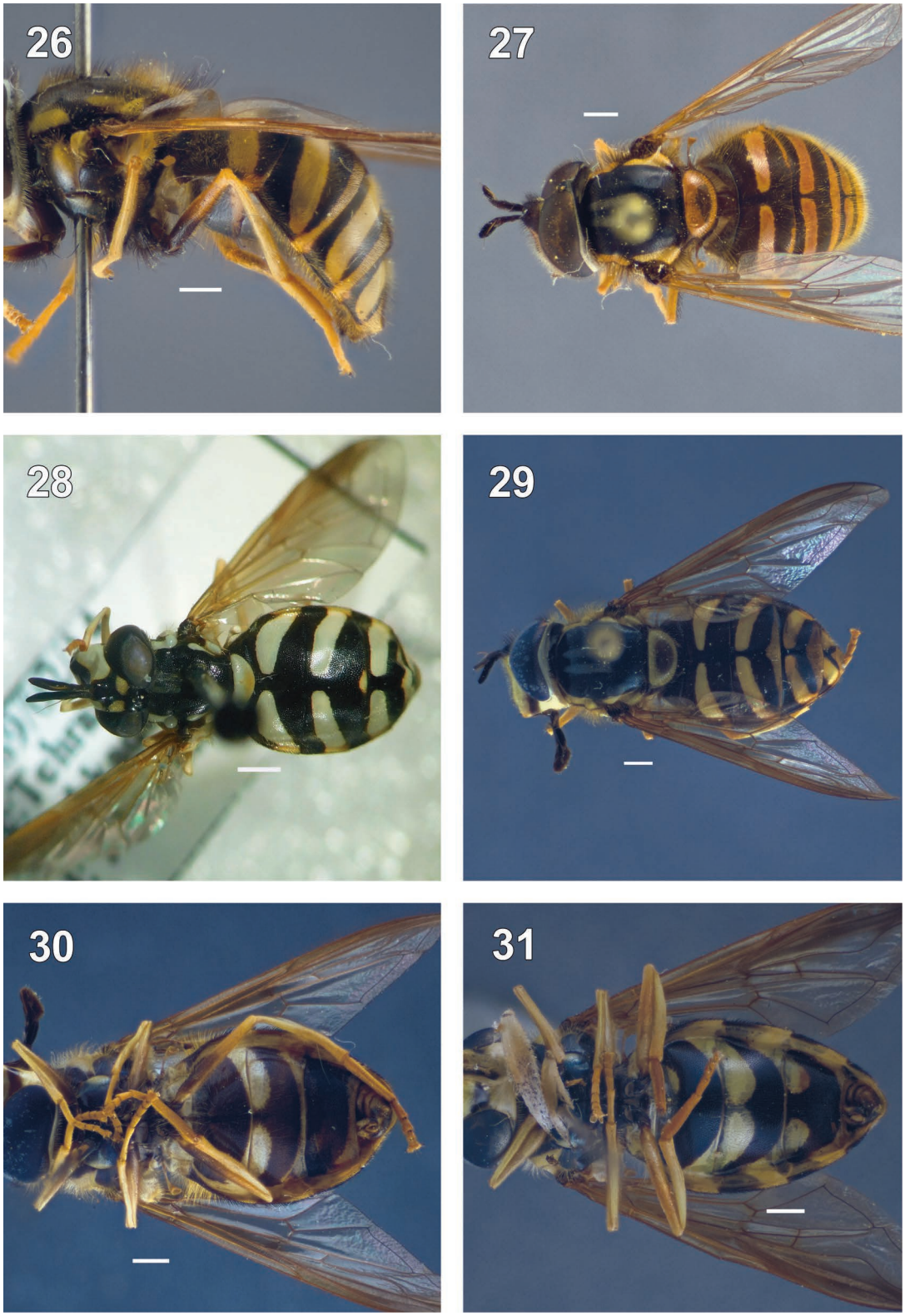


Figs 8–13. *Chrysotoxum robustum* Portschinsky. 8 – abdomen (from Violovitsh 1974). *Chrysotoxum coreanum* Shiraki. 9 – head, lateral view (from Violovitsh 1974). 10 – abdomen (from Violovitsh 1974). *Chrysotoxum festivum* (Linnaeus), female ZFMK-DIP-00017473. 11 – lateral view. 12 – dorsal view. *Chrysotoxum vernale* Loew, female ZFMK-DIP-00017476. 13 – lateral view. Scale bars = 1 mm.

Figs 14–19. *Chrysotoxum octomaculatum* Curtis, female CEUA00019589. 14 – dorsolateral view. *Chrysotoxum octomaculatum* Curtis, female CEUA00082597. 15 – abdomen, ventral view. *Chrysotoxum persicum* Vujić, Nedeljković & Hayat, paratype female ZFMK-DIP-00018048. 16 – abdomen, dorsolateral view. 17 – wing and abdomen. 18 – abdomen, ventral view. *Chrysotoxum verralli* Collin, female ZFMK-DIP-00017471. 19 – dorsal view. Scale bars = 1 mm.



Figs 20–25. *Chrysotoxum elegans* Loew, female ZFMK-DIP-00017470. 20 – dorsal view. *Chrysotoxum montivagum* Violovitsh, female ZFMK-DIP-00018049. 21 – abdomen, dorsal view. 22 – wing. *Chrysotoxum* sp., female from Qazi Chak, ZFMK-DIP-00018050. 23 – dorsal view. *Chrysotoxum cautum* (Harris). 24 – male ZFMK-DIP-00017464, lateral view. 25 – female ZFMK-DIP-00017468, posterior view. Scale bars = 1 mm.



Figs 26–31. *Chrysotoxum arcuatum* (Linnaeus). 26 – female ZFMK-DIP-00018046, lateral view. 27 – male ZFMK-DIP-00017472, dorsal view. *Chrysotoxum bactrianum* Violovitsh, female. 28 – dorsal view. *Chrysotoxum lessonae* Giglio-Tos, male ZFMK-DIP-00017475. 29 – dorsal view. 30 – ventral view. *Chrysotoxum intermedium* Meigen, male ZFMK-DIP-00017474. 31 – ventral view. Scale bars = 1 mm.

7 Pro- and mesofemur completely yellow (Fig. 11); katepisternum usually with dorsal yellow macula (Fig. 11) …….. ***C. festivum*** **(**Linnaeus)
– At least bases of pro- and mesofemur black; katepisternum usually without dorsal yellow macula; if present, size smaller than posterior spiracle (Fig. 13) …… ***C. vernale*** Loew
8 Terga 3 and 4 with black anterior margin not interrupted, continuously black. Tergum 5 with anterior black fascia reaching lateral margin; if not, lateral margin yellow (Fig. 19) …….. 10
– Terga 3 and/or 4 with black anterior margin interrupted at lateral margin by yellow vitta; lateral margin partly black (Figs 14, 16); although variable, most specimens exhibit this feature on at least one tergum. Tergum 5 with anterior black fascia also interrupted, sometimes lateral margin entirely yellow (Fig. 14) …….. 9
9 Wing with anterior margin yellow, without dark macula; wing tip hyaline (Fig. 14). Terga 3 and 4 with black anterior margin broader towards lateral margin because anterior margin of yellow maculae does not follow tergum anterior margin (Fig. 14); sternum 2 black, except posterolateral corners yellow, with two anterior large yellow maculae (joined medially or not) occupying at least 1/3 of sternum length (Fig. 15). Male genitalia: surstylus less elongated, about 3 times longer than wide …….. ***C. octomaculatum*** Curtis
– Wing with anterior margin yellow, with clear dark macula between end of R_1 and undulation of R_{4+5}; wing tip hyaline (Fig. 17). Terga 3 and 4 with black anterior margin very narrow, of equal width over much of its length because anterior margin of yellow macula follows tergum anterior margin closely (Figs 16, 17); sternum 2 black, except posterolateral corners yellow, with two very small anterior yellow maculae occupying less than 1/4 of sternum length (Fig. 18). Male genitalia: surstylus elongate, about 4 times longer than wide …….. ***C. persicum*** Vujić, Nedeljković & Hayat
10 Wing with darkened anterior margin, yellow, without subapical dark macula (Fig. 19) …….. 12
– Wing with darkened anterior margin, yellow to brownish, with subapical dark macula (Fig 22) …… 11
11 Scutellum yellow with medial black macula (Figs 21, 22) …… ***C. montivagum*** Violovitsh
– Scutellum black with posterior margin yellow (Fig. 23) …… ***Chrysotoxum*** **sp.** (female from Qazi Chak)
12 Tergum 2 with black anterior margin broader towards lateral margin because anterior margin of yellow maculae does not follow anterior margin of tergum (Fig. 20) …… ***C. elegans*** Loew
– Tergum 2 with black anterior margin of equal width over much of length because anterior margin of yellow macula follows closely anterior margin of tergum, separated only at side margin (Fig. 19) ……..***C. verralli*** Collin
13 Gena yellow, without black vitta (Figs 2, 4); mesonotum with lateral yellow vitta complete, uninterrupted (Fig. 3) …… ***C. baphyrum*** Walker
– Gena with black vitta (Figs 24, 29); mesonotum with lateral yellow vitta interrupted at transverse suture (Figs 24, 26) …… 14
14 Male: genitalia very large, protruding ventrally in lateral view; postabdomen (abdominal segments posterior of sternum 4) greatly enlarged (Fig. 24). Female: tergum 6 with longitudinal, median membranous slit (Fig. 25) …… ***C. cautum*** (Harris)
– Male: genitalia smaller, not visible in lateral view; postabdomen not enlarged (Figs 30, 31). Female: tergum 6 without membranous slit …… 15
15 Abdominal terga with long, erect pile, as long as or longer than scape; abdomen relatively short and broad (Figs 26, 27) …… ***C. arcuatum*** (Linnaeus)
– Abdominal terga with short, adpressed pile, some areas may look bare (Fig. 28) …… 16
16 Scutellum entirely pale yellow (Fig. 28); anterior margin of wing yellowish-brown with apical dark macula …… ***C. bactrianum*** Violovitsh
– Scutellum yellow with relatively small translucent, transparent macula in middle (Fig. 29); anterior margin of wing yellowish-brown without clear apical dark macula (Fig. 29) …… 17
17 Sterna: yellow fasciate maculae originated on posterolateral corner of sternum 2 do not join medially (Fig. 30) …… ***C. lessonae*** Giglio Tos
– Sterna: yellow fasciate maculae originated on posterolateral corner of sternum 2 broadly joint medially forming fascia (Fig. 31) …… ***C. intermedium*** Meigen
Note: *C. intermedium* is a species complex (Speight 2016), and the current definition might include more than one species. Wings of some specimens have a dark brown apical macula.

DISCUSSION

Although more data is available to establish boundaries between biogeographic regions, climate change and human actions alter the ecosystems and their fauna. Moreover, researchers use certain geographical or political boundaries to delimit faunal or biogeographical regions with considerable controversy (Mengual 2012). Thompson (1999b) illustrates the biotic regional boundaries based on political subunits, although this was not accurate. One of the few countries across biogeographical boundaries is China. Huo et al. (2007) reported several specimens of *C. baphyrum* from Cili, Hunan province (29˚25′47.7″ N 111˚08′17.6″ E). Hunan province is considered Palaearctic by Thompson (1999b), thus our records would not be the first for the Palaearctic Region.

But other divisions exist, such as Holt et al. (2013), which includes Hunan province in their Sino-Japanese zoogeographic realm. On the other side, Hoffman (2001) mentions a transition zone between Palaearctic and Indomalayan Regions, which resembles the Sino-Japanese realm of Holt et al. (2013), and Hunan province is included in this transition zone. The western boundary between Palaearctic and Indomalayan regions has more agreement, and somehow divides north-south Pakistan. Based on all the available divisions, Iran can be considered Palaearctic, making our records the first specimens of *C. baphyrum* collected from West Palaearctic. On the other hand, the use of political or historical names in reference to regions or realms should not be encouraged, such as Asia (Gilasian et al. 2015).

The genus *Chrysotoxum* is distributed mainly in the Holarctic Region, with a few species reported from tropical areas (Thompson 2013) and probably found in higher altitudes (Shannon 1926). Iran is located in the Western Palearctic Region, with some influences from the Indomalayan Region in the south-east, and it has a rich fauna of insects, acting as a connection between the Palearctic and Indomalayan faunas. The Hormozgan province, where *C. baphyrum* was collected, and the whole southern part of Iran are poorly sampled and understudied. So far, no long sampling period and large-scale survey has been done in forests and cultivated lands of Iran. Thus, it would not be surprising to record more Indomalayan species in Iran, or even new species to science due to the location of Iran, between biodiversity hotspots such as Caucasus, Anatolian peninsula (as part of the Mediterranean Basin) and the mountains of Central Asia. More taxonomic studies and field work are needed in this country, and there is hope to pursue this goal in the next years as more and more Iranian researchers focus on Syrphidae.

Acknowledgement. We thank the Department of Entomology, Tarbiat Modares University for providing financial support for this research. Our cordial thanks are expressed to A. Nadimi and M. Kheyrandish for collecting some of the studied specimens in this research.

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