Parasitoids and hyperparasitoids (Hymenoptera) on aphids (Hemiptera) infesting citrus in east Mediterranean region of Turkey

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ABSTRACT. The aphids, aphid parasitoids, and hyperparasitoids found in citrus orchards, the parasitoids’ and hyperparasitoids’ seasonal abundance, and the plant–aphid–parasitoid relationships in Hatay, Osmaniye, Adana, and Mersin provinces of the east Mediterranean region of Turkey are presented in the present 2-yr study. Aphidius colemani Viereck, Binodoxys angelicae (Haliday), and Lysiphlebus confusus Tremblay and Eady (Hymenoptera: Braconidae: Aphidiinae) were encountered as the most common parasitoids among 10 identified aphidine and aphelinid taxa on different citrus species. Hyperparasitoids belonging to the genera Alloxystra, Phaenoglyphis, Asaphes, Pachyneuron, Syrphophagus, and Dendrocerus are reported for the first time emerging from aphids feeding on citrus in Turkey. Among them, Asaphes spp., Pachyneuron spp., and Syrphophagus spp. were recorded as the most common ones. Citrus reticulata Blanco and Citrus limon (L.) Burm. fil. were recorded as main hosts for the aphid parasitoids and their hyperparasitoids.

Key Words: citrus, aphid, Aphidiinae, Aphelinidae, hyperparasitoid

Aphids are considered as important pests of citrus causing serious damages directly and indirectly, i.e., loss of saps, deformities, change of color, not normal development, reduction in photosynthesis due to sooty mold growth, and transmission of plant viruses (Blackman and Eastop 2000; Hermoso de Mendoza et al. 2001, 2006; Satar et al. 2007). Despite that more than 25 aphid species have been reported to infest citrus worldwide, only few of them can cause economic injury (Uygun et al. 2012). In the Mediterranean area, Aphis gossypii Glover, Aphis spiraecola Patch, and Toxoptera auranti (Boyer de Fonscolomb) (Hemiptera: Aphiidae) are the major species occurring on citrus and form effective vectors of citrus tristeza virus, a harmful disease of citrus (Hermoso de Mendoza et al. 2001, 2006; Kavallieratos et al. 2002; Marroquin et al. 2004; Satar et al. 2007; Tena and Garcia Mari 2011). Furthermore, the recently detected aphidine and aphelinid taxa on different citrus species. Hyperparasitoids belonging to the genera Alloxystra, Phaenoglyphis, Asaphes, Pachyneuron, Syrphophagus, and Dendrocerus are reported for the first time emerging from aphids feeding on citrus in Turkey. Among them, Asaphes spp., Pachyneuron spp., and Syrphophagus spp. were recorded as the most common ones. Citrus reticulata Blanco and Citrus limon (L.) Burm. fil. were recorded as main hosts for the aphid parasitoids and their hyperparasitoids.

Materials and Methods

Samples were collected from citrus trees between January 2007 and December 2008 from 15 areas in Hatay (Dörtyol, Erzin, Iskendurun), Adana (Ceyhan, Karataş, Koza, Seyhan, Tapakale, Yüreğir), and Mersin (Kumluca, Kuyuluk, Merkez, Silifke, Toros, Yenice), all located in the east Mediterranean region of Turkey. Ten orchards were visited in each location and 100 shoots of 20 cm long from 25 trees (four shoots per tree) were visually inspected for the presence of aphid colonies with mummies (Bora and Karaca 1970). The shoots were collected once per month from all locations throughout the experimental period. Out of 360,000 inspected shoots 316, upon which one or more aphid mummies were observed, were collected from the citrus trees. The shoots bearing aphid colonies and mummies were gently cut with scissors, placed in

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plastic bags, and were brought to the laboratory where aphids were identified to species. Living aphids were preserved in 90% ethyl alcohol plus 75% lactic acid (Eastop and van Emden 1972). Mummies were placed separately in plastic vials (50 ml) inside a growth room (22°C, 65% RH, 16:8 h [L:D]) for parasitoid and hyperparasitoid emergence (Kavalieratos et al. 2005b). The vials had a circular opening on their lid covered with muslin for ventilation in order to maintain conditions inside the vials similar to those existing in the growth room. Parasitoid adults were identified from ethanol-preserved samples, a part of them was point mounted or slide mounted for detailed examination. Specimens for slides were washed in distilled water, boiled in 10% KOH for about 2 min, rewashed, and then placed in a drop of Faure-Berlese medium (Krantz 1978) for dissection or whole mounting. External morphology was studied using an Olympus SZX9 (Olympus, Tokyo, Japan) or Carl Zeiss Microscopy GmbH SMXX (Carl Zeiss Microscopy GmbH, Jena, Germany) stereomicroscopes. Percentage of hyperparasitization was estimated by dividing the number of hyperparasitoid individuals to the total number of parasitoid and hyperparasitoid individuals. The voucher specimens are deposited in P. Stary’s personal collection at České Budějovice.

The chi-square analysis was performed to determine statistical differences in the following: 1) abundance of the most commonly identified parasitoid species on Citrus aurantium L., Citrus limon (L.) Burm. fil., Citrus reticulata Blanco, and Citrus sinensis (L.) Osbeck and 2) preference of each parasitoid species to C. aurantium, C. limon, C. reticulata and C. sinensis for the two years, 2007 and 2008, experimental period at P = 0.05 (Sokal and Rohlf 1995). Citrus paradoxis Macfad. was excluded from the analysis because only few parasitoid individuals were recorded on this plant species. All analyses were performed using the SPSS 17.0 software (Statistical Package for the Social Sciences (SPSS), Inc. 2008). Analysis was not conducted for hyperparasitoids because they were not identified in the species level and thus generalizations in higher taxonomic level (i.e., superfamilies) should be avoided.

**Results**

**Aphids and Parasitoids.** Seven aphid species were determined in the studied region, i.e., A. gossypii, A. spiraecola, Aphis craccivora Koch, Myzus persicae (Sulzer), T. aurantii, Brachycyclus helichrysi (Kaltenbach), and Macrosiphum euphorbiae (Thomas) (Hemiptera: Aphiidae). Although there were seven aphid species on citrus, A. gossypii had the most diverse aphidine spectrum, while no parasitoids were obtained from A. spiraecola, Ma. euphorbiae, and T. aurantii (Table 1). M. persicae was parasitized by Ap. colemani and B. angelicae on C. aurantium and C. reticulata while A. craccivora was parasitized only by L. confusus on C. reticulata and by Ap. colemani and B. angelicae on C. limon (Table 1).

Of the 316 samples, totally 2,752 parasitoid individuals were recorded belonging to the following taxa: Aphielinesp. (Hymenoptera: Aphiiliniae), Ap. colemani, Ap. matricariae, B. angelicae, E. persicae, Lysiphlebus sp., L. fabarum, L. confusus, Diaeretiella rapae (M’Intosh), and P. volucre (Hymenoptera: Braconidae: Aphidiinae) (Tables 1–3). The exotic parasitoid L. testaceipes (Hymenoptera: Braconidae: Aphiinae) was only obtained from Aphis ruborum (Börner and Schilder) (Hemiptera: Aphiadinae) (1 ½) which was creeping or rambling to citrus tree probably due to the close vicinity of C. sinensis trees to Rubus fruticosus L. growing at the margin of the citrus orchard in Yüreğir (Adana).

Ap. colemani, B. angelicae, and L. confusus were the most numerous and frequently recorded parasitoids (Tables 2 and 3). From these three species, only B. angelicae was recorded in all citrus species (Table 2). Within the citrus species, on C. reticulata, 9 parasitoid taxa were found parasitizing A. craccivora, A. gossypii, and M. persicae (Table 1). Also, 46.19% of parasitoids were identified on this citrus species followed by C. limon (27.10%) and C. sinensis (13.95%) (Table 2).

| Citrus plants | Aphids | Parasitoids | Number of parasitoid individuals |
|---------------|--------|-------------|----------------------------------|
| Citrus aurantium | Aphis gossypii | Aphidius matricariae | 14 |
| Citrus limon | Myzus persicae | Aphidius colemani | 6 |
| Citrus reticulata | A. gossypii | B. angelicae | 28 |
| Citrus sinensis | A. craccivora | A. colemani | 18 |
| Citrus paradisi | A. gossypii | B. angelicae | 252 |
| Citrus aurantium | A. gossypii | L. confusus | 49 |
| Citrus limon | A. craccivora | A. colemani | 150 |
| Citrus reticulata | A. gossypii | B. angelicae | 18 |
| Citrus sinensis | A. gossypii | L. confusus | 38 |
| Citrus paradisi | A. gossypii | B. angelicae | 2 |
| Citrus aurantium | A. gossypii | E. persicae | 1 |
| Citrus limon | A. gossypii | L. confusus | 21 |
| Citrus reticulata | A. gossypii | L. confusus | 34 |
| Citrus sinensis | A. gossypii | L. fabarum | 2 |
| Citrus paradisi | A. gossypii | L. confusus | 38 |
| Citrus sinensis | A. gossypii | L. fabarum | 2 |
| Citrus aurantium | A. gossypii | D. rapae | 7 |
| Citrus limon | A. gossypii | L. confusus | 143 |
| Citrus reticulata | A. gossypii | L. fabarum | 57 |
| Citrus sinensis | A. gossypii | L. confusus | 130 |
| Citrus paradisi | A. gossypii | L. fabarum | 3 |
| Citrus aurantium | A. gossypii | L. fabarum | 18 |
| Citrus limon | A. gossypii | L. fabarum | 2 |
| Citrus reticulata | A. gossypii | L. fabarum | 3 |
| Citrus sinensis | A. gossypii | L. fabarum | 28 |
| Citrus paradisi | A. gossypii | L. fabarum | 13 |

There is a statistical significant preference of parasitoid species to citrus species (\( \chi^2 = 273.4, df = 12, P < 0.01 \)). The chi-square analysis showed that there are statistical differences in the abundances of Ap. colemani, Ap. matricariae, B. angelicae, L. confusus, and L. fabarum on C. aurantium (\( \chi^2 = 27.9, df = 3, P < 0.01, \) C. limon (\( \chi^2 = 423.8, df = 4, P < 0.01, \) C. reticulata (\( \chi^2 = 777.9, df = 4, P < 0.01, \) and C. sinensis (\( \chi^2 = 356.4, df = 4, P < 0.01, \)) Furthermore, the chi-square analysis showed that there are statistical differences in the preferences of Ap. colemani (\( \chi^2 = 206.3, df = 3, P < 0.01, \) B. angelicae (\( \chi^2 = 370.6, df = 3, P < 0.01, \) L. confusus (\( \chi^2 = 215.9, df = 2, P < 0.01, \) and L. fabarum (\( \chi^2 = 275.7, df = 3, P < 0.01, \) but not for Ap. matricariae (\( \chi^2 = 1.7, df = 3, P = 0.63, \) to C. aurantium, C. limon, C. reticulata, and C. sinensis. The statistical differences in the abundances of Ap. colemani, Ap. matricariae, B. angelicae, L. confusus, and L. fabarum found on C. aurantium, C. limon, C. reticulata, and C. sinensis compared in pairs are shown in Table 4.

**Hyperparasitoids.** Alloxysta spp., Phaeoglyphis spp. (Hymenoptera: Cynipoidea), Syrphophagus spp., Asaephes spp., Pachyneuron spp. (Hymenoptera: Chalcidoidea), Dendrocerus spp. (Hymenoptera: Ceraphronoidea) were recorded as hyperparasitoids that attack primary parasitoids of aphids infesting citrus (Tables 2 and 3). The hyperparasitoid spectrum was composed mainly by Chalcidoidea (84.8%) followed by Cynipoidea (13.3%) and

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**Table 1. Citrus–aphid–parasitoid associations in East Mediterranean region of Turkey from January 2007 to December 2008**
Ceraphronoidea (1.9%) (Tables 2 and 3). The main period for hyperparasitoids’ activity was June (61.22%), although it was April (36.81) for parasitoids (Table 3). As in the case of parasitoids, *C. reticulata* also favored hyperparasitoids and assessed 33.42% composition of hyperparasitoids followed by *C. limon* (15.22%) (Table 2).

**Discussion**

Our study provides a rich parasitoid spectrum of *A. gossypii* feeding on citrus in the east Mediterranean region of Turkey which is composed of nine aphidiine taxa and *Aphelinus* sp. contrary to the rather narrow parasitoid complex provided by Yumruktepe and Uygun (1994). Given that previous studies have demonstrated that *A. gossypii* is a serious threat for citrus in southeastern Europe (Kavallieratos et al. 2002), in eastern Mediterranean (Yumruktepe and Uygun 1994, Yoldaş et al. 2011), and western Mediterranean (Hermoso de Mendoza et al. 1998 2001, 2006) makes the research on its natural enemies necessary not only in the studied geographical area but also in other citrus production areas. As in this study, the abundance of the parasitoids should also be estimated in order to distinguish which species is the most effective biocontrol agent in the target citrus area (Kavallieratos et al. 2002, 2004a).

| Parasitoids | Citrus spp. | C. aurantium | C. limon | Citrus paradisi | C. reticulata | C. sinensis | Total |
|-------------|-------------|--------------|----------|----------------|--------------|-------------|-------|
| *Aphelinus* sp. | 1 | — | — | 3 | — | 4 | |
| *Ap. colemani* | 140 | 6 | 162 | — | 140 | 35 | 483 |
| *Ap. matricariae* | 2 | 14 | 18 | — | 14 | 11 | 59 |
| *B. angelicae* | 90 | 34 | 270 | 3 | 409 | 140 | 946 |
| *D. rapae* | — | — | — | — | 1 | 2 | 3 |
| *E. persicae* | 3 | 1 | — | — | 1 | 7 | 15 |
| *Lysiphlebus* sp. | — | — | — | — | — | 1 | 1 |
| *L. confusus* | 13 | — | 273 | — | 552 | 187 | 1,025 |
| *L. fabarum* | 31 | 11 | 23 | — | 143 | 7 | 215 |
| *Praon volucre* | — | — | — | — | — | — | 1 |
| Total | 280 | 66 | 746 | 5 | 1,271 | 384 | 2,752 |
| Total (%) | 10.17 | 2.40 | 27.11 | 0.18 | 46.19 | 13.95 | 100 |

**Hyperparasitoids**

| Cynipoidea | 7 | — | — | 29 | — | 50 | 117 |
| Chalcidoidea | 21 | 6 | 101 | 9 | 585 | 26 | 748 |
| Ceraphronoidea | 1 | 4 | 4 | — | 3 | 5 | 17 |
| Total | 29 | 10 | 134 | 9 | 638 | 62 | 882 |
| Total (%) | 3.29 | 1.13 | 15.19 | 1.02 | 72.34 | 7.03 | 100 |

| Hyperparasitization (%) | 9.39 | 13.16 | 15.22 | 64.29 | 33.42 | 13.90 |

Cynipoidea includes the following genera: *Alloxysta* and *Phaenoglyphis*. Chalcidoidea includes the following genera: *Syrphophagus*, *Asaphes*, and *Pachyneuron*. Ceraphronoidea includes the genus *Dendrocerus*.

### Table 3. Seasonal abundance of parasitoids and hyperparasitoids found on citrus in east Mediterranean region of Turkey, between January 2007 and December 2008

| Months | Parasitoids | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|--------|-------------|---|---|---|---|---|---|---|---|---|----|----|----|-------|
| *Aphelinus* sp. | — | — | — | — | — | — | — | — | — | — | — | 4 | |
| *Ap. colemani* | — | — | — | — | — | 186 | 278 | 16 | — | — | 3 | 1 | 2 | 1 | 483 |
| *Ap. matricariae* | — | — | 1 | 38 | 16 | 3 | 1 | — | — | — | 1 | 2 | 1 | |
| *B. angelicae* | 12 | 5 | 589 | 153 | 3 | 1 | — | — | 2 | 76 | 105 | 946 |
| *D. rapae* | — | — | — | 2 | 1 | — | — | — | — | — | — | — | 3 |
| *E. persicae* | — | — | — | 8 | 5 | — | — | — | — | 1 | 1 | 15 |
| *Lysiphlebus* sp. | — | — | — | — | 1 | — | — | — | — | — | — | — | — |
| *L. confusus* | 60 | 380 | 575 | 7 | — | — | — | — | — | — | — | 1,025 |
| *L. fabarum* | 130 | 49 | 35 | — | — | — | — | — | — | — | — | 215 |
| *P. volucre* | — | — | — | — | — | — | — | — | — | — | — | — | 1 |
| Total | 12 | 6 | 1,013 | 887 | 633 | 9 | — | — | 2 | 83 | 107 | 2,752 |
| Total (%) | 0.44 | 0.22 | 36.81 | 32.23 | 23.00 | 0.33 | 0.07 | 0.02 | 3.88 | |

| Hyperparasitoids | Cynipoidea | — | — | — | — | — | — | 1 | 9 | 2 | 117 |
| Chalcidoidea | — | — | — | — | — | 121 | 73 | 537 | — | — | 5 | 7 | 748 |
| Ceraphronoidea | — | — | — | — | 13 | 1 | — | — | — | — | — | — | 17 |
| Total | — | — | 219 | 91 | 540 | — | 5 | 1 | 14 | 3 | 12 | 882 |
| Total (%) | — | — | 24.83 | 10.32 | 61.22 | — | 0.57 | 0.11 | 1.59 | 1.36 | 100 |

| Hyperparasitization (%) | 0.00 | 0.14 | 1.07 | 0.67 | 0.31 | 0.01 | 0.17 | 0.02 | 1.00 | 0.02 | 0.14 |

Each month includes the total number of identified individuals for 2007 and 2008. Cynipoidea includes the following genera: *Alloxysta* and *Phaenoglyphis*. Chalcidoidea includes the following genera: *Syrphophagus*, *Asaphes*, and *Pachyneuron*. Ceraphronoidea includes the genus *Dendrocerus*. The numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 correspond to January, February, March, April, May, June, July, August, September, October, November, and December, respectively.
Table 4. Differences in the abundances of parasitoids found on citrus in east Mediterranean region of Turkey between January 2007 and December 2008 (in all cases df = 1)

| Parasitoids   | Citrus            | \( \chi^2 \) | P value | Citrus            | Parasitoids   | \( \chi^2 \) | P value |
|---------------|-------------------|--------------|---------|-------------------|---------------|--------------|---------|
| **Ap. colemani** | C. aurantium versus C. limon | 144.9        | <0.01   | C. aurantium      | Ap. colemani versus Ap. matricariae | 3.2       | 0.07    |
|               | C. aurantium versus C. reticulata | 123.0        | <0.01   | Ap. colemani versus B. angilaceae | 19.6       | <0.01   |
|               | C. aurantium versus C. sinensis | 20.5         | <0.01   | Ap. colemani versus L. confusus | —           | —       |
|               | C. limon versus C. reticulata | 1.6          | 0.21    | Ap. colemani versus L. fabarum | 1.5         | 0.23    |
|               | C. reticulata versus C. sinensis | 63.0         | <0.01   | Ap. matricariae versus B. angilaceae | 8.3       | <0.01   |
| **Ap. matricariae** | C. aurantium versus C. limon | 0.5          | 0.48    | Ap. matricariae versus L. fabarum | 0.4         | 0.55    |
|               | C. aurantium versus C. reticulata | 0.0          | 1.00    | B. angilaceae versus L. confusus | —           | —       |
|               | C. aurantium versus C. sinensis | 0.4          | 0.55    | B. angilaceae versus L. fabarum | 11.8       | <0.01   |
|               | C. limon versus C. reticulata | 0.5          | 0.48    | L. confusus versus L. fabarum | —           | —       |
|               | C. limon versus C. sinensis | 1.7          | 0.19    | C. limon          | Ap. colemani versus Ap. matricariae | 115.2     | <0.01   |
|               | C. reticulata versus C. sinensis | 0.4          | 0.55    | Ap. colemani versus B. angilaceae | 27.0       | <0.01   |
| **B. angilaceae** | C. aurantium versus C. limon | 183.2        | <0.01   | Ap. colemani versus L. confusus | 28.3       | <0.01   |
|               | C. aurantium versus C. reticulata | 317.4        | <0.01   | Ap. colemani versus L. fabarum | 104.4      | <0.01   |
|               | C. aurantium versus C. sinensis | 64.6         | <0.01   | Ap. matricariae versus B. angilaceae | 220.5     | <0.01   |
|               | C. limon versus C. reticulata | 28.5         | <0.01   | Ap. matricariae versus L. fabarum | 223.5      | <0.01   |
|               | C. limon versus C. sinensis | 41.2         | <0.01   | Ap. matricariae versus L. fabarum | 0.6         | 0.44    |
|               | C. reticulata versus C. sinensis | 131.8        | <0.01   | B. angilaceae versus L. confusus | 0.0         | 0.90    |
| **L. confusus** | C. aurantium versus C. limon | —            | —       | L. confusus versus L. fabarum | 208.2       | <0.01   |
|               | C. aurantium versus C. reticulata | —            | —       | L. confusus versus L. fabarum | 211.3       | <0.01   |
|               | C. aurantium versus C. sinensis | —            | —       | L. confusus versus L. fabarum | 103.1       | <0.01   |
|               | C. limon versus C. reticulata | 94.4         | <0.01   | Ap. colemani versus B. angilaceae | 131.8       | <0.01   |
|               | C. limon versus C. sinensis | 16.1         | <0.01   | Ap. colemani versus L. confusus | 245.3       | <0.01   |
|               | C. reticulata versus C. sinensis | 180.3        | <0.01   | Ap. colemani versus L. fabarum | 0.0         | 0.86    |
| **L. fabarum** | C. aurantium versus C. limon | 4.2          | 0.04    | Ap. matricariae versus B. angilaceae | 368.9       | <0.01   |
|               | C. aurantium versus C. reticulata | 113.1        | <0.01   | Ap. matricariae versus L. confusus | 511.4       | <0.01   |
|               | C. aurantium versus C. sinensis | 0.9          | 0.35    | Ap. matricariae versus L. fabarum | 106.0       | <0.01   |
|               | C. limon versus C. reticulata | 86.8         | <0.01   | B. angilaceae versus L. confusus | 21.3        | <0.01   |
|               | C. limon versus C. sinensis | 8.5          | <0.01   | B. angilaceae versus L. fabarum | 128.2       | <0.01   |
|               | C. reticulata versus C. sinensis | 123.3        | <0.01   | L. confusus versus L. fabarum | 240.7       | <0.01   |
| **C. sinensis** | Ap. colemani versus A. matricariae | 12.5         | <0.01   | Ap. colemani versus B. angilaceae | 63.0        | <0.01   |
|               | Ap. colemani versus B. angilaceae | 104.1        | <0.01   | Ap. colemani versus L. fabarum | 104.1       | <0.01   |
|               | Ap. colemani versus L. confusus | 18.7         | <0.01   | Ap. matricariae versus B. angilaceae | 110.2       | <0.01   |
|               | Ap. matricariae versus L. confusus | 156.4        | <0.01   | Ap. matricariae versus L. fabarum | 0.9         | 0.35    |
|               | B. angilaceae versus L. confusus | 6.8          | <0.01   | B. angilaceae versus L. fabarum | 6.8         | <0.01   |
|               | B. angilaceae versus L. fabarum | 120.3        | <0.01   | L. confusus versus L. fabarum | 167.0       | <0.01   |

Dashes represent that no analysis was performed.

Tomanović et al. 2009, Pons et al. 2011). Furthermore, a possible alternation of these broadly oligophagous parasitoids to aphids on plants other than citrus may enhance the ecological friendly management of aphid infestations in the studied region, but further research is needed for the clarification of this issue. However, this hypothesis of possible exchange of parasitoid populations has been previously supported for different triotrophic systems of plants, aphids, and parasitoids in various geographical areas of the world (Starý and Pike 1998, Starý and Havelka 2008, Tomanović et al. 2009, Havelka et al. 2012).

Despite it has been demonstrated that Ma. euphorbiae, A. spiracola, and T. auranti are parasitized by a wide spectrum of parasitoids from the Mediterranean region (Starý 1976; Tremblay 1984; Kavallieratos et al. 2004, 2005), we did not record any parasitoids from these aphids during our study. This phenomenon has been previously documented in Greece for certain observational period (Kavallieratos et al. 2002). Different population density of aphids in citrus orchards or different climatic conditions depending on the area could be responsible for this issue (Starý 1970; Kavallieratos et al. 2002, 2004a).

Based on recent reports, the overall parasitoid fauna on citrus in the studied region is quite similar to the respective fauna in southeastern Europe and north Africa (Kavallieratos et al. 2005b, Boukhris Bouhachem 2011). Moreover, the main period for parasitoids’ highest population density was between April and June for both years of our study which stands in agreement with previous studies from Greece (Kavallieratos et al. 2002, 2004a). Generally, the period between March and June is the most suitable for aphids infesting citrus in east Mediterranean region of Turkey like in other Mediterranean countries, i.e., Greece, Italy, and Spain (Barbaggio and Patti 1983; Michenla and Sanchis 1997; Kavallieratos et al. 2002, 2004b). According to Tomanović et al. (2009), the Mediterranean climatic conditions favor the presence of host aphids on plants in that period and consequently the parasitoids’ activity.

The strong presence of hyperparasitoids could be the reason for the limitation of the numbers of the parasitoids rather late in the season (June). Despite the fact that the aphid densities and parasitism were not estimated in this study, our observations stand in accordance with previous reports from other geographical areas (Everhuis 1964; Latteur 1973; Starý 1988; Kavallieratos et al. 2002, 2005a). The high presence of hyperparasitoids is favored by the architecture of the citrus trees. The canopy of citrus plants offers a natural protection against the solar radiation and consequently the aphids suffered by high percentage of hyperparasitization (Brodeur and McNeill 1991, 1992; Kavallieratos et al. 2005a). Hyperparasitoids which attack primary parasitoids in citrus orchards are reported in Turkey for the first time. In our study, the individuals of the superfamily Chalcidoidea belonging to the genera Aphidicyrtus, Asaphes, and Pachyneuron constituted the 84.8% of the total number of the obtained hyperparasitoids and they stably
dominated upon the other groups of hyperparasitoids during the entire experimental period. Similar results for hyperparasitoids on citrus trees have been reported by Kavallieratos et al. (2002).

Our study suggests that different citrus species affect both the species composition and the parasitization preference of Aphidinae species. Thus, Ap. colemani is the main parasitoid for C. limon and C. reticulata; B. angelicola and L. confusus for C. limon, C. reticulata, and C. sinensis; and L. fabarum for C. reticulata. Kavallieratos et al. (2002) demonstrated the existence of significant differences in the percentages of Ap. colemani, Ap. matricariae, B. acalpephae, B. angelicola, D. rapae, E. persicae, or L. testaceipes, all emerged from A. gossypii infesting C. auranturn, C. deliciosa, and C. sinensis, and concluded that the factor plant species affects the parasitization preference of these aphidines. New evidences in the east Mediterranean region of Turkey showed that populations of A. gossypii are distinguished to one existing on cucumber, sweet pepper, citrus, eggplant, and okra and another one on cotton (Satar et al. 2013). It would be interesting to examine if different host races do exist for aphids feeding on different citrus species in the region and could influence the tritrophic (parasitoid–aphid–plant) associations.

Recent efforts for the introduction of L. testaceipes through augmentative releases in the east Mediterranean region of Turkey led to the recovery of this species on aphids feeding on cultivated and noncultivated plants, i.e., Capsella bursa-pastoris (L.) and citrus (Satar et al. 2011). The fact that we recorded L. testaceipes as a single specimen from A. ruborum is attributed to the timing of conducting this study which coincided with the commencement of the release of this species in 2008. Additionally, efforts are needed on aphids infesting citrus in the east Mediterranean area of Turkey and their parasitoids because the establishment of L. testaceipes causes changes in the native parasitoid–aphid associations (Starý et al. 1988, 2004; Cecilio 1994; Tomanović et al. 2009).

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