

Braconinae parasitoids (Hymenoptera, Braconidae) emerged from larvae of *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera, Tortricidae) feeding on *Daphne gnidium* L.

Augusto Loni¹, Konstantin G. Samartsev², Pier Luigi Scaramozzino¹,
Sergey A. Belokobylskij^{2,3}, Andrea Lucchi¹

1 Department of Agriculture, Food and Environment, Pisa University, Via del Borghetto, 80-56124 Pisa, Italy

2 Zoological Institute, Russian Academy of Sciences, Universitetskaya nab., 1, St Petersburg 199034, Russia

3 Museum and Institute of Zoology, Polish Academy of Sciences, Wilcza 64, Warszawa 00-679, Poland

Corresponding author: Augusto Loni (augusto.loni@unipi.it)

Academic editor: K. van Achterberg | Received 14 March 2016 | Accepted 7 April 2016 | Published 10 May 2016

<http://zoobank.org/DE4293C5-2A2D-47E4-90AF-96ECA45290F7>

Citation: Loni A, Samartsev KG, Scaramozzino PL, Belokobylskij SA, Lucchi A (2016) Braconinae parasitoids (Hymenoptera, Braconidae) emerged from larvae of *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera, Tortricidae) feeding on *Daphne gnidium* L.. ZooKeys 587: 125–150. doi: 10.3897/zookeys.587.8478

Abstract

Bracon admotus Papp, 2000, and three species of the genus *Habrobracon* Ashmead, 1895, *H. concolorans* (Marshall, 1900), *H. hebetor* (Say, 1836) and *H. pillerianae* Fischer, 1980, were obtained from the larvae of *Lobesia botrana* (Denis & Schiffermüller, 1775) (Lepidoptera, Tortricidae) feeding on *Daphne gnidium* Linnaeus, 1753 (Thymelaeaceae) in the natural reserve of Migliarino-San Rossore-Massaciuccoli (Pisa-Central Italy). *Bracon admotus*, *Habrobracon concolorans* and *H. pillerianae* were found for the first time to be associated with *L. botrana*, while *H. hebetor* was reared for the first time from the larvae of *Cryptoblabes gnidiella* (Millière, 1867) (Lepidoptera, Pyralidae, Phycitinae) that was found on the same host plant. *Bracon admotus* and *H. pillerianae* are new to the fauna of Italy and Western Europe. A key is proposed for the determination of *Habrobracon* species reared from *L. botrana* and related Palaearctic species of this genus. *Habrobracon lineatellae* Fisher, 1968 is considered as a valid species.

Keywords

European grapevine moth, idiobiont ectoparasitoids, Italy, natural environment, spurge flax, Thymelaeaceae, Tuscany

Introduction

With about 2,500 species from almost two hundred genera, Braconinae is one of the largest subfamilies within the family Braconidae (Shaw and Huddleston 1991, Quicke 2015). This parasitoid group has a worldwide distribution with the largest number of taxa found in the Old World tropics (Quicke 2015). Most Braconinae species are idiobiont ectoparasitoids that develop on concealed or semi-concealed hosts mainly represented by late larval instars of numerous Coleoptera and Lepidoptera taxa, and more rarely by sawflies (Hymenoptera, Symphyta) and flies (Diptera), predominantly gall midges (Cecydomyiidae) and fruit flies (Tephritidae). Females of Braconinae are synovigenic, practicing additional host feeding and laying large eggs. The larvae develop as gregarious or solitary parasitoids (Shaw and Huddleston 1991, Quicke 2015). Their host range includes many species with a large variety of habits, but all the victims show a certain degree of concealment in the tissues of annual and biennial plants, including galls, rolled leaves, inflorescences, seeds, stems and, more rarely, leaf mines or hard wood tissues (Quicke 2015). Several species of Braconinae attack pests of an economic interest, such as stored products and field crops pests (Quicke 2015).

Among Braconinae, *Bracon* Fabricius, 1804 is a cosmopolitan and very common genus composed of the largest number of species. European fauna includes about 200 species of *Bracon* living on larvae of Lepidoptera, Coleoptera and Diptera (van Achterberg 2013). This genus is considered as a para- or also a polyphyletic group, predominantly of small and middle-sized species (Quicke 2015) spread over several subgenera. *Habrobracon* Ashmead, 1895 was once considered to be a distinct genus (Quicke 2015, Papp 2008, Yu et al. 2012) or one of the *Bracon* subgenera (Shenefelt 1978, Tobias 1986, Belokobylskij et al. 2012, Broad et al. 2012, Ameri et al. 2013, 2015, Zargar et al. 2015) or sometimes is considered as a synonym (Marsh 1979, van Achterberg 2013).

In agreement with the latest opinions of Papp (2008) and Quicke (1987, 2015) recorded in the World Catalogue by Yu et al. (2012), we consider *Habrobracon* as a separate genus in spite of the intermediate position of *Bracon variegator* Spinola and various Nearctic species between the two genera together with the lack of diagnostic characters at the generic level.

Habrobracon is a worldwide group of small to very small wasps (Quicke 1987). Twenty-one *Habrobracon* species have been recorded in the Western Palearctic (Papp 2008), some of which have a host range of more than 50 host-species with a high ecological flexibility (Tobias 1986, Yu et al. 2012, Beyarslan et al. 2014). *Bracon admotus* Papp, 2000 was originally included in the *B. obscurator* species-group within the subgenus *Glabrobracon* Fahringer, 1927.

This paper presents the results of a study carried out in the natural reserve of Migliarino-San Rossore-Massaciuccoli in the province of Pisa (Tuscany, Italy). All over this area there is a large population of spurge flax, *Daphne gnidium* Linnaeus, 1753, a small shrub of the family Thymelaeaceae, whose sprouts, flowers and infructescences host a large community of moth larvae, most of which are represented by *Lobesia botrana* (Denis & Schiffermüller, 1775) (Lepidoptera: Tortricidae). This species which was recently de-

efined as European grapevine moth (EGVM) is a major pest of grapes in the Mediterranean basin and had recently been found in the Americas (Ioriatti et al. 2011, 2012).

Predators and parasitoids associated with this moth have been studied in various European countries, and more than a hundred works have been published on the subject. To date there is still an incomplete list of the natural enemies of *L. botrana*, and information about these enemies is contained in some works published in the twentieth century, when the moth caused the first extensive damage to European vineyards (Marchal 1912, Voukassovitch 1924, Leonardi 1925, Boselli 1928, Stellwaag 1928, Thompson 1946, Coscollà 1997, Hoffmann and Michl 2003, Villemant et al. 2011).

In Italy, about thirty studies have been published reporting on 89 species of parasitoids living on *L. botrana* (Del Guercio 1899, Catoni 1914, Silvestri 1912, Nuzzaci and Triggiani 1982, Delrio et al. 1987, Luciano et al. 1988, Pinna et al. 1989, Lozzia and Rigamonti 1991, Roat and Forti 1994, Marchesini and Dalla Montà 1994, Colombera et al. 2001, Bagnoli and Lucchi 2006, Lucchi and Santini 2011).

One of the problems with identifying the parasitoid complex of a pest is that the much of the data regards pests in agroecosystems, which usually simply represent pests outside of their natural environment. This is also valid for the European grapevine moth. The hundred or so published papers on its parasitoids only concern the dynamics in the vineyard. There are only three exceptions, all by Italian authors (Nuzzaci and Triggiani 1982, Luciano et al. 1988, Lucchi and Santini 2011) who have tried to highlight the population dynamics of the moth and its parasitoids on *D. gnidium*, which is its typical spontaneous host plant in wild habitats.

This paper reports on a study carried out in 2014 and 2015. It provides new information on one species of *Bracon* and three species of *Habrobracon* obtained from the larvae of *L. botrana* living on *D. gnidium* in a natural reserve in Tuscany (Italy). The massive presence of this important pest in a wild area offers a very interesting environmental context where to perform observations on the relationships among this phytophagous and its parasitoids complex in comparison with the cultivated field.

Methods

The environmental context

Weekly surveys were carried out in 2014 and 2015 in the natural reserve of Migliarino-San Rossore-Massaciuccoli, which covers around 23,000 hectares in the provinces of Pisa and Lucca (Tuscany, Italy) (<http://www.parcosanrossore.org/>). The landscape has a variety of environments, such as sandy shores and dunes stretching for about 23 km along the coast, wetlands with marshes, rivers, lakes, ponds, and forests. The Tyrrhenian Sea delimits the western border, the Lake of Massaciuccoli, the northern border, and the river Arno, the southern border. To the east, the landscape changes gradually from wild to rural areas. The distance from the east border to the west coast varies ranging from 6 to 10 kilometers.

In the back dunes and the thermophile Mediterranean wood, dominated by pine tree and holm oak, *Daphne gnidium* L. (Malvales, Thymelaeaceae) shrubs are widespread,

covering the spaces where the sun can easily penetrate and the soil is mostly sandy. From March to October, sprouts, flowers and infructescences, depending on the period, host a wide and diverse community of Lepidoptera, mainly represented by *Lobesia botrana*.

Sampling methodology

An experimental area was selected, delimited by the following four geographical points 43.733642 N, 10.277524 E; 43.712864 N, 10.279648 E; 43.732913 N, 10.292371 E; 43.720101 N, 10.293094 E (DDM) and characterized by various habitats (Fig. 1). We subdivided this area in a hypothetical grid of 3 × 3 rectangles, each one being 500m × 300m, thus the sampling was replicated in each habitat typology three times (Fig. 2). In each of the nine rectangular sites, transects of 200 meters in length were organized along where *D. gnidium* sprout sampling was carried out. On a weekly basis in each transect 20 infested sprouts were sampled from ten plants (two per plant) (Fig. 3A). In 2014, sampling was begun on May 22 and concluded on October 23. In 2015, surveys started on May 14 and finished on October 23. On the same or the following day of the sample collection, the sprouts were analyzed under a stereomicroscope to isolate the preimaginal stages of the moths. Then each individual specimen was stored inside a glass vial, recording its precise developmental stage. Until the moth or the parasitoids emerged, samples were stored in boxes and maintained in an unheated room with an open window, to maintain as similar environmental conditions as possible to those of the sampling sites (Fig. 3B).

Among the huge number of parasitoid species that emerged during the rearing period, we focused on a small group of individuals belonging to the genera *Bracon* and *Habrobracon*, examining their role in the observed context, and their geographical distribution. The species mentioned in this work were identified by K. Samartsev. The specimens are now stored both at the Laboratory of Insect Taxonomy of the Zoological Institute of the Russian Academy of Sciences (St Petersburg, Russia) and at the Department of Agriculture, Food and Environment of Pisa University (Italy). For a description of the morphological features of the species, we referred to Quicke (2015). The following abbreviations are used in the paper:

POL postocellar line;
OOL ocular-ocellar line;
Od maximum diameter of lateral ocellus.

Wing venation nomenclature follows van Achterberg (1993). Those terms that follow Tobias's nomenclature (1986) are:

1-R1 metacarp;
2-SR first radiomedial vein;
2-SR+M second medial abscissa;
3-SR second radial abscissa;

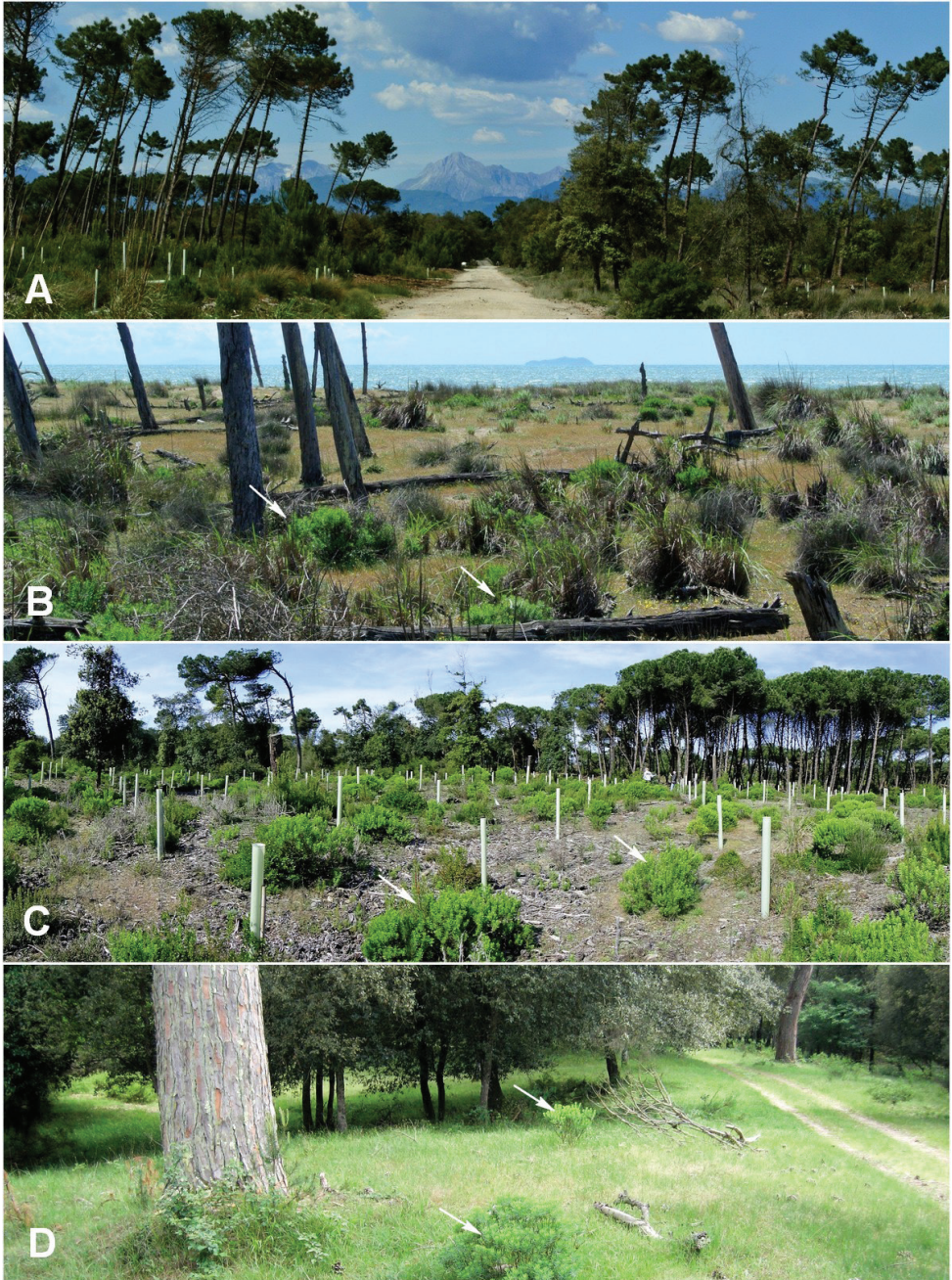


Figure 1. Natural Reserve of San Rossore (Pisa): different habitats of the experimental area. **A** Landscape **B** Fore dune close to sandy shores **C** vegetation of established dunes **D** Wooded area with holm oak. White arrows indicate plants of *Dapne gnidium*.

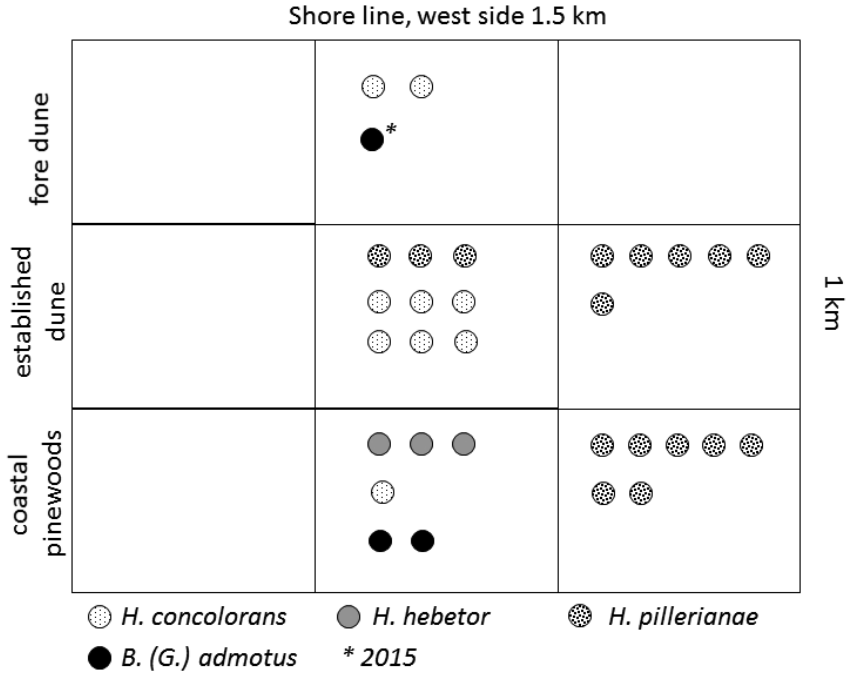


Figure 2. Sampling grid, with distribution of specimens collected.



Figure 3. Sprouts of *D. gnidium* infested by moth larvae. **A** Field situation **B** Nests stored in vials until emergence of the moth or the parasitoid.

m-cu	recurrent vein;
r	first radial abscissa;
SR1	third radial abscissa;
marginal cell	radial cell.

Results

In 2014 and 2015 approximately 4,200 infested sprouts of *D. gnidium* were examined, obtaining 1,254 larvae of *L. botrana* in 2014, and 942 in 2015. In 2014 30 specimens of two genera were obtained, *Bracon* spp. and *Habrobracon* spp., emerging from the larvae of *L. botrana* and *Cryptoblabes gnidiella* (Millière, 1867) (Lepidoptera: Pyralidae), one of the other moths found on *D. gnidium*, while in 2015 we obtained only one specimen of *Bracon*.

These specimens represent approximately 11% of the parasitoid complex emerging from all samples in 2014, the majority of which were Ichneumonidae. They were mainly represented by the species *Campoplex capitator* Aubert, 1960, occurring across all sites and which contributed for more than 58% of the total number of parasitoids found in 2014 (Table 1) and more than 73% in 2015. In 2014 we obtained 2 males of *Bracon admotus* Papp, 7 females and 2 males of *Habrobracon concolorans* (Marshall, 1900), 3 females of *H. hebetor* (Say, 1836), 9 females and 7 males of *H. pillerianae* Fischer, 1980. Each species of *Habrobracon* was distributed at most over three of the nine collecting sites, the two specimens of *B. admotus* were collected only in one site (Fig. 2). In 2015 we obtained one male of *B. admotus*.

Bracon (Glabrobracon) admotus Papp, 2000

Bracon admotus Papp, 2000: 237; Yu et al. 2012.

Material examined. 2 males, October 14, 2014; 1 male, October 1, 2015.

This is the first record for Italy and Western Europe and *L. botrana* represents a new host for this parasitoid. The most important characters for distinguishing of *B. admotus* from the similar species of *B. variator* and *B. obscurator* species groups are: longitudinal diameter of eye 3.3–3.4 times (about 4.4 times in males) longer than malar space (front view); hypoclypeal depression 1.5–1.6 times (1.6–1.7 times in male) as wide as distance from depression to eye; mesosoma short, about 1.4 times (about 1.5 times in males)

Table 1. List of the main parasitoids emerged from the *Daphne gnidium* sprouts (2014).

<i>Campoplex capitator</i> Auber, 1960 (Ichneumonidae)	Other Ichneumonidae	<i>Bracon</i> spp. <i>Habrobracon</i> spp. (Braconinae)	Other Braconidae (Cheloninae and Rogadinae)	Chalcidoidea	Diptera Tachinidae
126	35	30	9	13	7

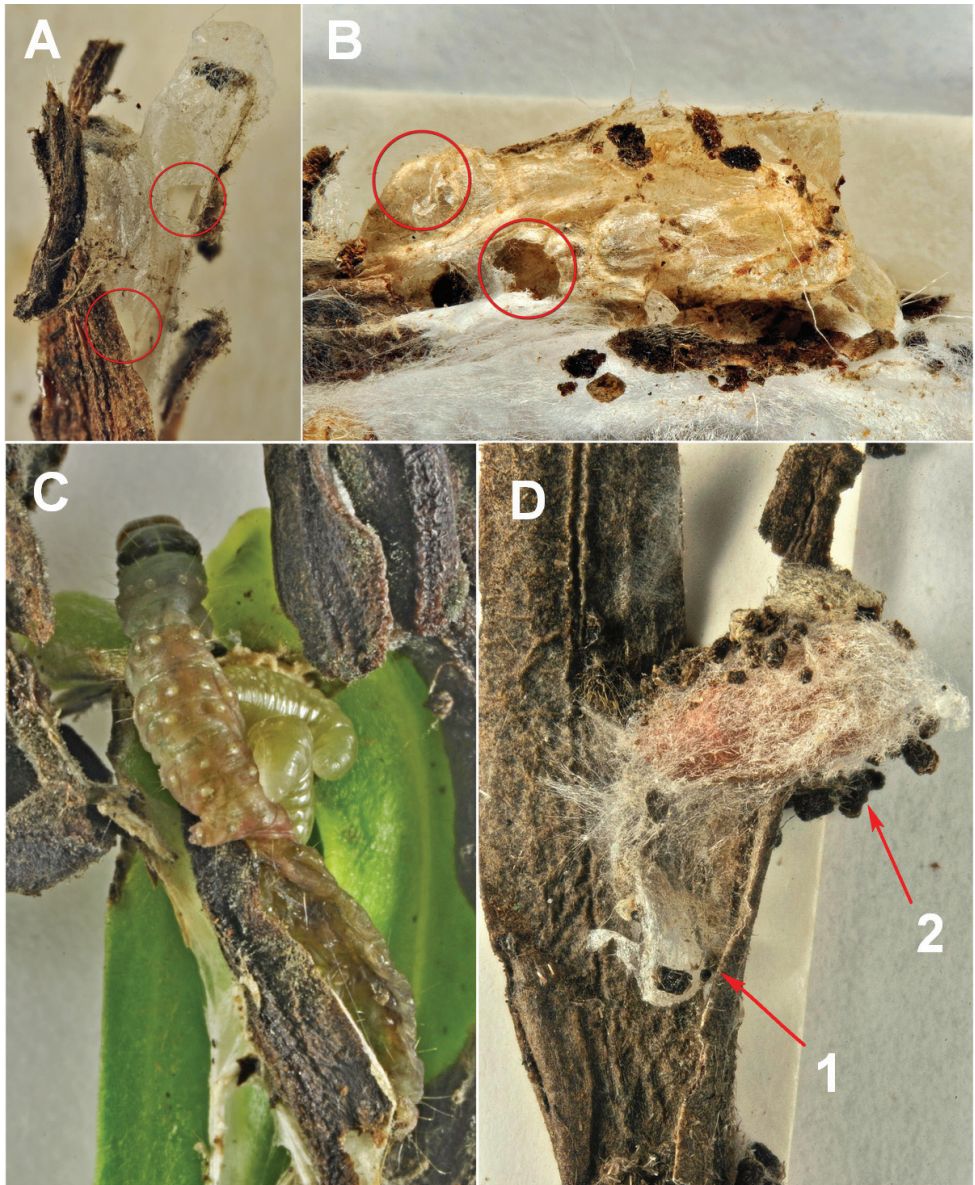


Figure 4. *Habrobracon* preimaginal stages on the hosts *L. botrana* (**A, B, C**) and *C. gnidiella* (**D**). **A** *H. pillerianae* cocoons, the circles surround the exit holes **B** *H. concolorans* cocoons **C** *H. pillerianae* larvae feeding on mature larvae of *L. botrana* **D** *H. hebetor* (1) and *C. gnidiella* (2) cocoons.

longer than maximum height; face and frons evenly granulate; vein r issued clearly before middle of pterostigma; first metasomal tergite (if measured from basomedian tubercle) 1.1–1.3 times as long medially as its apical width; furrow of first tergite and suture between second and third tergites crenulate; metasoma usually completely smooth.

Figure 5 reports various morphological details of the species.

***Habrobracon concolorans* (Marshall, 1900)**

Bracon concolor Thomson, 1892: 1807; Yu et al. 2012.

Bracon concolorans Marshall, 1900: 345 (new name for *Bracon concolor* Thomson, 1892 nec *Bracon concolor* Walker, 1871); Yu et al. 2012.

Habrobracon nigricans Szépligeti, 1901: 181; Yu et al. 2012.

Habrobracon mongolicus Telenga, 1936: 130, 342; Yu et al. 2012.

Material examined. 1 female, May 29, 2014; 4 females from the same host larva, July 4, 2014; 2 males from the same host larva, July 23, 2014; 2 females, October 2, 2014.

Habrobracon concolorans is a Trans-Eurasian species (Samartsev and Belokobylskij 2013), widely distributed in the Palaearctic region and has been recorded in the following countries (Yu et al. 2012): Europe: Ireland, United Kingdom, Sweden, Denmark, France, Spain, Italy, including Sicily (Zappalà et al. 2012b), Lithuania, Russia (Kaliningrad and Astrakhan provinces), Poland, Czech Republic, Slovakia, Hungary, Romania, Moldova, Bulgaria, Croatia, Greece; Middle East: Turkey, Cyprus, Jordan (Al-Jboory et al. 2012; Zappalà et al. 2013), Iran; Caucasus: Russia (Ciscaucasia: Krasnodar Territory), Georgia, Armenia, Azerbaijan; Central Asia: Kazakhstan, Turkmenistan (Papp 2008), Kyrgyzstan, Mongolia (Papp 2009); Russian Far East: Sakhalin, Khabarovsk Territory, Primorskiy Territory; China: Shanxi, Ningxia, Fujian; Africa: Egypt (Zappalà et al. 2013), Tunisia (Papp 2014), Sudan (Ghoneim 2014, Mahmoud 2013).

The collecting period of the *L. botrana* larvae hosting *H. concolorans* ranged from May 29 to October 2. *L. botrana* is considered a new host for *H. concolorans*. Also on *L. botrana*, *H. concolorans* develops as ectoparasitoids of mature larvae showing both solitary and gregarious habit, with up to four individuals feeding on the same host larva (Fig. 4B). Figure 6 reports the morphological details of the species.

***Habrobracon hebetor* (Say, 1836)**

Bracon hebetor Say, 1836: 252; Yu et al. 2012.

Bracon brevicornis Wesmael, 1838: 23; Yu et al. 2012.

Bracon juglandis Ashmead, 1889: 621; Yu et al. 2012.

Other less valuable synonyms are listed in Yu et al. 2012.

Material examined. 1 female from larva of *C. gnidiella*, May 29, 2014; 2 females from larvae of *L. botrana*, June 6, 2014.

We found two specimens on mature larvae of *L. botrana*, but we also obtained one specimen by *C. gnidiella* (Fig. 4D), thus confirming its suitability in many environmental situations, where it can occupy a large variety of ecological niches.

Figure 7 shows various morphological details of this species.

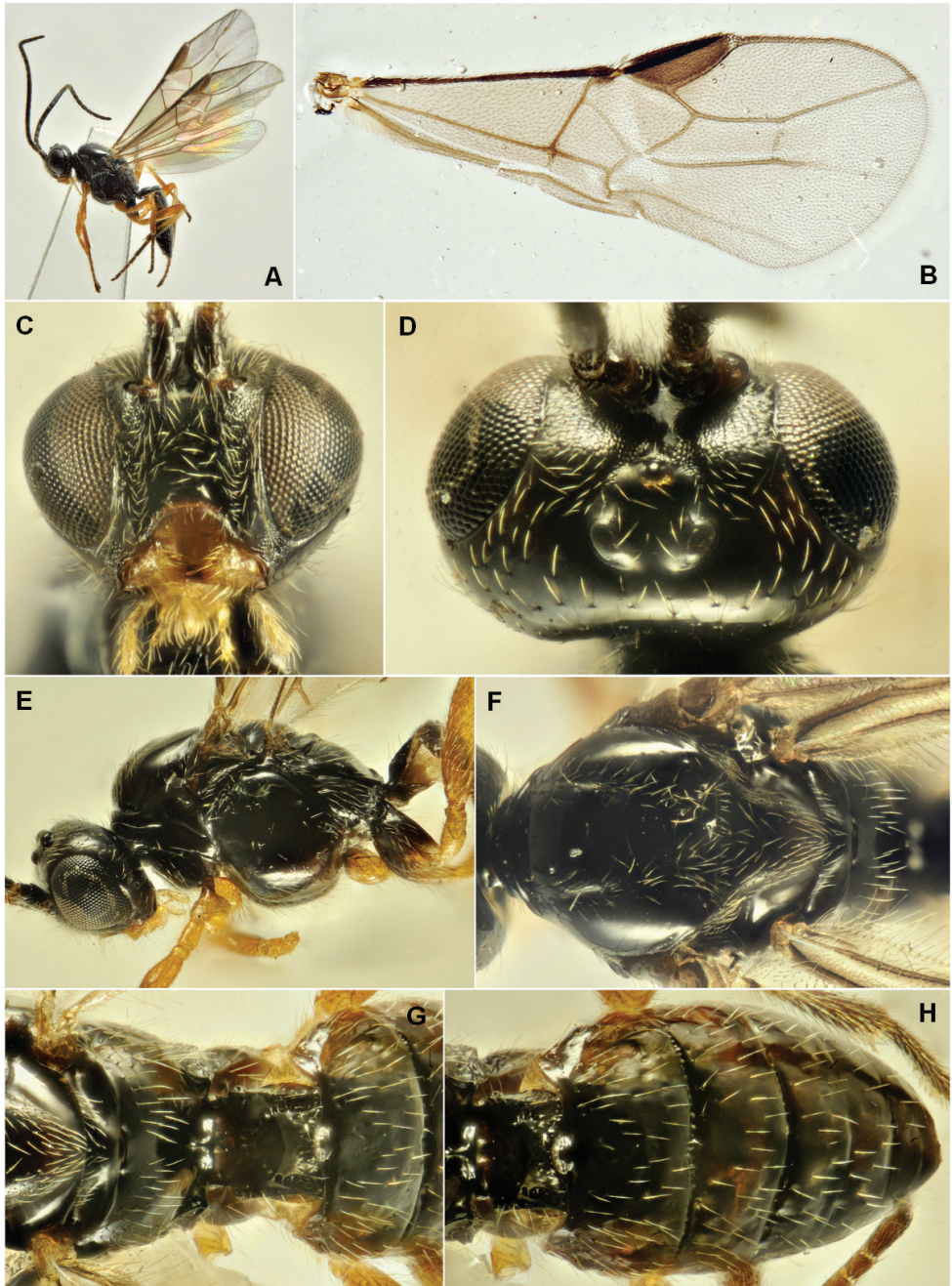


Figure 5. *B. (G.) admotus* Papp 2000, male. **A** Body, lateral view **B** Fore wing **C** Head, front view **D** Head, dorsal view **E** Head and mesosoma, lateral view **F** Mesosoma, dorsal view **G** Metanotum, propodeum and basal segments of metasoma, dorsal view **H** Metasoma, dorsal view.



Figure 6. *H. concolorans* (Marshall, 1900), female. **A** Body, dorsal view **B** Wings **C** Head and mesonotum, dorsal view **D** Head, sub-lateral view **E** Head, front view **F** Propodeum and metasoma, dorsal view **G** Metasoma, dorsal view.

Habrobracon pilleriana Fischer, 1980

Habrobracon pilleriana Fischer, 1980: 150; Yu et al. 2012.

Material examined. 5 females and 2 males, June 27, 2014 (3 females and 1 female + 2 males from the same host larva); 2 females and 1 male (1 male and 1 female reared from the same host larva) July 23, 2014; 1 female, 4 males, July 31, 2014; 1 female September 10, 2014.

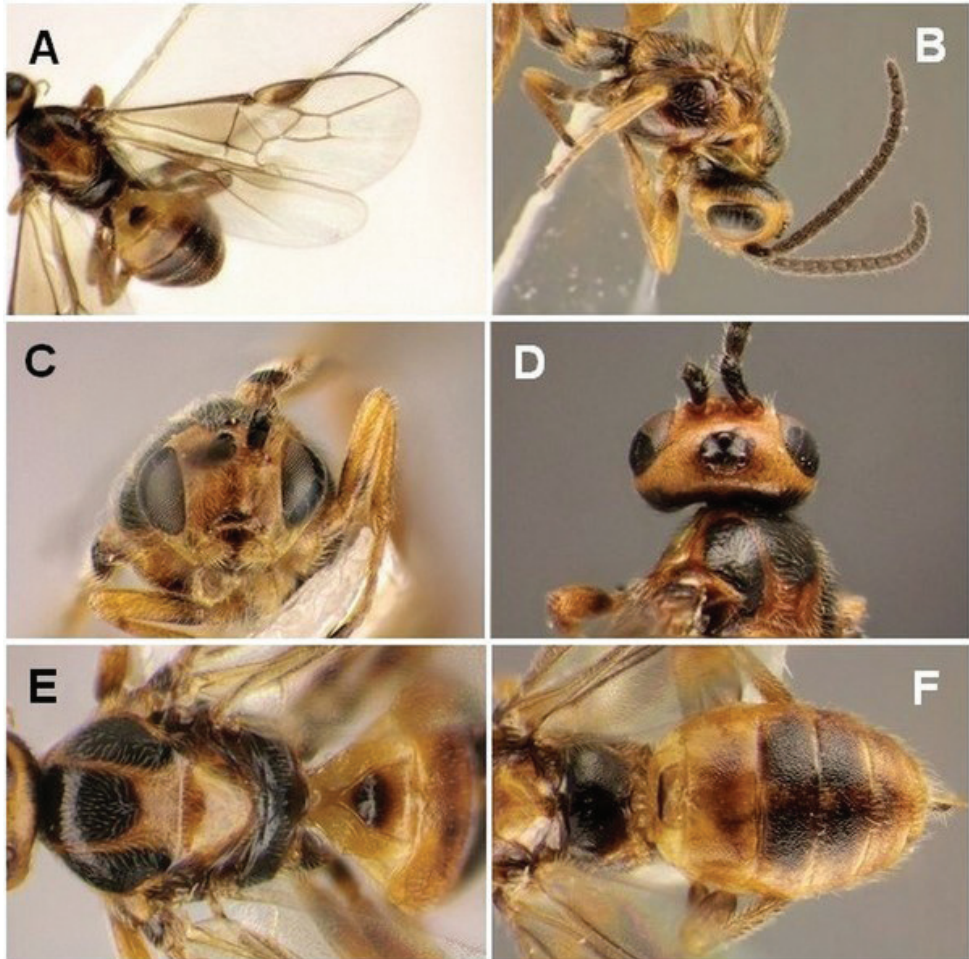


Figure 7. *H. hebetor* Say, 1936, female, **A** Wings **B** Head and mesosoma, lateral view **C** Head, front view **D** Head, dorsal view **E** Mesosoma, dorsal view **F** Metasoma, dorsal view.

Six specimens of this species were described by Fischer (1980) which were reared from larvae of *Sparganothis pilleriana* (Denis & Schiffermüller, 1775) (Lepidoptera Tortricidae) in Ankara Province, Central Anatolia, Turkey (Fischer 1980). To date, this is the only paper reporting original information on this species (Yu et al. 2012). We obtained this species in our rearing programme from June 27 to September 10, 2014. The dates of the emergence of the specimens well fitted with those reported by Fisher, who described *H. pillerianae* from specimens collected on July 20, 1976. Also in this species the larvae developed both solitary and gregariously, with up to three individuals feeding on the same host larva (Fig. 4A, C). This is the first report of this species for Italy and Europe as well as the first association with *L. botrana*. Figure 8 shows various morphological features of this species.

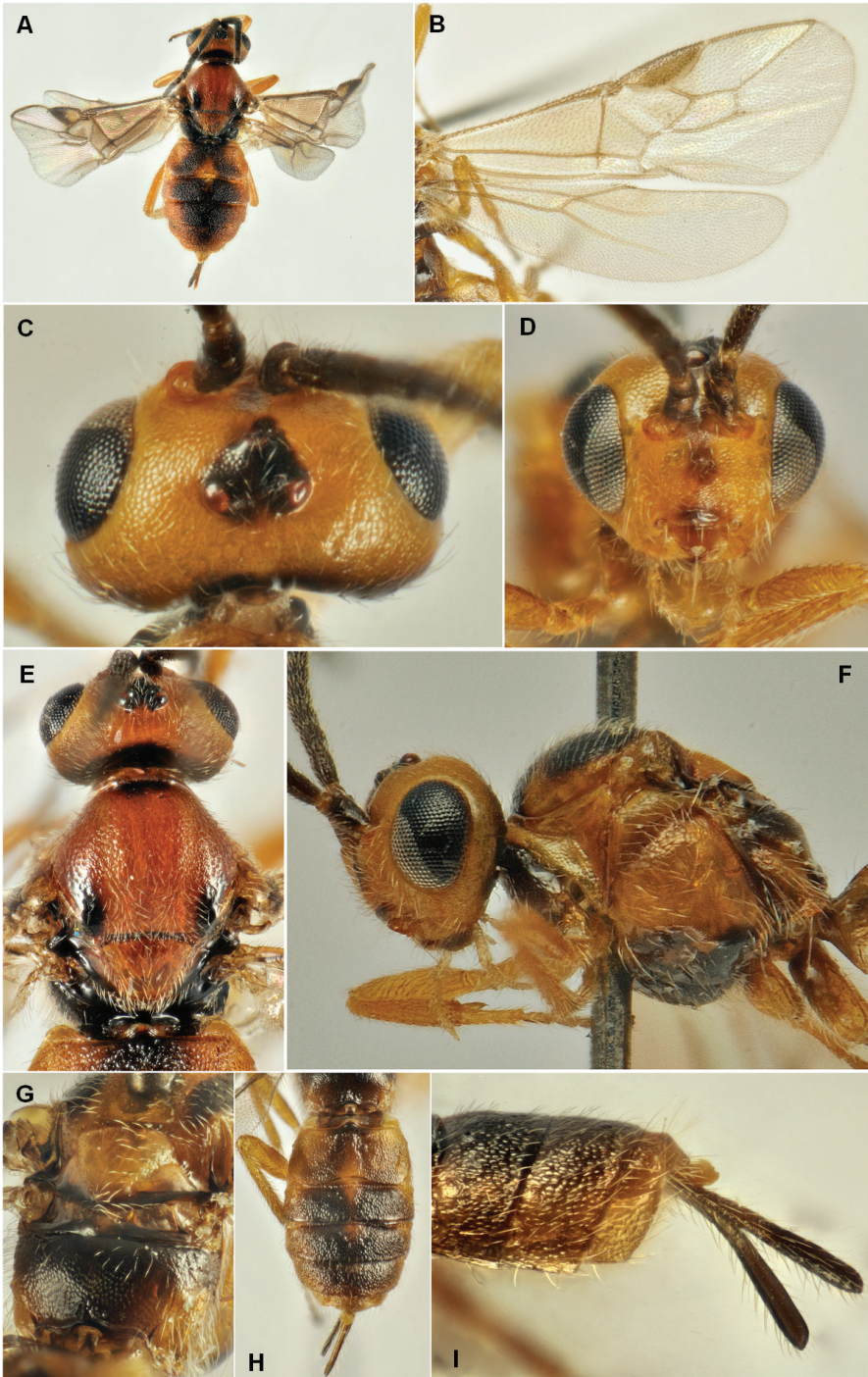


Figure 8. *H. pillerianae* Fischer, 1980, female. **A** Body, dorsal view, **B** Wings **C** Head, dorsal view **D** Head, front view **E** Mesosoma, dorsal view **F** Head and mesosoma, lateral view **G** Metanotum and propodeum, subdorsal view **H** Metasoma, dorsal view **I** Apex of metasoma, lateral view.

Key to the *Habrobracon* species reared from *Lobesia botrana* on *Daphne gnidium* with respect to related species recorded in the Western Palearctic

Using the most complete key for the Palearctic species (Tobias 1986), the specimens of *H. pilleriana* are to be identified as *H. telengai* or *H. viktorovi*, the difference between *H. concolorans* and related species is also not very clear. Therefore, it seems appropriate to indicate the position of the three identified species in the whole genus by providing the following key. Suggested key does not aim to help to identify the *Habrobracon* species groups not related with *H. concolorans*, *H. hebetor* and *H. pilleriana*. Such unrelated species are distinguished in the key couplets 1 and 5. In some couplets, additional information helping the species identification is listed after a dash (–). Measures adopted for the head in the key are shown in Figure 9A. Wing veins are measured excluding their junctions (Fig. 9B). The most important synonyms are given in parentheses.

- 1 Middle lobe of mesoscutum glabrous (as in Fig. 5F). Vein 3-SR 1.1–1.3 times longer than vein 2-SR.....
..... *H. variegator* (Spinola, 1808) species group (sensu Tobias)
- Middle lobe of mesoscutum (often evenly) setose (Figs 6C, 7E, 8E). Vein 3-SR not longer than vein 2-SR (except *H. lineatellae*; Figs 6B, 7A, 9B)..... 2
- 2 Mesoscutum (except middle lobe posteriorly and notauli lines) and most of mesopleuron completely smooth. Vein 2-SR+M 0.5–0.7 times as long as vein 2-SR, 1.1–1.4 times as long as vein m-cu (Fig. 7A; if rarely 0.8–0.9 times then vein 1-R1 not longer than pterostigma). - Metanotum smooth (Fig. 7F). Metasomal tergites with weak sculpture, shiny (Fig. 7F). First metasomal tergite with smooth furrow (Fig. 7E) 3
- Mesoscutum and mesopleuron distinctly granulose or shagreened (Fig. 6C), if sometimes with smoothed areas (Fig. 8E, 8F) then vein 2-SR+M 0.3–0.5

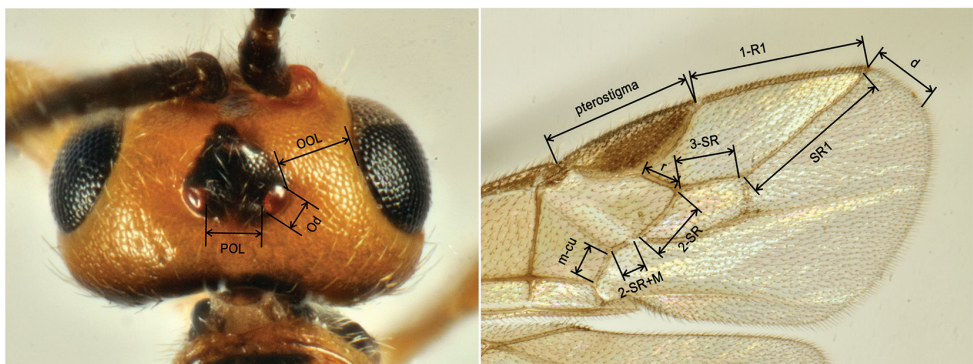


Figure 9. Measures adopted in the key for head. **A** (Od = Ocellar diameter, OOL = Ocular - Ocellar Line, POL = Post-Ocellar Line) and distal part of fore wing **B** (d = distance from apex of marginal cell to apex of wing).

- times as long as vein 2-SR and 0.4–0.8 times as long as vein m-cu (Fig. 8B) and first metasomal tergite usually with crenulate furrow.....4
- 3 Antennae not thickened; first flagellar segment 1.8–2.0 times longer than its apical width, middle flagellar segments 1.6–1.7 times longer than wide. Vein 1-R1 0.85–1.00 times as long as pterostigma, 1.1–1.3 times longer than distance from apex of marginal cell to apex of wing. Face width 1.8–1.9 times its height with clypeus. Hypoclypeal depression 1.4–1.5 times wider than shortest distance from depression to eye. Transverse diameter of eye (dorsal view) 2.3–2.6 times longer than temple. Fore wing almost hyaline. 2.0–2.6 mm..... ***H. breviradiatus* Tobias, 1957**
- Antennae thickened; first flagellar segment 1.5–1.8 times longer than its apical width, middle flagellar segments 1.3–1.4 times longer than wide (Fig. 7B). Vein 1-R1 1.3–1.5 times longer than pterostigma, 3.5–5.0 times longer than distance from apex of marginal cell to apex of wing. Face width 1.4–1.6 times its height with clypeus. Hypoclypeal depression 1.1–1.2 times wider than distance from depression to eye. Transverse diameter of eye (dorsal view) 1.5–1.6 times longer than temple. Fore wing faintly darkened in basal half and under pterostigma. 2.0–3.5 mm..... ***H. hebetor* (Say, 1836)**
- 4 Mesosoma usually black, evenly granulose (except ventral side of mesopleuron; Figs 6A, 6C, 6D). Vein 2-SR+M 0.5–0.9 times as long as vein 2-SR, 0.8–1.3 times as long as vein m-cu (Fig. 6B). - Transverse pronotal sulcus deep and often crenulate (Fig. 6D). Lateral area of metanotum usually sculptured. Antero-lateral areas on third metasomal tergite not separated by grooves.....5
- Mesosoma reddish-yellow or black, with wide reddish pattern and smoothed areas on mesoscutum, pronotum and lateral side of mesopleuron (Fig. 8E, 8F). Vein 2-SR+M 0.25–0.50 times as long as vein 2-SR, 0.4–0.8 times as long as vein m-cu (Fig. 8B, 9B) **8**
- 5 Vein 1-R1 0.8–1.1 times as long as pterostigma complex of species [*H. didemie* (Beyarslan, 2002), *H. excisus* Tobias, 1957, *H. kopetdagi* Tobias, 1957, *H. marshakovi* (Tobias, 2000), *H. nigerrimus* Fischer, 1968, *H. ponticus* (Tobias, 1986), *H. radialis* Telenga, 1936]
- Vein 1-R1 1.3–1.5 times longer than pterostigma (Fig. 6B) **6**
- 6 Vein 3-SR 0.75–0.95 times as long as vein r (Fig. 6B). OOL 3.0–4.0 times Od; POL 2.3–3.0 times Od (Fig. 6C). Face width 1.7–1.8 times its height with clypeus (Fig. 6E). - Hypoclypeal depression 1.2–1.6 times wider than shortest distance from depression to eye. Middle lobe of mesoscutum without longitudinal stripes of smoothed sculpture (Fig. 6C). Fore wing almost hyaline. Vein 1-R1 2.0–2.5 times longer than distance from apex of marginal cell to apex of wing (Fig. 6B). 2.0–3.2 mm..... ***H. concolorans* (Marshall, 1900)**
- Vein 3-SR 1.4–1.7 times longer than vein r. OOL 2.2–2.8 times Od; POL 1.3–1.9 times Od. Face width 1.4–1.6 times its height with clypeus.....7
- 7 Second tergite basally 1.4–1.6 times wider than its median length, coarsely rugose on sides of median convex area. Fore wing almost hyaline. Vein 1-R1

- 1.8–2.1 times longer than distance from apex of marginal cell to apex of wing. Hypoclypeal depression 1.2–1.3 times wider than minimum distance from depression to eye. Middle lobe of mesoscutum sometimes only with two longitudinal stripes of smoothed sculpture. 2.3–3.2 mm
 ***H. crassicornis* (Thomson, 1892)** (*H. flavosignatus* Tobias, 1957)
- Second tergite basally 1.7–2.0 times wider than its median length, evenly striate-rugose medially and without median convex area. Fore wing faintly darkened in basal half. Vein 1-R1 3.0–4.5 times longer than distance from apex of marginal cell to apex of wing. Hypoclypeal depression 0.9–1.0 times as wide as shortest distance from depression to eye. Middle lobe of mesoscutum with two smooth longitudinal stripes. 2.5–3.0 mm
 ***H. stabilis* (Wesmael, 1838)**
- 8 Vein 3-SR 1.2–1.3 times longer than vein 2-SR. Vein 1-R1 1.4–1.5 times longer than pterostigma, 5.0–6.0 times longer than distance from apex of marginal cell to apex of wing. Fore wing distinctly darkened in apical half. – Second metasomal tergite coarsely rugose on sides of short, almost smooth and convex median area. Middle lobe of mesoscutum with two smooth longitudinal stripes, but sometimes completely smooth. Median area of first metasomal tergite with roughly crenulate margins. Sculpture of mesosoma and metasoma often smoothed. 2.5–3.0 mm
 ***H. lineatellae* Fischer, 1968, stat. resurr.**
- Vein 3-SR 0.6–1.0 times as long as vein 2-SR (Fig. 8B). Vein 1-R1 1.00–1.35 times as long as pterostigma, 1.7–5.5 times longer than distance from apex of marginal cell to apex of wing. Fore wing hyaline in apical half..... **9**
- 9 Vein 1-R1 1.0–1.2 times as long as pterostigma, 1.7–2.2 times longer than distance from apex of marginal cell to apex of wing. Vein SR1 4.0–4.5 times longer than vein 3-SR. Fore wing almost hyaline. – First flagellar segment 2.1–2.3 times longer than its apical width; middle and penultimate flagellar segments 1.7–1.9 times longer than wide..... **10**
- Vein 1-R1 1.25–1.35 times longer than pterostigma, 2.5–5.5 times longer than distance from apex of marginal cell to apex of wing. Vein SR1 2.4–3.8 times longer than vein 3-SR. Fore wing faintly darkened at least under pterostigma (Figs 8B, 9B). – Side of metanotum smooth (Fig. 8G). Middle lobe of mesoscutum with two smoothed longitudinal stripes (sometimes hardly visible Fig. 8E)..... **11**
- 10 Antennae 23–25-segmented. Vein 3-SR 1.75–1.85 times longer than vein r. Transverse diameter of eye (dorsal view) 1.9–2.2 times longer than temple. Lateral areas of metanotum rugose to areolate with granulation. Propodeum with median keel and rugosity on wide area. OOL 1.4–2.0 times POL; POL 0.9–1.5 times Od. 2.8–3.6 mm ***H. nygmiae* Telenga, 1936**
- Antennae 17–19-segmented. Vein 3-SR 1.0–1.4 times as long as vein r. Transverse diameter of eye (dorsal view) 2.6–3.1 times longer than temple. Lateral areas of metanotum faintly granulose to smooth. Propodeum evenly

- granulose, without median keel. OOL 1.1–1.2 times POL; POL 1.6–2.0 times Od. 2.0–2.6 mm ***H. telengai* Mulyarskaya, 1955**
- 11 In female, POL 1.2–1.6 times Od, OOL 1.5–1.7 times POL (male unknown). Metasomal sculpture finer and shiny (same in large specimens; as in Fig. 7F). Lateral and median areas of first tergite almost with same type of sculpture, with carinate furrow (i.e. with carinae going beyond furrow). - In small specimens (body length 1.5–2.0 mm), all tergites weakly sculptured, shagreened; - first tergite with smooth furrow. 1.5–2.7 mm ***H. viktorovi* Tobias, 1961**
- In female, POL 1.7–2.2 times Od, OOL 1.2–1.4 times POL (Fig. 8C; in male, 1.3–1.4 and 1.05–1.10 times, respectively). Metasomal sculpture coarser, matt (Fig. 8H, I). Lateral areas of first tergite coarser sculptured in comparison with median area, with areolate furrow (i.e. with carinae not going beyond furrow). - In small specimens (body length 2.1–2.2 mm), metasomal sculpture shiny but distinctly visible; - first tergite with smooth furrow. 2.1–2.7 mm ***H. pillerianae* Fischer, 1980**

Discussion and conclusions

Our data provide new information about host association and distribution of *Bracon* and *Habrobracon* species. In the literature, there are few reports of *Habrobracon* or *Bracon* species living on *L. botrana* (Table 2). *Habrobracon gelechiaae* (Ashmead, 1889), a well-known parasitoid of the potato tuber moth, *Phthorimaea operculella* (Zeller, 1873) (Lepidoptera, Gelechiidae), was introduced into France to control this harmful insect, and has been experimentally reared from larvae of *L. botrana* (Trouvelot 1924). In the vineyards of Sardinia, Delrio et al. (1987) obtained an unidentified *Habrobracon* from the larvae of EGVM, while from the same host in northwest Iran, along with *H. hebetor*, an unidentified *Bracon* was also obtained (Akbarzadeh Shoukat 2012). As it is well known (Tobias 1961, Shaw and Huddleston 1991, Quicke 2015), *Bracon* and *Habrobracon* are all generalist idiobiont, solitary or gregarious ectoparasitoids, predominantly of Lepidoptera and Coleoptera mature larvae. The data we obtained on *B. admotus*, *H. concolorans*, *H. hebetor* and *H. pillerianae* consistently matched with the existing knowledge of these genera.

B. admotus was described by J. Papp (2000) by examining 14 specimens (13 females and 1 male) from Hungary and Bulgaria. Ten females were obtained by Papp himself, from the larvae of *Byctiscus betulae* (Linnaeus, 1758) (Coleoptera: Attelabidae), which fed on rolled leaves of *Populus tremula* L. Beyarslan and Erdoğan (2012) recorded the species in Turkey.

H. concolorans was re-described by J. Papp in 2008; however, it is still reported as *Bracon* (*Habrobracon*) *nigricans* (Szépligeti) in recent papers (Wang et al. 2012, Zappalà et al. 2012a, b, 2013, Biondi et al. 2013a, b, Beyarslan et al. 2014, Gabarra et al. 2014). *H. concolorans* was considered as a synonym of *Bracon stabilis* Wesmael by Belokobylskij et al. (2003) following the World Catalogues by Shenefelt and van

Table 2. List of records of *Habrobracon* and *Bracon* spp. on *Lobesia botrana* arranged in chronological order.

Names as used in scientific publication	Valid names	Geographic area	Authors
<i>Habrobracon</i> sp.	<i>Habrobracon</i> sp.	Sardinia	Delrio et al. 1987
<i>Habrobracon</i> spp.	<i>Habrobracon</i> sp.	South Italy	Moleas 1979, 1995; Coscollà 1997
<i>Habrobracon johannseni</i> Viereck, 1912	<i>Habrobracon gelechia</i> (Ashmead, 1889)	France, experimentally reared from <i>L. botrana</i> larvae	Trouvelot 1924
<i>Microbracon gelechia</i> Ashmead	<i>Habrobracon gelechia</i> (Ashmead)	France	Trouvelot 1924; Thompson 1946; Coscollà 1997
<i>Habrobracon gelechia</i> (Ashmead)	<i>Habrobracon gelechia</i> (Ashmead)	France	Coscollà 1997; Hoffman and Michl 2003
<i>Bracon</i> sp.	<i>Bracon</i> sp.	Northwest Iran	Akbarzadeh-Shoukat 2012
<i>Habrobracon</i> sp.	<i>Habrobracon</i> sp.	Northwest Iran	Lotfalizadeh et al. 2012

Achterberg (1978), and is still considered as such by Beyarslan et al. (2014). This species is a generalist ectoparasitoid of various Lepidopteran families and one coleopteran species of the family Anobiidae. Table 3 reports an updated and revised list of its host species. Biondi et al. (2013b) studied the biology and the developmental strategies of this species on the highly invasive South American tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera Gelechiidae), on tomato in Italy.

Habrobracon hebetor has been re-described many times and has a large number of synonyms because of the wide distribution, the broad host range and morphological variability. Regarding its generic attribution, in addition to *Bracon* and *Habrobracon*, it was also once assigned to *Microbracon* Ashmead, 1890 (synonym of *Bracon*). Although they were synonymised for the first time more than 50 years ago (Lal 1942, Puttarudriah and Channa Basavanna 1956, cited through Yu et al. 2012, Tobias 1959), *H. hebetor* was later separated from *H. brevicornis* (Wesmael, 1838) on the basis of various morphological characteristics: the number of antennal segments and the length of the antenna, the length of the vein 3-SR of the fore wing in relation to that of the vein r (van Achterberg and Polaszek 1996). Today *H. brevicornis* is not considered to be valid, given the large variability of the species, and in more recent works, it is reported as a junior synonym of *H. hebetor* (Papp 2008, Yu et al. 2012). The names *Habrobracon brevicornis* and *Microbracon brevicornis* were also used in the case of *L. botrana* (Table 4), but should be replaced by the name *H. hebetor*, which is a well-known species: Yu et al. (2012) list 631 papers on it in their database. The host range is also very large. Yu et al. (2012) list 130 species, of which the vast majority are Lepidoptera, but there are also two Coleoptera and one Hymenoptera, Cynipidae. The behavior of *H. hebetor* is well known and, like the other species of the same genus, it acts as a gregarious larval ectoparasitoid. *H. hebetor* has been the object of great interest regarding its mass rearing and is used as a biocontrol agent against many pests (Ghimire and Phillips 2014).

Table 3. List of the hosts of *Habrobracon concolorans* (Marshall).

Taxa	Main references
LEPIDOPTERA	
GELECHIIDAE	
<i>Pexicopia malvella</i> (Hübner, 1805)	Tobias 1971 1986; Tobias and Belokobylskij 2000; Belokobylskij et al. 2012; Yu et al. 2012
<i>Phthorimaea operculella</i> (Zeller, 1873)	Ortu and Floris 1989
<i>Tuta absoluta</i> (Meyrick, 1917)	Zappalà et al. 2013; Ghoneim 2014
NOCTUIDAE	
<i>Heliothis maritima</i> Graslin, 1855	Tobias and Belokobylskij 2000; Belokobylskij et al. 2012
NYMPHALIDAE	
<i>Vanessa cardui</i> (Linnaeus, 1758)	Tobias and Belokobylskij 2000; Belokobylskij et al. 2012
PYRALIDAE	
<i>Assara terebrella</i> (Zincken, 1818) (= <i>Ephestia terebellum</i> Zincken nec Zeller)	Györfi 1956; Yu et al. 2012
<i>Etiella zinckenella</i> (Treitschke, 1832)	Tobias 1971, 1986; Tobias and Belokobylskij 2000; Belokobylskij et al. 2012; Yu et al. 2012
<i>Loxostege sticticalis</i> (Linnaeus, 1761)	Tobias 1971, 1986; Tobias and Belokobylskij 2000; Belokobylskij et al. 2012; Yu et al. 2012
TORTRICIDAE	
<i>Cnephasia sedana</i> (Constant, 1884)	Tobias 1971, 1986; Tobias and Belokobylskij 2000; Belokobylskij et al. 2012; Yu et al. 2012
<i>Cydia cosmophorana</i> (Treitschke, 1835)	Györfi 1956
<i>Cydia strobilella</i> (Linnaeus, 1758)	Györfi 1956; Yu et al. 2012
<i>Lobesia botrana</i> (Denis et Schiffermüller, 1775)	new host for <i>H. concolorans</i>
COLEOPTERA	
ANOBIIDAE	
<i>Ernobius nigrinus</i> (Sturm, 1837)	Györfi 1956; Yu et al. 2012

Table 4. List of records of *H. hebetor* on *L. botrana* arranged in chronological order.

Names as used in scientific publication	Geographic area	Authors
<i>Habrobracon</i> sp.	South Italy	Silvestri 1912; Boselli 1928; Stellwaag 1928
<i>Habrobracon brevicornis</i> (Wesmael)	Italy	Silvestri 1912; Goidanich 1934
<i>Microbracon brevicornis</i> (Wesmael)	Italy	Silvestri 1912; Thompson 1946; Coscollà 1997
<i>Habrobracon hebetor</i> (Wesmael)	South Italy	Moleas 1979
<i>Bracon</i> sp. [<i>Habrobracon</i> sp.]	Italy	Stellwaag 1928; Hoffman and Michl 2003
<i>Habrobracon hebetor</i> (Say)	Greece, laboratory test	Milonas 2005
<i>Habrobracon hebetor</i> (Say)	Northwest Iran	Akbarzadeh Shoukat et al. 2008; Akbarzadeh Shoukat 2012; Lotfalzadeh et al. 2012

All these collected Braconinae represent only a minor component of the parasitoid complex we found, mainly represented by the larval endophagous koinobiont *Cam-poplex capitator* (Hymenoptera: Ichneumonidae). They showed a reduced prevalence,

occurring only in three sites out of the nine sampled, while *C. capitator* was found everywhere. These are the typical features of rare taxa, that can play a crucial role in the case of a local and temporal extinction of the main parasitoids (Jain et al. 2014). It is known that generalist parasitoids can play a key role in many insect communities, since they can more easily switch between different species, exerting an influence on the abundance, coexistence and the community structure of many host populations (Jones et al. 2015). In terms of their strong phenotypic plasticity, they are a very important resource as pest-control agents. Their “switching” behavioral skills (Murdoch 1969) make them very suitable to performing rapid changes in the host range, depending on the relative abundance of hosts, or the establishment of a new host in the community. This is a very important behavioural trait under the current climate-change scenario, where increasingly more frequently and intensively, exotic pest introductions occur, often breaking the ecological balance (Stireman et al. 2005, Tylianakis et al. 2008). It is not by chance that two of the first autochthone parasitoids, switched on the introduced exotic pest *Tuta absoluta* (Meyrick) in Europe, are represented by *H. hebetor* and *H. concolorans* (Al-Jboory et al. 2012, Doğanlar and Yiğit 2011, Ferracini et al. 2012, Zappalà et al. 2013).

Our findings of three *Habrobracon* and one *Bracon* species living on *L. botrana* larvae in the natural reserve of Migliarino-San Rossore-Massaciuccoli provide important evidence that this wild area could be of great advantage to the surrounding territories. The Tuscan rural landscape is covered in vineyards, where *L. botrana* is the key pest. The vineyard agroecosystem is well integrated with the surrounding areas, rich in natural habitats, and hosts a very diverse braconid fauna (Loni et al. 2012, Belokobylskij et al. 2013, Loni and Lucchi 2014). Indeed, the presence of a natural wild reserve, near to rural and anthropic areas, can play a crucial role as a biodiversity reservoir from which beneficials can spill over and colonize or recolonize perturbed areas.

Acknowledgements

We would like to thank Dominique Zimmermann (Naturhistorisches Museum Wien, Austria) for providing the type of *Habrobracon pilleriana* for the study, Dr. Rebecca Marzani and Dr. Luca Gandini for their field and lab support. We are grateful to the Reserve Director, Andrea Gennai, and the ranger Marco Lorenzini, for hosting the research. This study was partly supported by grants provided by the Russian Foundation for Basic Research (grant No. 15-29-02466, 16-04-00197 and 16-34-00236) for K.G. Samartsev and S.A. Belokobylskij and by Fondi di Ateneo of Pisa University.

References

Achterberg C van (1993) Illustrated key to the subfamilies of the Braconidae (Hymenoptera: Ichneumonoidea). Zoologische Verhandlungen 283: 1–189.

- Achterberg C van (2013) Fauna Europaea: Hymenoptera, Braconidae. Fauna Europaea version 2.6.2, <http://www.faunaeur.org>
- Achterberg C van, Polaszek A (1996) The parasites of cereal stem borers (Lepidoptera: Cossidae, Crambidae, Noctuidae, Pyralidae) in Africa, belonging to the family Braconidae (Hymenoptera: Ichneumonoidea). *Zoologische Verhandlungen* 304: 1–123.
- Al-Jboory IJ, Katbeh–Bader A, Shakir Al-Z (2012) First observation and identification of some natural enemies collected from heavily infested tomato by *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Jordan World Applied Sciences Journal* 17(5): 589–592.
- Alkabarzadeh-Shoukat G, Ebrahimi E, Masnadi-Yazdinejad A (2008) Larval parasitoids of *Lobesia botrana* (Denis & Schiff.) (Lep.: Tortricidae) on grape in Orumieh, Iran. In: Proceeding of 18th Iranian Plant Protection Congress, 24–27 Aug, Hamedan, Iran, 20.
- Alkabarzadeh-Shoukat G (2012) Larval Parasitoids of *Lobesia botrana* (Denis and Schiffermüller, 1775) (Lepidoptera: Tortricidae) in Orumieh Vineyards. *Journal of Agricultural Science and Technology* 14: 267–274.
- Ameri A, Talebi AA, Beyarslan A, Kamali K, Rakhshani E (2013) Study of the genus *Bracon* Fabricius 1804 (Hymenoptera: Braconidae) of Southern Iran with description of a new species. *Zootaxa* 3754(4): 353–380.
- Ameri A, Talebi AA, Rakhshani E, Beyarslan A, Kamali K (2015) Additional evidence and new records of the genus *Bracon* Fabricius 1804 (Hymenoptera: Braconidae) in southern Iran. *Turkish Journal of Zoology* 39: 1110–1120. 10.3906/zoo-1404-62
- Bagnoli B, Lucchi A (2006) Parasitoids of *Lobesia botrana* (Den. & Schiff.) in Tuscany. Integrated Protection in Viticulture. IOBC wprs Bulletin / Bulletin OILB srop 29(11): 139–142.
- Belokobylskij SA, Taeger A, Achterberg C van, Haeselbarth E, Riedel M (2003) Checklist of the Braconidae (Hymenoptera) of Germany. *Beiträge zur Entomologie* 53(2): 341–435.
- Belokobylskij SA, Tobias VI, Kotenko AG, Proshchalykin M, Yu DSK (2012) 48. Fam. Braconidae – braconidy. In: Lelej AS (Ed.) Annotated catalogue of insects of the Russian Far East. Volume I Hymenoptera, Dal'nauka 1, Vladivostok, 300–389.
- Belokobylskij SA, Loni A, Lucchi A, Bernardo U (2013) First records of the genera *Histeromerus* Wesmäl (Hymenoptera, Braconidae, Histeromerinae) and *Ecclitura* Kokujev (Hymenoptera, Braconidae, Euphorinae) in Italy. *ZooKeys* 310: 29–40. doi: 10.3897/zookeys.310.5136
- Beyarslan A, Erdogan OC, Aydogdu M (2010) A synopsis of *Bracon* species of Turkey with description of a new species (Hymenoptera: Braconidae: Braconinae). *Biologia* 65(1): 104–109. doi: 10.2478/s11756-009-0220-6
- Beyarslan A, Erdogan OC (2012) The Braconinae (Hymenoptera: Braconidae) of Turkey, with new locality records and descriptions of two new species of *Bracon* Fabricius, 1804. *Zootaxa* 3343: 45–56.
- Beyarslan A, Gözüaçik C, Özgen I (2014) First research on Braconinae fauna of South-eastern Anatolia region with new localities of Turkey (Hymenoptera: Braconidae). *Entomofauna* 35(10): 177–204.
- Biondi A, Chailleux A, Lambion J, Han P, Zappalà L, Desneux N (2013a) Indigenous natural enemies attacking *Tuta absoluta* (Lepidoptera: Gelechiidae) in Southern France. *Egyptian Journal of Biological Pest Control* 23(1): 117–121.

- Biondi A, Desneux N, Amiens-Desneux E, Siscaro G, Zappalà L (2013b) Biology and developmental strategies of the Palaearctic parasitoid *Bracon nigricans* (Hymenoptera: Braconidae) on the Neotropical moth *Tuta absoluta* (Lepidoptera: Gelechiidae). *Journal of Economic Entomology* 106(4): 1638–1647.
- Boselli F (1928) Elenco delle specie d'insetti dannosi e loro parassiti ricordati in Italia dal 1911 al 1925. Laboratorio di Entomologia Agraria, R Istituto Superiore Agrario Portici, 1–265.
- Broad GR, Shaw MR, Godfray HC (2012) Checklist of British and Irish Braconidae (Hymenoptera). <http://www.nhm.ac.uk/resources-rx/files/braconidae-checklist-for-web-34139.pdf>
- Catoni G (1914) Die Traubenwickler (*Polychrosis botrana* Schiff. und *Cochylis ambiguella* Huebn.) und ihre natürlichen Feinde in Sudtyrol. *Zeitschrift für Angewandte Entomologie* 1(2): 248–259.
- Colombera S, Alma A, Arzone A (2001) Comparison between the parasitoids of *Lobesia botrana* and *Eupoecilia ambiguella* in conventional and integrated vineyards. *Integrated Control in Viticoltura. IOBC wprs Bulletin / Bulletin OILB* srop 24(7): 91–96.
- Coscollà R (1997) La polilla del racimo de la vid (*Lobesia botrana* Den y Schiff.). Generalitat Valenciana, Conselleria de Agricultura, Pesca y Alimentacion, Valencia, 613 pp.
- Del Guercio G (1899) Delle tortrici della fauna italiana specialmente nocive alle piante coltivate. *Nuove Relazioni della R Stazione di Entomologia agraria di Firenze Serie Prima* 1: 117–193.
- Delrio G, Luciano P, Prota R (1987) Researches on grape-vine moths in Sardinia. In: Cavalloro R (Ed.) *Integrated pest control in viticulture. Proceedings of a meeting of the EC Experts' Group, Portoferraio, Italy, 26–28 September, 1985.* AA Balkema, Rotterdam, 57–67.
- Doğanlar M, Yiğit A (2011) Parasitoid complex of the tomato leaf miner, *Tuta absoluta* (Meyrick 1917), (Lepidoptera: Gelechiidae) in Hatay, Turkey. *KSÜ Dog a Bil Derg* 14: 28–37.
- Ferracini C, Ingegno BL, Navone P, Ferrari E, Mosti M, Tavella L, Alma A (2012) Adaptation of indigenous larval parasitoids to *Tuta absoluta* (Lepidoptera: Gelechiidae) in Italy. *Journal of Economic Entomology* 105: 1311–1319. doi: 10.1603/EC11394
- Fischer M (1980) Fünf neue Raupenwespen (Hymenoptera, Braconidae). *Frustula Entomologica (NS)* 1, 15: 147–160.
- Gabarra R, Arnó J, Lara L, Verdú MJ, Ribes A, Beitia F, Urbaneja A, del Mar Téllez M, Mollá O, Riudavets J (2014) Native parasitoids associated with *Tuta absoluta* in the tomato production areas of the Spanish Mediterranean Coast. *Biocontrol* 59(1): 45–54. doi: 10.1007/s10526-013-9545-8
- Ghimire MN, Phillips TW (2014) Oviposition and reproductive performance of *Habrobracon hebetor* (Hymenoptera: Braconidae) on six different pyralid host species. *Annals of the Entomological Society of America* 107(4): 809–817.
- Ghoneim K (2014) Parasitic insects and mites as potential biocontrol agents for a devastating pest of tomato, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) in the world: a review. *International Journal of Advanced Research* 2(8): 81–115.
- Goidanich A (1934) Materiali per lo studio degli Imenotteri Braconidi III. *Bollettino del Laboratorio di Entomologia del R. Istituto Superiore Agrario di Bologna* 6: 246–261.
- Györfi J (1956) Nadelholzzaofen und Nadelholzamenschädlinge und ihre Parasiten. *Acta Agronomica Hungarica* 6: 321–373.

- Hoffmann C, Michl G (2003) Parasitoide von Traubenwicklern ein Werkzeug der natürlichen Schadlingsregulation? Deutsches Weinbaujahrbuch 55: 1–13.
- Ioriatti C, Anfora G, Tasin M, De Cristofaro A, Witzgall P, Lucchi A (2011) Chemical ecology and management of *Lobesia botrana* (Lepidoptera: Tortricidae). Journal of Economic Entomology 104(4): 1125–1137. doi: 10.1603/EC10443
- Ioriatti C, Lucchi A, Varela LG (2012) Grape Berry Moths in Western European Vineyards and their recent movement into the New World. In: Bostanian NJ, Vincent C, Isaacs R (Eds) Arthropod Management in Vineyards: pests, approaches, and future directions, Springer, New York, London, 329–359. doi: 10.1007/978-94-007-4032-7_14
- Jain M, Flynn DFB, Prager CM, Hart GM, DeVan CM, Ahrestani FS, Palmer MI, Bunker DE, Knops JMH, Jouseau CF, Naeem S (2014) The importance of rare species: a trait-based assessment of rare species contributions to functional diversity and possible ecosystem function in tall-grass prairies. Ecology and Evolution 4(1): 104–112. doi: 10.1002/ece3.915
- Jones TS, Bilton AR, Mark L, Sait SM (2015) Host switching in a generalist parasitoid: contrasting transient and transgenerational costs associated with novel and original host species. Ecology and Evolution 5(2): 459–465. doi: 10.1002/ece3.1333
- Lal KB (1942) The relationship of *Microbracon hebetor* Say and *M. brevicornis* Wesm. Proceedings of the Indian Science Congress 28(3): 201–202.
- Leonardi G (1925) Elenco delle specie di Insetti dannosi e dei loro parassiti ricordati in Italia fino all'anno 1911. Parte II. Ord. Lepidoptera. Annali della Scuola superiore di Agricoltura di Portici 19–20: 81–301.
- Loni A, Spooner-Hart R, Lucchi A (2012) First record of *Zombrus bicolor* (Enderlein) Hymenoptera, Braconidae, Doryctinae) in Western Europe. ZooKeys 219: 87–91. doi: 10.3897/zookeys.219.3439
- Loni A, Lucchi A (2014) Hymenoptera parasitoid, a suitable biodiversity resource for vineyard environmental discrimination. Journal of Agricultural Science 6(12): 36–106. doi: 10.5539/jas.v6n12p36
- Lotfalizadeh H, Masnadi-Yazdinejad A, Saber M (2012) New records of the grape berry moth hymenopterous parasitoids in Iran. Munis Entomology & Zoology 7(1): 284–291.
- Lozzia GC, Rigamonti EI (1991) Osservazioni sulle strategie di controllo biologiche e integrate delle tignole della vite in Italia settentrionale. Vignevini 11: 33–37.
- Lucchi A, Santini L (2011) Life history of *Lobesia botrana* on *Daphne gnidium* in a Natural Park of Tuscany - Integrated protection and production in viticulture. IOBC wprs Bulletin / Bulletin OILB srop 67(2): 197–202.
- Luciano P, Delrio G, Prota R (1988) Osservazioni sulle popolazioni di *Lobesia botrana* (Den. & Schiff.) su *Daphne gnidium* L. in Sardegna. Atti XV Congresso nazionale italiano di Entomologia L'Aquila, 543–548.
- Mahmoud MEE (2013) Natural enemies of *Tuta absoluta* in Kassala State, Sudan. In: Bertelsen M (Ed.) *Tuta absoluta*: Meeting the challenge of the tomato leafminer, Ethiopia, Nov. 26–28, 4.
- Marchal P (1912) Rapport sur les travaux accomplis par la mission d'études de la *Cochylis* et de l'*Eudémis*. Librairie Polytechnique, Paris et Liege, 326 pp.

- Marchesini E, Dalla Montà L (1994) Observations on natural enemies of *Lobesia botrana* (Den. Et Schiff.) (Lepidoptera Tortricidae) in Venetian vineyards. Bollettino di Zoologia agraria e Bachicoltura ser. II 26(2): 201–230.
- Marsh PM (1979) Family Braconidae. In: Krombein KV, Hurd PD Jr, Smith DR, Burks BD (Eds) Catalog of Hymenoptera in America North of Mexico. Smithsonian Institution Press, Washington DC 1: 144–295.
- Milonas PG (2005) Influence of initial egg density and host size on the development of the gregarious parasitoid *Bracon hebetor* on three different host species. BioControl 50: 415–428. doi: 10.1007/s10526-004-2837-2
- Moleas T (1979) Essais de lutte dirigée contre la *Lobesia botrana* Schiff. Dans les Pouilles (Italie). In: Proceedings International Symposium of IOBC/wprs on Integrated Control in Agriculture and Forestry. Wien, 8–12 October, 542–551.
- Moleas T (1995) Lotta alle tignole della vite da tavola nell'Italia meridionale. Informatore Fitopatologico 45(5): 8–11.
- Murdoch WW (1969) Switching in general predators: experiments on predator specificity and stability of prey populations. Ecological Monographs 39: 335–354. doi: 10.2307/1942352
- Nuzzaci G, Triggiani O (1982) Note sulla biocenosi in Puglia della *Lobesia (Polychrosis) botrana* (Schiff.) (Lepidoptera: Tortricidae) infeudata a *Daphne gnidium* L. Entomologica 17: 47–52.
- Ortu S, Floris I (1989) Indagine preliminare per il controllo di *Phthorimaea operculella* su coltivazioni di patata in Sardegna. La Difesa delle Piante 12: 81–88.
- Papp J (2000) First synopsis of the species of *obscurator* species-group, genus *Bracon*, subgenus *Glabrobracon* (Hymenoptera: Braconidae, Braconinae). Annales Historico-Naturales Musei Nationalis Hungarici Budapest 92: 229–264.
- Papp J (2008) Redescriptions of *Habrobracon concolorans* (Marshall) and *Habrobracon crassicornis* (Thomson) (Hymenoptera: Braconidae: Braconinae). Entomologisk Tidskrift 129(3): 165–172.
- Papp J (2009) Braconidae (Hymenoptera) from Mongolia, XVII. Eleven Subfamilies. Acta Zoologica Academiae Scientiarum Hungaricae 55(2): 139–173.
- Papp J (2014) Braconidae (Hymenoptera) from Tunisia, 4. Fourteen subfamilies. Folia Entomologica Hungarica 75: 143–166. doi: 10.17112/FoliaEntHung.2014.75.143
- Pinna M, Gremo F, Scaramozzino PL (1989) A preliminary investigation into the influence of biotic and abiotic environmental factors on the winter populations of *Lobesia botrana*, Den. & Schiff., in vineyards in Piedmont, Italy, Lepidoptera Tortricidae. In: Cavalloro R (Ed.) Influence of Environmental Factors on the Control of Grape Pests, Diseases and Weeds. Proceedings of a meeting of EC Experts' Group, Thessaloniki, 6–8 October 1987, 77–86.
- Puttarudriah M, Channa Basavanna GP (1956) A study on the identity of *Bracon hebetor* Say and *Bracon brevicornis* Wesmäl (Hymenoptera: Braconidae). Bulletin of Entomological Research 47: 183–191. doi: 10.1017/S0007485300046617
- Quicke DLJ (1987) The Old World genera of braconine wasps (Hymenoptera: Braconidae). Journal of Natural History 21: 43–157. doi: 10.1080/00222938700770031
- Quicke DLJ (1997) Subfamily Braconinae. In: Wharton RA, Marsh PM, Sharkey MJ (Eds) Manual of the new world Genera of the family Braconidae (Hymenoptera). The International Society of Hymenopterist, Washington DC, 149–174.

- Quicke DLJ (2015) The braconid and ichneumonid parasitoid wasps: biology, systematics, evolution and ecology. Wiley-Blackwell, Oxford UK, 704 pp.
- Roat C, Forti D (1994) Indagine sulla parassitizzazione della tignoletta della vite (*Lobesia botrana* Den. & Schiff.) in Trentino. Bollettino ISMA 1/1994: 37–41.
- Samartsev KG, Belokobyl'skij SA (2013) On the fauna of the true cyclostome Braconid wasps (Hymenoptera, Braconidae) of Astrakhan' Province. Entomological Review 93(6): 755–774. doi: 10.1134/S0013873813060080
- Shaw M, Huddleson T (1991) Classification and biology of Braconids wasps (Hymenoptera Braconidae). Handbooks for the identification of British Insects 7 Part. 11, 126 pp.
- Shenefelt RD (1978) Braconidae 10. In: Achterberg C van, Shenefelt RD (Eds) Hymenopterorum Catalogus (nova editio), Pars 15. Dr W Junk BV, The Hague, Holland, 1425–1872.
- Silvestri F (1912) Contribuzioni alla conoscenza degli insetti dannosi e dei loro simbioti. III. La Tignoletta dell'uva (*Polychrosis botrana* Schiff.) con un cenno sulla Tignola dell'uva (*Conchylis ambiguella* Hübn). Bollettino del Laboratorio di Zoologia Generale e Agraria Portici 6: 246–307.
- Stellwaag F (1928) Die Weinbauinsekten der Kulturländer, Lehr- und Handbuch. Verlagsbuchhandlung Paul Parey, Berlin, 884 pp.
- Stireman JO, Dyer LA, Janzen DH, Singer MS, Lill JT, Marquis RJ, Ricklefs RE, Gentry GL, Hallwachs W, Coley PD, Baronett JA, Greeney HF, Connahs H, Barbosa P, Moraisim HC, Diniz IR (2005) Climatic unpredictability and parasitism of caterpillars: Implications of global warming. Proceedings of the National Academy of Sciences of the United States of America 102, 48: 17384–17387. doi: 10.1073/pnas.0508839102
- Thompson WR (1946) A Catalogue of the parasites and predators of insect pests. Section 1 Parasite host catalogue Part 8 Parasites of the Lepidoptera (N-P). Imperial Agricultural Bureaux, Institute of Entomology Parasite Service, Belville, Ontario-Canada, 386–523.
- Tobias VI (1959) *Habrobracon brevicornis* Wesm., 1838, a synonym of *H. hebetor* Say 1836. Izv Akad Nauk Armyanskoi SSR 11: 13–17.
- Tobias VI (1971) Obzor nayechnikov-brakonid (Hymenoptera, Braconidae) fauny SSSR. [Review of the Braconidae (Hymenoptera) of the USSR.] Trudy Vsesoyuznogo Entomologicheskogo Obshchestva 54: 156–268.
- Tobias VI (1986) Braconinae. In: Medvedev GS (Ed.) 27. Order Hymenoptera. Family Braconidae. Opredelitel' Nasekomykh Evropeiskoi Chasti SSSR, Tom III, Pereponchatokrylye, Chetvertaia Chasf. Nauka Publishers Leningrad Division, Leningrad 145, 94–149. [Key to the Insects of the European Part of the USSR. Vol. III Hymenoptera, Part IV. English translation, Oxonian Press Pvt. Ltd., New Delhi, 1995, 883 pp.]
- Tobias VI, Belokobyl'skij SA (2000) 6. Subfam. Braconinae. In: Lehr PA (Ed.) 54 Family Braconidae. Key to the Insects of Russian Far East Vol IV. Neuropteroidea, Mecoptera, Hymenoptera, part 4 Dal'nauka, Vladivostok, 109–192. [In Russian]
- Trouvelot B (1924) Recherches de biologie appliquee sur la teigne des pommes de terre et ses parasites et considerations generales sur l'utilisation des Insectes entomophages en agriculture. Etude des conditions de pullulation des insectes. Annales des Epiphyties 10(1 & 2): 1–132.

- Tylianakis JM, Didham RK, Bascompte J, Wardle DA (2008) Global change and species interactions in terrestrial ecosystems. *Ecology Letters* 11: 1351–1363. doi: 10.1111/j.1461-0248.2008.01250.x
- Villemant C, Delvare G, Martinez M, Sentenac G, Kuntzmann P (2011) Parasitoïdes de tordeuses. In: Sentenac G (Ed.) *La faune auxiliaire des vignobles de France*. Editions France Agricole, Paris, 119–140.
- Voukassovitch P (1924) Contribution à l'étude de l'Eudémis (*Polychrosis botrana* Schiff.) de la Pyrale de la Vigne (*Oenophthira pilleriana* Schiff.) et de leurs parasites. Theses de la Faculté des Sciences de l'Université de Toulouse. Librairie Marqueste EH Guitard Toulouse, 248 pp.
- Wang YP, Chen XX, He JH (2012) A new species of *Bracon* (Hymenoptera: Braconidae) parasitic on larvae of the pest *Orgyia ericae* Germar (Lepidoptera: Lymantriidae) in Northern China. *Entomological News* 122(1): 74–78. doi: 10.3157/021.122.0110
- Yu DSK, Achterberg C van, Horstmann K (2012) Taxapad, Ichneumonoidea 2011. Database on flash-drive. www.taxapad.com, Ottawa, Ontario, Canada.
- Zappalà L, Bernardo U, Biondi A, Cocco A, Deliperi S, Delrio G, Giorgini M, Pedata P, Rapisarda C, Tropea Garzia G, Siscaro G (2012a) Recruitment of native parasitoids by the exotic pest *Tuta absoluta* (Meyrick) in Southern Italy. *Bulletin of Insectology* 65: 51–61.
- Zappalà L, Biondi A, Siscaro G, Garzia GT, Achterberg K van, Desneux N (2012b) Adattamento di limitatori naturali indigeni di *Tuta absoluta* in Italia. Il parassitoide *Bracon nigricans*. *Atti Accademia Nazionale Italiana di Entomologia Anno LX*: 85–93.
- Zappalà L, Biondi A, Alma A, Al-Jboory IJ, Arnó J, Bayram A, Chailleux A, El-Arnaouty A, Gerling D, Guenaoui Y, Shaltiel-Harpaz L, Siscaro G, Stavrinides M, Tavella L, Aznar RV, Urbaneja A, Desneux N (2013) Natural enemies of the South American moth, *Tuta absoluta*, in Europe, North Africa and Middle East, and their potential use in pest control strategies. *Journal of Pest Science* 86: 635–647. Doi: 10.1007/s10340-013-0531-9
- Zargar M, Talebi AA, Hajiqaanbar H, Papp J (2015) A study on the genus *Bracon* Fabricius (Hymenoptera: Braconidae) in north central Iran with four new records for Iranian fauna. *Entomofauna* 36(32): 425–440.