Ichneumonid parasitoids (Hymenoptera: Ichneumonidae) of fruit flies (Diptera: Tephritidae) in the northwest of Iran

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ABSTRACT. This study was conducted to collect and identify ichneumonid parasitoids of tephritid fruit flies (Diptera: Tephritidae) feeding on the plants of the family Asteraceae in the northwest of Iran during 2013-2015. Five species of ichneumon wasps on five species of fruit flies were reared. They were as follows: Cremastus lineatus on Urophora terebrans; Diadegma maculatum on Hypenidium robrowskii; Scambus brevicornis on Sphenella marginata, Scambus rufator on Terellia gynacochroma and Urophora sp. and Tranosema sp. on Tephritis sp. dioecrea group. Of them, Cremastus lineatus, S. rufator and Tranosema sp. are new records for ichneumonid fauna of Iran. All host-parasitoid-plant associations were newly established to the science. General distribution of these parasitoids and their biological associations were discussed.

Key words: Host, distribution, new record, Palaearctic.

Introduction

The family Ichneumonidae is known as the most diverse family of Hymenoptera parasitoid wasps in the world with more than 24481 described species classified into 8 higher groups and 48 subfamilies (Yu et al. 2012; together with subsequent described species). Almost all ichneumonids are parasitoid and mainly parasitize larvae of holometabolous insects through different host-parasitoid interactions and life history patterns (Belshaw and Quicke 2002; Quicke et al. 2009). Thus, they could play a substantial role as biological control agents in decreasing the population of forest and agricultural pests (Bennet 2008).

Dipterans provide a large source of hosts for ichneumonid parasitoids. Their relationship may be vary from highly specific even at high taxonomic categories to general. Four families of Diptera are specific hosts of three subfamilies of Ichneumonidae (Quicke at al. 2009). Hover flies (Dip.: Syrphidae) are attacked by the wasps of the subfamily Diplazontinae.
Ichneumonid parasitoids of Tephritidae

(Klopfstein 2014). Tipulids (Dip.: Tipulidae) are parasitized by members of the subfamily Cylloceriinae and species of Mycetophilidae and Sciaridae are known as hosts of Orthocentrinae (Wahlund Gauld 1998). Other species of Diptera are attacked by wasps of eight subfamilies of Ichneumonidae, mainly Campopleginae, Cryptinae, Cremastinae, Ophioninae and Pimplinae (Yu et al. 2012).

Tephritid fruit flies (Dip.: Tephritidae) comprises more than 4400 phytophagous species in the world feeding on reproductive organs of plants (White 1988). Some species such as Ceratitis capitata (Wiedemann), Bacterocera oleae (Rossi) and Rhagoletis cerasi (L.) are among well-known and economically the most important pests of fruit crops around the world (Daniel and Grunder 2012). A wide effort has been made on the implementation and releasing the biological control agents as an ecologically safe and long term part of integrated pest management programs of tephritid fruit flies. For example, Phygaedon wiesmanni Sachtlen, 1934 (Hym.: Ichneumonidae, Cryptinae) is a major parasitoid of European cherry fruit fly, R. cerasi, and released against R. pomonella (Walsh, 1867) from 1985 in Ontario (Hagely et al. 1993).

Plants of the family Asteraceae is one of the largest and economically most important family of flowering plants and consists of 12-17 tribes, approximately 1100 genera and 20,000 species (Cronquist 1981). Species of this family are of wide economic importance as vegetables (lettuce, artichokes and endive), sources of oil (sunflower, safflower) and insecticides (pyrethrum), and garden ornamentals (chrysanthemum, dahlia, marigold and many others) (Jansen and Palmer 1987).

Fruit flies are important widespread pests of crop fruits and vegetables, which infest agreat variety of native and exotic fruits (White 1988; Aluja and Norrbom 2001). Almost 250 species are known to be associated with plants and vegetables of economic importance, including about 100 that are pests, ranging in status from minor to very serious (White and Elson-Harris 1992). A few species induce the formation of galls in the upper or subterranean parts of stems of Asteraceae (Freidberg 1984; Korneyev 2003).

Till now, more than 502 species of the family Ichneumonidae have been recorded from Iran (Barahoei et al. 2012; Mohammadi-Khoramabadi et al. 2013a, b). Of them, 21 species belong to the subfamily Diplazoninae, parasitoids of hover flies (Dip.: Syrphidae) (Mohammadi-Khoramabadi et al. 2013a) and nine species to the subfamily Orthocentrinae, parasitoids of Mycetophilidae and Sciaridae (Mohammadi-Khoramabadi and Talebi 2013).

Fruit flies (Dip.: Tephritidae) have a rich species diversity. There is not a complete list of determined Iranian tephritids, but based on the available papers, it can estimate more than 120 species of this family were collected (Mohammadzade-Namin and Rasoulian 2009; Mohammadzade-Namin et al. 2010; Mohammadzade-Namin 2012; Gharajedaghi et al. 2012; Gharali et al. 2005).

Tephritid parasitoids were studied by Aluja et al. (1990), but in spite of the large material, of more than 1300 reared parasitoids, no ichneumonid wasp was recorded. Most parasitoid species recorded from fruit flies belonged to the families Braconidae, Figitidae, Eulophidae, Diapriidae, Chalcididae, Eurytomidae, and Pteromalidae (Wharton 1998; Sivinski et al. 2000; Ovruski et al. 2004; Gates et al. 2008).

This study was conducted to collect and identify ichneumonid parasitoids of tephritid fruit flies (Diptera: Tephritidae) feeding on the plants of the family Asteraceae in the northwest of Iran during 2013-2015.
Material and methods

This study was carried out in East and West-Azarbaijan provinces of Iran (from 35°58′-39°47′ N to 44°02′-48°21′ E) during 2013 to 2015. Infested reproductive organs of six species of Asteraceae were widely collected and then were reared in separate boxes (3308 cm³) at 25±2°C until the adults of flies and/or their parasitoids were appeared. Tephritidae and their ichneumonid parasitoids were identified using keys and descriptions provided by Korneyev and White (1999), Kasparyan (1981), Broad (2011), Townes (1969, 1970, 1971). Specimens were deposited in the insect collection of the Department of Plant Protection, East-Azarbaijan Research Center for Agriculture and Natural Resources, Tabriz and Department of Plant Production, College of Agriculture and Natural Resources of Darab, Shiraz University, Iran.

Results

A total of 13 adult individuals of ichneumonid parasitoids were reared on five species of tephritid fruit flies infesting six species of Asteraceae (Table 1). They represented five species belonging to three subfamilies, one from the subfamily Cremastinae, two from the subfamily Campopleginae and two from the subfamily Pimplinae as follow:

Subfamily Cremastinae Forster, 1869

*Cremastus lineatus* Gravenhorst, 1829 (Fig. 4)

**Material examined:** Iran, East-Azarbaijan, Aland (38°48′45″N, 44°33′56″E, 1722m), 10 July 2014, 3♂, ex *Urophora terebrans* (Loew) on *Onopordon* sp., leg.: A.R. Pourhaji.

**Distribution within Iran:** Khorasan-e-Razavi province (Ghahari et al. 2014).

**General distribution:** Austria, Germany, Finland, France, Italy, Poland, Turkey and United Kingdom (Yu et al. 2012).

**Host association:** It was reared on *Urophora terebrans* (Dipt.: Tephritidae) on the plant *Onopordon* sp. (Asteraceae) for the first time in this study. There was no any host record for this species.

**Diagnosis:** *Cremastus lineatus* can be distinguished from other species of the genus by a combination of the following characters: first tergite with the ventral edges medially closed together; second recurrent vein interstitial; in male ocelli large; head and thorax shiny, densely punctate and with red pattern; lateral lobes of mesocutum red; propodeum with areola 3 x as long as the posterior width (Fig. 4) (Kasparyan 1981).

Subfamily Campopleginae Forster, 1869

*Diadegma maculatum* (Gravenhorst, 1829) (Fig. 3)

**Material examined:** Iran, West-Azarbaijan, Shahin-Dejh (36°36′38″N & 46°33′52″E, 1370m), 19 August 2014, 1♀, ex *Hypenidium robrowskii* (Becker, 1908) on *Lactuca serriola* L.; Kilisa-Kandi (38°50′3 4″N & 44°27′38″E, 2319m), 6 August 2015, 1♂, reared on *Cirsium congestum* (Fisch. & C.A. Mey. ex DC), leg.: A.R. Pourhaji.

**Distribution within Iran:** Khorasan-e-Razavi province (Ghahari et al. 2014).

**General distribution:** Austria, Bulgaria, Finland, France, Italy, Poland, Turkey and United Kingdom (Yu et al. 2012).

**Host association:** *Hypenidium robrowskii* on *Lactuca serriola* L. (Asteraceae) is firstly reported as the host of this species.

**Diagnosis:** *Diadegma maculatum* can be identified by a combination of the following morphological characters (Fig. 3): head narrowed posteriorly; hind coxa black; hind tibia yellow-red at the middle and brown at the base and top; second and third metasomal tergites in their posterior margin red, the subsequent tergites entirely red; ovipositor sheath less
than 1.5 x as long as hind tibia; fore wing with an areolet; 7th metasomal tergite posteriorly with a deep median incision (Kasparyan 1981).

**Tranosema** sp. (Fig. 6)

**Material examined:** Iran, East-Azarbaijan, Arshad-Chamani (37°45'00"N & 46°18'55"E, 2847m), 11 August 2014, 1♂, ex *Tephritis sp. dioscuraea* group on *Echinops* sp., leg.: A.R. Pourhaji.

**Distribution within Iran:** East-Azarbaijan province (new record for Iran).

**General distribution:** Holarctic (Yu *et al.* 2012).

**Host association:** Species of the genus are mainly parasitoids of Microlepidoptera (Yu *et al.* 2012). *Tephritis sp. dioscuraea* group on *Echinops* sp. is newly established.

**Diagnosis:** The genus *Tranosema* can be identified by the following characters (Fig. 6): clypeus weakly convex; eyes weakly indented opposite antennal sockets; fore wing with an areolet; hind wing with nervellus vertical and not intercepted; posterior mesosternal carina medially absent; hind tibia with basal and apical dark bands; propodeal spiracle circular; propodeum with a short and wide areola which is confluent with the very wide petiolar area; first metasomal tergite with glymma (Townes 1970).

**Subfamily Pimplinae Wesmael, 1845**

**Scambus brevicornis** (Gravenhorst, 1829) (Fig. 5)

**Material examined:** Iran, East-Azarbaijan, Arshad-Chamani (37°45'00"N & 46°18'55"E, 2847m), 28 July 2014, 2♂, 1♀, ex *Terellia gynaecochroma* and *Urophora sp.* on *Onopordon acanthium* L.: in East-Azarbaijan, Kandovan (37°47'42"N & 46°14'58"E, 2265m), 22 September 2013, 2♂, ex *Terellia gynaecochroma*, on *Onopordon acanthium* L., leg.: A.R. Pourhaji.

**Distribution within Iran:** Kurdistan (Kolarov and Ghahari 2006) and Qazvin provinces (Ghahari and Schwarz 2012).

**General distribution:** Europe, North America, northern Africa and Middle East (Yu *et al.* 2012).

**Host association.** *Scambus brevicornis* is a very polyphagous parasitoid and has been reported on 133 host species on Hemiptera, Coleoptera, Lepidoptera, Diptera and Hymenoptera (Yu *et al.* 2012). Dipteran hosts of this species are *Chaetostomella cylindrica* (Robineau-Desvoidy, 1830), *Euphranta connexa* (Fabricius, 1794) and *Noeeta pupillata* (Fallen, 1814) (Dip.: Tephritidae) and *Gimnomera dorsata* (Zetterstedt, 1838) (Dip.: Anthomyidae) (Yu *et al.* 2012). In this study, the fourth host species of tephritid fruit fly, *Sphennella marginata* (Fallen, 1814) on *Senecio vulgare* L., has been recorded for this species.

**Diagnosis:** *Scambus brevicornis* can be separated from other species of the genus by a combination of the following characters: antenna short, as long as the distance between base of the fore wing to the pterostigma; upper angle of pronotum before tegula white; coxae black; trochanters yellow with black base; hind tibia white with dark pattern on base and top; all metasomal tergites black; metasomal tergites 6 and 7 with distinct and sharp edge punctures (Fig. 5) (Kasparyan 1981).

**Scambus rufator** Aubert, 1963 (Figs. 1-1, 2)

**Material examined:** Iran, East-Azarbaijan, Arshad-Chamani (37°45'00"N & 46°18'55"E, 2847m), 28 July 2014, 3♂1♀, ex *Terellia gynaecochroma* (Hering) and *Urophora sp.* on *Onopordon acanthium* L.: in East-Azarbaijan, Kandovan (37°47'42"N & 46°14'58"E, 2265m), 22 September 2013, 2♂, ex *Terellia gynaecochroma*, on *Onopordon acanthium* L., leg.: A.R. Pourhaji.

**Distribution within Iran:** East-Azarbaijan (new record for Iran).

**General distribution:** Bulgaria, former Czechoslovakia, France, Italy, Romania, Turkey and former Yugoslavia (Yu *et al.* 2012).
Host association: This species has yet been reported only on Chamaesphecia palustris (Kautz, 1927) (Lep.: Sesiidae) (Yu et al. 2012). In this study, Terellia gynaecochroma and Urophora sp. (Dip.: Tephritidae) on Onopordon acanthium L. were found as new hosts for S. rufator.

Diagnosis: Scambus rufator can be identified by the combination of the following characters: female (Fig. 1) with hind tibia monochrome red; metasomal tergites 1-4 red; first metasomal tergite laterally smooth and finely sculptured; ovipositor compressed laterally, about 0.8 x as long as metasoma; hypopygium with a large membranous area; male (Fig. 2) with hind tibia uniformly red; head distinctly narrowed posteriorly; propodeum with dorsal longitudinal carinae widely separated; first metasomal tergite as long as wide (Kasparyan 1981).

Discussion

From five parasitoid species reared on tephritid flies one genus and two species are new record for Iranian ichneumonid fauna. All host-parasitoid-plant associations were newly established to the science (Table 1).

In present study Scambus brevicornis and Cremastus lineatus were respectively the most abundant parasitoid species of fruit flies in the studied area (Fig. 2).

Ichneumonidae quite rarely parasitize dipterous hosts, and few ichneumonid subfamilies are trophically connected with flies. Two ichneumonid subfamilies, Diplazontinae and Orthocentrinae, are specialized on dipterous hosts of Syrphidae and Mycetophilidae, and most other host records from Diptera belong to Cryptinae and Pimplinae (Hoffmeister 1992; Hagley et al. 1993). López-Ortega and Khalaim (2012) reported for the first time, a Calliephialtes species associated with Diptera, representing one of the few detailed records of an ichneumonid parasitoid on Tephritidae. Calliephialtes sittenfeldae was reported as a common parasitoid of the fruit fly Anastrepha spatulata Stone (Diptera: Tephritidae).

In the subfamily Cremastinaceae, the genus Cremastus Gravenhorst is a relatively large one with about 129 described species around the world (Yu et al. 2012). In Iran, there have been recorded just two species of the genus and C. lineatus is the third species reported here (Amiri et al. 2015; Barahoei et al. 2012). Members of the genus Cremastus associated with species from Coleoptera, Lepidoptera, Diptera and Hymenoptera (Yu et al. 2012). One species of the genus, Cremastus incompletus (Provancher, 1875), has been reported as a monophage parasitoid of Rhagoletis pomonella (Dip.: Tephritidae) in the world (Yu et al. 2012). Here we reported, the second genus, Urophora (Robineau-Desvoidy, 1830) of the family Tephritidae as host for this genus. Similar to C. incompletus, it may be possible that C. lineatus is a species-specific parasitoid for its hosts, Urophora sp.

Diadegma Förster is a large genus of the subfamily Campopleginae that mainly known as parasitoids of Microlepidoptera (Yu et al. 2012). From Cyclorrhapha, some species of the families Ephedridae, Chloropidae and Syrphidae has been reported as hosts of the genus (Yu et al. 2012). Tephritidae is established as the fourth cyclorrhaph family parasitized by one species of Diadegma. Hypenidium (Loew,1862) has three species worldwide which of them two species occurred in Iran on the plant Lactuca spp. (Korneyev et al. 2011). A recent study showed that there were no any ichneumonids associated with its nearest species, H. oculatum in Iran (Mohammadi-Khoramabadi et al. 2014).
Figure 1–6. Ichneumonidae parasitoids of Tephritidae in Iran: 1. *Scambus rufator* (female); 2. *Scambus rufator* (male); 3. *Diadegma maculatum* (female); 4. *Cremastus lineatus* (male); 5. *Scambus brevicornis* (male); 6. *Tranosema* sp. (female) (scale bar: 1 mm).
Table 1. Tephritid hosts and host plants of Ichneumonidae in Iran († new record of parasitoid, * new host record, ** new host plant record).

<table>
<thead>
<tr>
<th>Parasitoid</th>
<th>Hosts</th>
<th>Host plants</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cremastus lineatus†</td>
<td>Urophora terebrans *</td>
<td>Onopordon sp. **</td>
<td>Present study</td>
</tr>
<tr>
<td>Diadegma maculatum</td>
<td>Hypenidium robrowskii*</td>
<td>Lactuca serriola**</td>
<td>Present study</td>
</tr>
<tr>
<td></td>
<td>Unknown species</td>
<td>Cirsium congestium**</td>
<td>Present study</td>
</tr>
<tr>
<td>Scambus brevicornis</td>
<td>Sphenella marginata*</td>
<td>Senecio vulgaris**</td>
<td>Present study</td>
</tr>
<tr>
<td>Scambus rufator†</td>
<td>Terellia gynaecochroma*</td>
<td>Onopordon acanthium**</td>
<td>Present study</td>
</tr>
<tr>
<td></td>
<td>Urophora sp. *</td>
<td>Onopordon acanthium**</td>
<td>Present study</td>
</tr>
<tr>
<td>Tranosema sp. †</td>
<td>Tephritis dicoides *</td>
<td>Echinops sp. **</td>
<td>Present study</td>
</tr>
</tbody>
</table>

Figure 2. Composition of ichneumonid parasitoids of Tephritidae (Dipera) in the northwest of Iran.
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Ichneumonid parasitoids of Tephritidae

Diptera: Tephritidae

In Iran, the genera Asteraceae (Hymenoptera: Ichneumonidae) have been studied for their parasitoids. The following species have been observed:

1. Cremastus lineatus
2. S. rufator
3. Tranosema sp.

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