

Research Article

Associated Chalcidoidea (Hymenoptera) with the cotton mealybug *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) in the southwestern Iran

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Abstract: Eleven species of Chalcidoidea (Hymenoptera) belonging to Aphelinidae, Encyrtidae, Eriaporidae and Signiphoridae associated with the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) were collected and identified during 2017-2018 from Khuzestan province in the southwestern Iran. *Prochiloneurus rex* (Girault) (Encyrtidae) is new record for the fauna of Iran. Meanwhile, biological associations of *Bothriothorax serratellus* (Dalman), *Leptomastix dactylopii* Howard and *L. mayri* Özdikmen (Encyrtidae) as parasitoids and *Marietta picta* (André), *P. rex* and *Chartocerus kurdjumovi* (Nikolskaya) (Signiphoridae) as hyperparasitoids of *Ph. solenopsis* were new.

Keywords: *Phenacoccus solenopsis*, Chalcidoidea, parasitoids, Khuzestan province, southwestern Iran

Introduction

The cotton mealybug, *Phenacoccus solenopsis* Tinsley, 1898 (Hemiptera: Pseudococcidae) is a phytophagous insect with large populations causing serious damage to numerous plants including economically important hosts such as cotton *Gossypium hirsutum* L., sugarcane *Saccharum officinarum* L. and tomato *Solanum lycopersicum* L. (Hodgson *et al.*, 2008; Wang *et al.*, 2010; Mossadegh *et al.*, 2015; Seyfollahi *et al.*, 2016). This pest and its damage have been reported from the New World, Afrotropical, Australia, Oriental, and the Middle East (Wei *et al.*, 2017) including Iran. It was firstly recorded

from Hormozgan province in the southern on Chinese hibiscus shrubs, *Hibiscus rosa-sinensis* L. (Moghadam and Bagheri, 2010). Its report was followed by Bushehr, Khuzestan, Fars, Kerman, Yazd and Kohgiluyeh-va-Boyerahmad provinces, respectively on various hosts such as Chinese hibiscus, okra and potato (Mossadegh *et al.*, 2015).

As a dispersing key pest and an increasing threat to horticultural and ornamental plants in particular, control measures must be taken to prevent economic damage. As with other mealybugs, chemical control of cotton mealybug is difficult especially due to protection created by producing waxy materials around the body and the encapsulated eggs, as well as overlapping generations (Grasswitz and Burts, 1995). Further, excessive and long-term use of pesticides against mealybugs including cotton mealybug causes resistance

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to insecticides and their repercussion (Kaur and Virk, 2011). Therefore, utilization of other control options is required such as biological control by natural enemies as predators or parasitoids, which has attracted considerable attention since the outbreak of this mealybug. Several natural enemies as well as other associates (e.g. hyperparasitoids and parasitoids of predators) have been documented for the cotton mealybug (Nagrare *et al.*, 2011; Suoshe *et al.*, 2013). Ladybirds (Coccinellidae) and *Aenasius arizonensis* (Girault) (Hym.: Encyrtidae) have been reported as the most effective enemies (Mossadegh *et al.*, 2015). Cotton mealybug was reported in 2009 on the Chinese hibiscus shrubs from different cities of Khuzestan province and currently is known to have 219 host plants belonging to 70 families. This mealybug can lead to irreparable damage to horticultural, crop and vegetable products such as citrus, sugarcane, corn, tomato, okra and eggplant (Mossadegh *et al.*, 2015).

Due to the lack of comprehensive study on the parasitic wasps associated with cotton mealybug, this investigation was conducted to collect and identify Hymenoptera including parasitoid, hyperparasitoid, and ladybirds' parasitoid on cotton mealybug from Khuzestan province of Iran.

Materials and Methods

During 2017-2018, samplings were obtained from Chinese hibiscus shrubs, *Hibiscus rosa-sinensis* infested with cotton mealybug in Ahvaz (31°19'N, 48°42'E, Altitude: 18 m), Abadan (30°21'N, 48°16'E, Altitude: 3 m), Bawi (Mollasani: 31°35'N, 48°53'E) and Baghe-Malek (31°31'N, 49°53'E) in Khuzestan province in the southwestern Iran by cutting off the infested leaves which were then placed in a ventilated container and transferred to the laboratory, where they were maintained for four weeks at room condition (temperature: 25 ± 5 °C, relative humidity: 45-60%) for further inspection.

The containers were visited daily, during which the wasps emerging in each container were recorded and stored in 75% ethanol for identification. The specimens were identified by relevant references e. g., Timberlake (1919), Mercet (1929), Ferrière (1956), Hayat (1986, 1998, 2006, 2009a, 2009b), Noyes and Hayat (1994), Noyes (2000) and Çalışkan *et al.* (2016). The specimens were photographed under a stereomicroscope equipped with a Coolpix S10 digital camera (Nikon, Tokyo, Japan) attached to a binocular microscope. The material is deposited at the Insect Collection of Department of Plant Protection, College of Agriculture, Shahid Chamran University of Ahvaz.

For each species, the following parts are presented: the material examined in this study, reference(s) used for morphology and diagnosis, inland and world distribution and know host species from Iran.

Results

Eleven species of wasps which were all chalcid (superfamily Chalcidoidea) were collected and determined belonging to four families as Aphelinidae, Encyrtidae, Eriaporidae and Signiphoridae with 8, 1, 1 and 1 species, respectively. Taxa are listed alphabetically.

Aphelinidae

Marietta picta (André, 1878) (Fig. 1-A)

Material examined: Abadan: 2 ♀♀, 1 ♂, 2018.iii.8. Ahvaz: 2 ♀♀, 2018.x.12; 1 ♀, 2018.x.19. Baghe-Malek: 2 ♀♀, 2 ♂♂, 2018.x.4.

Morphology and Diagnosis: see Hayat (1986 and 1998).

Distribution in Iran: Fars (Lotfalizadeh and Ahmadi, 2001; Hesami and Fallahzadeh, 2004; Fallahzadeh *et al.*, 2008, 2011), Khorasan-Jonubi (Lotfalizadeh *et al.*, 2019), East Azarbaijan (Jafari *et al.*, 2015), Hamadan (Rajabi Mazaher and Sadeghi, 2006), Kerman (Yazdani and Mehrnejad, 1993; Jalaiean *et al.*, 2011), Tehran (Talebi *et al.*, 2008), Zanjan (Keyhanian *et al.*, 1995)

and Khuzestan provinces (Baniameri, 1996; this study).

Distribution outside Iran: throughout Palaearctic including Iraq (Hayat, 1986), Nearctic, Neotropical and Oriental (Noyes, 2019).

Hosts: Parasitoids of *A. arizonensis* and *P. aegyptiacus* (Encyrtidae), and hyperparasitoid of *Ph. solenopsis* (this study). In Iran, the following hosts have been reported: *Agonoscena cisti* (Paton) (Hemiptera: Psyllidae) (Yazdani and Mehrnejad, 1993), *Anophococcus abaii* (Danzig, 1990) (Lotfalizadeh et al., 2019), *Planococcus vovae* (Nasonov) (Lotfalizadeh and Ahmadi, 2001; Talebi et al., 2008), *P. ficus* (Signoret) (Fallahzadeh et al., 2008, 2011), and also it is hyperparasitoid of *Pseudococcus comstocki* (Kuwana) (Jafari et al., 2015), *Euphyllura olivina* Costa (Keyhanian et al., 1995) (Hemiptera: Aphalaridae), *Psyllopsis repens* Loginova (Rajabi Mazaher and Sadeghi, 2006) (Hemiptera: Psyllidae), and *Anagyrus* sp. (Baniameri, 1996). Noyes (2019) lists at least 46 species of Hemiptera as primary hosts and 17 species of Hymenoptera as parasitoid hosts for this wasp.

Encyrtidae

***Aenasius arizonensis* (Girault, 1915) (Fig. 1-B)**

Material examined: Abadan: 18 ♂♂, 27 ♀♀, 2018.iii.8. Ahvaz: 1 ♂, 2018.iii.23; 1 ♂, 3 ♀♀, 2018.iii.30; 2 ♀♀, 2018.iv.6; 1 ♀, 2018.iv.16; 1 ♂, 3 ♀♀, 2018.iv.20; 1 ♂, 4 ♀♀, 2018.iv.27; 8 ♂♂, 3 ♀♀, 2018.v.4; 16 ♂♂, 23 ♀♀, 2018.v.11; 30 ♂♂, 57 ♀♀, 2018.v.18; 26 ♂♂, 81 ♀♀, 2018.v.25; 44 ♂♂, 29 ♀♀, 2018.vi.1; 38 ♂♂, 24 ♀♀, 2018.vi.8; 44 ♂♂, 57 ♀♀, 2018.vi.15; 7 ♂♂, 22 ♀♀, 2018.vi.22; 3 ♂♂, 15 ♀♀, 2018.vi.29; 6 ♂♂, 6 ♀♀, 2018.vii.6; 7 ♂♂, 13 ♀♀, 2018.vii.13; 10 ♂♂, 14 ♀♀, 2018.vii.20; 18 ♂♂, 27 ♀♀, 2018.vii.27; 21 ♂♂, 14 ♀♀, 2018.viii.3; 23 ♂♂, 32 ♀♀, 2018.viii.10; 28 ♂♂, 32 ♀♀, 2018.viii.17; 38 ♂♂, 44 ♀♀, 2018.viii.24; 82 ♂♂, 102 ♀♀, 2018.viii.31; 67 ♂♂, 79 ♀♀, 2018.ix.7; 157 ♂♂, 139 ♀♀, 2018.ix.14; 174 ♂♂, 160 ♀♀, 2018.ix.21; 89 ♂♂, 109 ♀♀, 2018.ix.28; 61 ♂♂, 80 ♀♀, 2018.x.5; 21 ♂♂, 40 ♀♀, 2018.x.12; 1 ♂, 1 ♀, 2018.x.19; 1 ♂, 2018.xi.9; 4 ♀♀, 2018.xi.16. Baghe-Malek: 3 ♂♂, 7 ♀♀, 2018.x.4. Bawi

(Mollasani): 21 ♂♂, 28 ♀♀, 2017.iv.30; 29 ♂♂, 25 ♀♀, 2017.v.25; 14 ♂♂, 13 ♀♀, 2018.iv.25; 31 ♂♂, 24 ♀♀, 2018.v.8.

Morphology and Diagnosis: see Hayat (2009a).

Distribution in Iran: Hormozgan, Bushahr, Fars, Kerman, Kohgiluyeh-va-Boyerahmad, and Khuzestan provinces (Fallahzadeh et al., 2014, 2016; Mossadegh et al., 2015; this study).

Distribution outside Iran: USA, Oriental (Noyes, 2019) and the Middle East (Abdul-Rassoul, 2018; Spodek et al., 2018).

Hosts: *Ph. solenopsis* in this study, in Iran (Fallahzadeh et al., 2014, 2016; Mossadegh et al., 2015), and from extralimital (Noyes, 2019). The host recorded in India includes *Pseudococcus longispinus* (Targioni-Tozzetti) (Nalini and Manickavasagam, 2011).

***Anagyrus aligarhensis* Agarwal and Alam, 1959 (Fig. 1-C)**

Material examined: Ahvaz: 1 ♀, 2018.ix.14; 1 ♀, 2018.ix.21.

Morphology and Diagnosis: see Çalışkan et al (2016).

Distribution in Iran: Tehran (Noyes and Hayat, 1994), Fars (Hesami and Fallahzadeh, 2004, 2005), and Khuzestan provinces (Asadeh and Mossadegh, 1991, 1993; Novin et al., 2000; Mossadegh et al., 2015; this study).

Distribution outside Iran: Old World and USA (Çalışkan et al., 2016).

Hosts: *Ph. solenopsis* (this study). The hosts recorded in Iran include *Nipaeococcus viridis* (Asadeh and Mossadegh, 1991, 1993; Noyes and Hayat, 1994; Novin et al., 2000; Hesami and Fallahzadeh, 2004, 2005), and *Ph. solenopsis* (Mossadegh et al., 2015). Noyes (2019) lists one coccinellid and 16 pseudococcid species as hosts for this wasp.

***Bothriothorax serratellus* (Dalman, 1820) (Fig. 1-D)**

Material examined: Ahvaz: 2 ♂♂, 2018.x.5.

Morphology and Diagnosis: see Ferrière (1956).

Distribution in Iran: Khuzestan province (this study).

Distribution outside Iran: Europe, Armenia, Mongolia, Russia, Tajikistan and Turkey (Noyes, 2019).

Hosts: Hyperparasitoid of *Ph. solenopsis* (this study), and *Syrphus albostrigatus* (Noyes, 2019).

***Homalotylus flaminus* (Dalman, 1820)** (Fig. 1-E)

Material examined: Ahvaz: 5 ♀♀, 2 ♂♂, 2018.x.5; 14 ♀♀, 5 ♂♂, 2018.x.12. Baghe-Malek: 3 ♀♀, 2 ♂♂, 2018.x.4.

Morphology and Diagnosis: see Timberlake (1919).

Distribution in Iran: Fars (Fallahzadeh *et al.*, 2006a) and Khuzestan provinces (Moravvej *et al.*, 2018; this study).

Distribution outside Iran: Nearly cosmopolitan (Noyes, 2019).

Hosts: Larvae of Coccinellidae (this study). In Iran, *Nephus bipunctatus* (Coccinellidae) (Fallahzadeh *et al.*, 2006a) is known as its host. Noyes (2019) lists 1, at least 62, 2 and 3 host species of Chrysomelidae, Coccinellidae, Coccidae, and Pseudococcidae, respectively for this wasp.

***Leptomastix dactylopii* Howard, 1885** (Fig. 1-F)

Material examined: Ahvaz: 1♀, 2018.ix.7; 1♀, 2018.ix.14.

Morphology and Diagnosis: see Noyes and Hayat (1994) and Noyes (2000).

Distribution in Iran: Fars (Fallahzadeh and Japoshvili, 2010; Fallahzadeh *et al.*, 2011), Kermanshah (Jalilvand *et al.*, 2014) and Khuzestan provinces (this study).

Distribution outside Iran: Nearly cosmopolitan (Noyes, 2019).

Hosts: *Ph. solenopsis* (this study). *Planococcus ficus* (Fallahzadeh and Japoshvili, 2010; Fallahzadeh *et al.*, 2011), and *Phenacoccus* sp. (Jalilvand *et al.*, 2014) are known Iranian hosts. Noyes (2019) lists one and 48 host species of Diaspididae and Pseudococcidae, respectively for this wasp.

***Leptomastix mayri* Özdikmen, 2011** (Fig. 1-G)

Material examined: Ahvaz: 1♀, 2018.vi.22; 1♀, 2018.vii.6.

Diagnosis: see Noyes and Hayat (1994).

Distribution in Iran: Fars (Fallahzadeh *et al.*, 2006b), Kermanshah (Jalilvand *et al.*, 2014) and Khuzestan (this study) provinces.

Distribution outside Iran: Palaearctic and Oriental (Fallahzadeh and Japoshvili, 2017).

Hosts: Three pseudococcids, viz. *Ph. solenopsis* (this study), *Peliococcus kimmericus* (Fallahzadeh *et al.*, 2006b), and *Chorizococcus* sp. (Jalilvand *et al.*, 2014) are hosts recorded in Iran for this wasp.

***Prochiloneurus aegyptiacus* (Mercet, 1929)** (Fig. 1-H)

Material examined: Abadan: 15 ♀♀, 6 ♂♂, 2018.iii.8. Ahvaz: 3 ♀♀, 1 ♂, 2018.v.11; 1♀, 1♂, 2018.v.18; 35 ♀♀, 14 ♂♂, 2018.v.25; 50 ♀♀, 16 ♂♂, 2018.vi.1; 51 ♀♀, 10 ♂♂, 2018.vi.8; 34 ♀♀, 20 ♂♂, 2018.vi.15; 10 ♀♀, 5 ♂♂, 2018.vi.22; 10 ♀♀, 1 ♂, 2018.vi.29; 5 ♀♀, 1 ♂, 2018.vii.6; 5 ♀♀, 1 ♂, 2018.vii.13; 5 ♀♀, 2018.vii.20; 3 ♀♀, 1 ♂, 2018.vii.27; 5 ♀♀, 1 ♂, 2018.viii.3; 8 ♀♀, 2 ♂♂, 2018.viii.10; 27 ♀♀, 9 ♂♂, 2018.viii.17; 20 ♀♀, 7 ♂♂, 2018.viii.24; 75 ♀♀, 7 ♂♂, 2018.viii.31; 108 ♀♀, 21 ♂♂, 2018.ix.7; 203 ♀♀, 55 ♂♂, 2018.ix.14; 306 ♀♀, 30 ♂♂, 2018.ix.21; 202 ♀♀, 40 ♂♂, 2018.ix.28; 97 ♀♀, 40 ♂♂, 2018.x.5; 42 ♀♀, 10 ♂♂, 2018.x.12. Baghe-Malek: 8 ♀♀, 3 ♂♂, 2018.x.4. Bawi (Mollasani): 9 ♀♀, 4 ♂♂, 2017.iv.30; 13 ♀♀, 7 ♂♂, 2017.v.25; 4 ♀♀, 1 ♂, 2018.iv.25; 6 ♀♀, 4 ♂♂, 2018.v.8.

Morphology and Diagnosis: see Mercet (1929).

Distribution in Iran: Tehran (OILB, 1971), Fars (Hesami and Fallahzadeh, 2004; Fallahzadeh *et al.*, 2007), Hormozgan (Fallahzadeh *et al.*, 2016) and Khuzestan provinces (Alizadeh *et al.*, 2013; this study).

Distribution outside Iran: Cosmopolitan excluding Australia and South America (Noyes, 2019).

Hosts: Parasitoids of *A. arizonensis* and *Anagyrus* sp., and hyperparasitoid of *Ph. solenopsis* (this study). *Anagyrus* spp. (Hesami and Fallahzadeh, 2004), *Nephus hiekei* (Coleoptera: Coccinellidae), *Homalotylus turkmenicus* (Fallahzadeh *et al.*, 2016), and hyperparasitoid of *Maconellicoccus hirsutus* (Fallahzadeh *et al.*, 2007), from Iran. *Homalotylus quaylei* (OILB, 1971), as well, Noyes (2019) listed 3, 2 and at least 21 host species of Coccinellidae, Coccidae, and Pseudococcidae, respectively for this wasp.

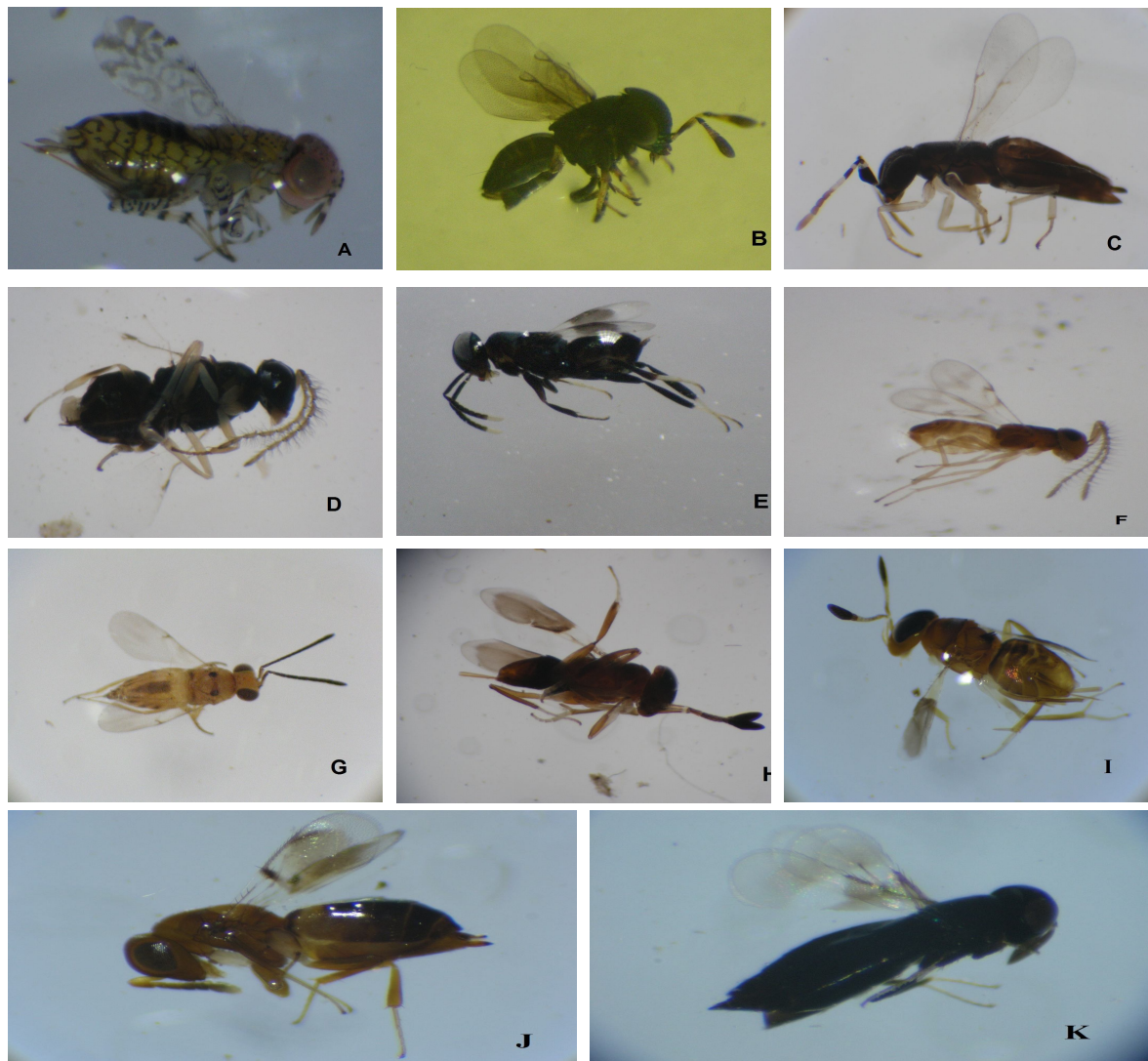


Figure 1 A. *Marietta picta* (Female); B. *Aenasius arizonensis* (Female); C. *Anagyrus aligarhensis* (Female); D. *Bothriothorax serratellus* (Male); E. *Homalotylus flaminius* (Female); F. *Leptomastix dactylopii* (Female); G. *Leptomastix mayri* (Female); H. *Prochiloneurus aegyptiacus* (Female); I. *Prochiloneurus rex* (Female); J. *Promuscidea unfasciiventris* (Female); K. *Chartocerus kurdjumovi* (Female).

***Prochiloneurus rex* (Girault, 1920) (Fig. 1-I)**

Material examined: Ahvaz: 2 ♀♀, 2 ♂♂, 2018.viii.17; 4 ♀♀, 2 ♂♂, 2018.viii.24; 2 ♀♀, 1 ♂♂, 2018.viii.31; 5 ♀♀, 2 ♂♂, 2018.ix.7; 7 ♀♀, 2 ♂♂, 2018.ix.14; 2 ♀♀, 1 ♂, 2018.ix.21; 4 ♀♀, 1 ♂, 2018.ix.28.

Morphology and Diagnosis: see Hayat (2006), however, some specimens studied here differ

from the extralimital material by the absence of basal infuscation in forewing.

Distribution in Iran: Khuzestan province (this study).

Distribution outside Iran: India, Philippines and Puerto Rico (Noyes, 2019).

Hosts: Parasitoid of *A. arizonensis* and hyperparasitoid of *Ph. solenopsis* in Iran (this

study) and *Planococcus citri* and *Pseudococcus citri* (Noyes, 2019).

Eriaporidae

***Promuscidea unfasciativentris* Girault, 1917** (Fig. 1-J)

Material examined: Ahvaz; 3 ♀♀, 1 ♂, 2018.ix.7; 13 ♀♀, 6 ♂♂, 2018.ix.14; 28 ♀♀, 6 ♂♂, 2018.ix.21; 19 ♀♀, 13 ♂♂, 2018.ix.28; 123 ♀♀, 30 ♂♂, 2018.x.5; 61 ♀♀, 18 ♂♂, 2018.x.12; 3 ♀♀, 2018.x.19.

Morphology and Diagnosis: see Hayat (1998).

Distribution in Iran: Hormozgan, Fars and Khuzestan provinces (Mossadegh *et al.*, 2015; this study).

Distribution outside Iran: Afrotropical and Oriental (Noyes, 2019).

Hosts: Parasitoids of *A. arizonensis* and *Anagyrus* sp. (this study). In Iran it is known as parasitoid of Encyrtidae (Mossadegh *et al.*, 2015). Noyes (2019) lists at least 17 species of Hemiptera and at least eight chalcidoids as hosts for this wasp.

Signiphoridae

***Chartocerus kurdjumovi* (Nikolskaya, 1950)** (Fig. 1-K)

Material examined: Ahvaz: 1 ♀, 2018.vi.29; 4 ♀♀, 1 ♂, 2018.vii.20; 5 ♀♀, 2018.vii.27; 1 ♀, 2018.viii.3; 4 ♀♀, 2 ♂♂, 2018.8.10; 7 ♀♀, 1 ♂, 2018.8.17; 2 ♀♀, 2018.8.24; 5 ♀♀, 3 ♂♂, 2018.8.31; 6 ♀♀, 2 ♂♂, 2018.ix.7; 4 ♀♀, 2018.ix.14; 17 ♀♀, 4 ♂♂, 2018.ix.21; 46 ♀♀, 8 ♂♂, 2018.ix.28; 52 ♀♀, 14 ♂♂, 2018.x.5; 50 ♀♀, 12 ♂♂, 2018.x.12. Bawi (Mollasani): 3 ♀♀, 2 ♂♂, 2017.iv.30; 8 ♀♀, 3 ♂♂, 2017.v.25; 4 ♀♀, 2 ♂♂, 2018.v.8.

Morphology and Diagnosis: see Hayat (2009b).

Distribution in Iran: Fars (Fallahzadeh *et al.*, 2008), Khuzestan (Asadeh and Mossadegh, 1991, 1993; Novin, 2000; Alizadeh *et al.*, 2013), and East Azarbaijan provinces (Jafari *et al.*, 2015).

Distribution outside Iran: Europe and India (Noyes, 2019).

Hosts: Parasitoid of *A. arizonensis*, and hyperparasitoid of *Ph. solenopsis* (this study).

In Iran, it is known as parasitoid of *Planococcus ficus* (Fallahzadeh *et al.*, 2008), hyperparasitoid of *Nipaecoccus viridis* (Asadeh and Mossadegh, 1991, 1993; Novin, 2000), and parasitoid or hyperparasitoid of *Pseudococcus comstocki* (Kuwana) (Jafari *et al.*, 2015). Noyes (2019) lists one and at least 13 species of Diptera and Hemiptera, respectively as hosts for this wasp.

Discussion

In this study, *Prochiloneurus rex* is recorded for the first time from Iran and three species, viz. *Bothriothorax serratellus*, *Leptomastix dactylopii* and *L. mayri* are reported as new provincial records from Khuzestan. *Marietta picta*, *P. rex*, and *C. kurdjumovi* as hyperparasitoid and *B. serratellus*, *L. dactylopii*, and *L. mayri* are also documented as parasitoids of *Ph. solenopsis*. Similar to this research, several species of natural enemies have been previously reported from the cotton mealybugs (e. g. Mossadegh *et al.*, 2015; Çalışkan *et al.*, 2016) (Table 1); however, it is expected that more species associated with cotton mealybugs will be identified in the future.

Among cotton mealybug's parasitoids, *A. arizonensis* is assumed to be the most important species (Mossadegh *et al.*, 2015), which has been reported as the factor of up to 100% parasitism of *Ph. solenopsis* in Israel (Spodek *et al.*, 2018). Nevertheless, the rates of parasitism are sometimes diminished by hyperparasitoid wasps like *M. picta*, *Prochiloneurus* spp., and *C. kurdjumovi*.

Effort to create an effective biological control program of *Ph. solenopsis* must be accompanied by accurate identification of natural enemies (e.g. parasitoid and predator, etc.) of the pest and the accompanying insects (e. g. hyperparasitoid and parasitoid). It is hoped that this study will make a significant contribution to the development of the biological control program of this serious pest in southwestern Iran and other regions with similar climate.

Table 1 Insects associated with cotton mealybug *Phenacoccus solenopsis*.

Order	Family	Scientific name	Role
Coleoptera	Coccinellidae	<i>Chilocorus bipustulatus</i> (L.), <i>Clistothethus arcuatus</i> Rossi, <i>Coccinella septempunctata</i> (L.), <i>Cryptolaemus montrouzieri</i> Mulsant, <i>Exochomus nigripennis</i> (Erichson), <i>Hyperaspis polita</i> Weise, <i>H. vinciguerrae</i> (Capara), <i>Nephus arcuatus</i> Kapur, <i>N. includes</i> Kirsch, <i>Nephus</i> near <i>fenestratus</i> , <i>N. nigricans</i> Weise, <i>N. hieki</i> Fursch, <i>Scymnus pallipes</i> Mulsant, <i>S. argutus</i> Mulsant, <i>S. apetzi</i> Mulsant, <i>S. flavicollis</i> (Redtenbacher), <i>S. levaillanti</i> Mulsant, <i>S. syriacus</i> (Marseul)	Predator
Diptera	Cecidomyiidae	<i>Dicrodiplosis manihoti</i> Harris	Predator
Hemiptera	Anthocoridae	<i>Anthocoris</i> sp.	Predator
Hymenoptera	Aphelinidae	<i>Marietta picta</i> (André, 1878) (this study)	Hyperparasitoid
	Eriaporidae	<i>Promuscidea un fasciiventris</i> Girault, 1917 (this study)	Hyperparasitoid
	Encyrtidae	<i>Aenasius arizonensis</i> (Girault) (= <i>bambawalei</i> Hayat) (this study), <i>Anagyrus agraensis</i> Sarawat, <i>A. aligarhensis</i> Agarwal and Alam (= <i>diversicornis</i> Mercet) (this study), <i>A. dactylopii</i> (Howard), <i>A. near kamali</i> , <i>A. mirzai</i> Agarwal and Alam, <i>A. osmoi</i> Guerrieri and Ghahri, <i>Homalotylus flaminus</i> (Dalman, 1820) (this study), <i>Leptomastix dactylopii</i> Howard, 1885 (this study), <i>L. mayri</i> Özdikmen, 2011 (this study) <i>Bothriothorax serratellus</i> (Dalman, 1820) (this study), <i>Prochiloneurus aegyptiacus</i> (Mercet, 1929) (this study), <i>P. rex</i> (Girault, 1920) (this study)	Parasitoid
	Signiphoridae	<i>Chartocerus kurdjumovi</i> (Nikolskaya, 1950) (this study)	Hyperparasitoid
Neuroptera	Chrysopidae	<i>Chrysoperla carnea</i> (Stephens)	Predator

References: Mossadegh *et al.* (2015), Guerrieri and Ghahri (2018), this study.

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References

- Abdul-Rassoul, M. S. 2018. First record of *Aenasius arizonensis* (Girault, 1915) (Hymenoptera, Encyrtidae), a parasitoid of *Phenacoccus solenopsis* Tinsly, 1898 (Hemiptera, Pseudococcidae) in Iraq. Bulletin of Iraq Natural History Museum, 15 (1): 93-100.
- Alizadeh, M. S., Mossadegh, M.S. and Esfandiari, M. 2013. Natural enemies of *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) and their population fluctuations in Ahvaz, southwest of Iran. Journal of Crop Protection, 2: 13-21.
- Asadeh, Gh. A. and Mossadegh, M. S. 1991. An investigation of the mealybug (*Pseudococcus* spp.) natural enemies' fauna in the Khuzestan's province. Proceedings of the 10th Iranian Plant Protection Congress, September, Kerman, Iran. Ministry of Agriculture, p. 3.
- Asadeh, Gh. A. and Mossadegh, M. S. 1993. Important natural enemies of mealybugs (*Pseudococcus* spp.) in the Khuzestan province Iran. Plant Protection (Scientific Journal of Agriculture), 16: 46-52.
- Baniamery, V. 1996. Biology of two parasitoids, *Anagyrus dactylopii* (How) and *A. agraensis* (Sara.) and comparison of their efficiency on *Nipaecoccus viridis* (New.) control in Khuzestan, Iran. (Unpublished master's Dissertation), Department of Plant Protection, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
- Çalışkan, A. F., Hayat, M., Ulusoy, M. R. and Kaydan, M. B. 2016. Parasitoids (Hymenoptera: Encyrtidae) of an invasive mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Turkey. Turkish Journal of Entomology, 40 (2): 133-148.

- Fallahzadeh, M. and Japoshvili, G. 2010. Checklist of Iranian encyrtids (Hymenoptera: Chalcidoidea) with descriptions of new species. *Journal of Insect Science*, 10: 1-24.
- Fallahzadeh, M. and Japoshvili, G. 2017. An updated checklist of Iranian Encyrtidae (Hymenoptera, Chalcidoidea). *Zootaxa*, 4344 (1), 1-46.
- Fallahzadeh, M., Japoshvili, G. and Saghaei, N. 2016. A contribution to the knowledge of the encyrtid wasps (Hymenoptera: Chalcidoidea, Encyrtidae) from southern Iran, with four new records. *Journal of Insect Biodiversity and Systematics*, 2 (3): 309-319.
- Fallahzadeh, M., Japoshvili, G., Abdmaleki, R. and Saghaei, N. 2014. New records of Tetracneminae (Hymenoptera, Chalcidoidea, Encyrtidae) from Iran. *Turkish Journal of Zoology*, 38: 515-518.
- Fallahzadeh, M., Japoshvili, G., Saghaei, N. and Daane, K. M. 2011. Natural enemies of *Planococcus ficus* (Hemiptera: Pseudococcidae) in Fars province vineyards, Iran. *Biocontrol Science and Technology*, 21 (4): 427-433.
- Fallahzadeh, M., Shojaei, M., Ostovan, H. and Kamali, K. 2006a. The first report of two parasitoid wasps on the larvae of *Nephus bipunctatus* (Col.: Coccinellidae) from Iran. *Journal of Entomological Society of Iran*, 26 (1): 95-96.
- Fallahzadeh, M., Shojaei, M., Ostovan, H. and Kamali, K. 2006b. The first report of four parasitoid wasps on *Peliococcus kimmericus* (Hem.: Pseudococcidae) from Iran. *Journal of Entomological Society of Iran*, 26 (1): 97-98.
- Fallahzadeh, M., Shojaei, M., Ostovan, H. and Kamali, K. 2007. Study of the parasitoids and hyperparasitoids of *Maconellicoccus hirsutus* (Hem., Pseudococcidae) in Fars province. *Journal of Agricultural Sciences*, 13 (3): 593-609.
- Fallahzadeh, M., Shojai, M., Ostovan, H. and Kamali, K. 2008. Natural enemies of *Planococcus ficus* (Homoptera: Pseudococcidae) in Fars province vineyards, Iran. *Proceedings of the 18th Iranian Plant Protection Congress*, August, Hamedan, Iran. p. 79.
- Ferrière, C. 1956. Encyrtides parasites de syrphides. *Entomophaga*, 1: 54-64.
- Grasswitz, T. R. and Burts, E. C. 1995. Effects of native natural enemies on the population dynamics of the grape mealybug, *Pseudococcus maritimus* (Hom.: Pseudococcidae), in apple and pear orchards. *Entomophaga*, 40: 105-117.
- Guerrieri, E. and Ghahari, H. 2018. New records, descriptions and notes on Encyrtidae (Hymenoptera: Chalcidoidea) from Iran. *Zootaxa*, 4444 (3): 316-326.
- Hayat, M. 1986. Notes on some species of *Marietta* (Hymenoptera: Aphelinidae), with a key to World species. *Colemania*, 2: 1-18.
- Hayat, M. 1998. Aphelinidae of India (Hymenoptera: Chalcidoidea): A taxonomic revision. *Memoirs on Entomology, International*, 13 (8): 1-416.
- Hayat, M. 2006. Descriptions of eight new species of Encyrtidae from India, with some records (Hymenoptera: Chalcidoidea). *Oriental Insects*, 40: 303-315.
- Hayat, M. 2009a. Description of a new species of *Aenasius* Walker (Hymenoptera: Encyrtidae), parasitoid of the mealybug, *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae) in India. *Biosystematica*, 3: 21-26.
- Hayat, M. 2009b. A review of the Indian Signiphoridae (Hymenoptera: Chalcidoidea). *Biosystematica*, 3(2): 5-27.
- Hesami, S. and Fallahzadeh, M. 2004. Study of the natural enemies of the citrus mealybug *Nipaecoccus viridis* (Homoptera: Pseudococcidae) in Jahrom region of Fars province. *Proceeding of the 16th Plant Protection Congress of Iran*, August, Tabriz, Iran, p. 50.
- Hesami, S. and Fallahzadeh, M. 2005. Recorded species of mealybug parasitoids of the genus *Anagyrus* (Hymenoptera; Encyrtidae) from Fars province of Iran. *Caspian Journal of Environmental Sciences*, 3 (1): 63-68.

- Hodgson, C. J., Abbas, G., Arif, M. J., Saeed, S. and Karar, H. 2008. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. *Zootaxa*, 19 (13): 1-35.
- Jafari, N., Lotfalizadeh, H., Karimpour, Y. and Gharali, B. 2015. Natural enemies of the Comstock mealybug, *Pseudococcus comstocki* (Kuwana) (Hem.: Pseudococcidae) as an important pest of mulberries in Tabriz, Iran. *Applied Entomology and Phytopathology*, 3 (2): 1-10.
- Jalaeian, M., Basirat, M. and Joyandeh, A. 2011. Introduction of natural enemies of the common pistachio psylla (*Agonoscaena pistaciae*) (Hem.: Psyllidae) in Khorasan Razavi province (Iran). *Proceedings of 2nd Iranian Pest Management Conference*, Kerman, Iran, p. 56.
- Jalilvand, K., Shirazi, M., Fallahzadeh, M., Vahedi, H. A., Samih, M. A. and Naghadeh, N. M. 2014. Survey of natural enemies of mealybug species (Hemiptera, Pseudococcidae) in Kermanshah province, western Iran to inform biological control research. *Journal of the Entomological Research Society*, 16 (3): 1-10.
- Kaur, H. and Virk, J. S. 2011. Feeding potential of *Cryptolaemus montrouzieri* against the mealybug *Phenacoccus solenopsis*. *Phytoparasitica*, 40 (2): 131-136.
- Keyhanian, A. A., Taghaddosi, M. V. and Farzaneh, A. 1995. The study of the biology and ecology of olive psyllid (*Euphyllura olivina* Costa) (Hom.: Aphalaridae) and of its natural enemies in Tarom Olya, Zandjan. *Proceedings of 12th Iranian Plant Protection Congress*, September. Karaj, Iran, p. 191.
- Lotfalizadeh, H. and Ahmadi A. 2001. Natural enemies of cypress tree mealybug, *Planococcus vovae* (Nasanov), and their parasitoids in Shiraz, Iran. *Iran. Agricultural Research*, 19: 145-154.
- Lotfalizadeh, H., Tavakoli-Korghond, G. and Mokhtari, A. 2019. On the parasitoid complex (Hymenoptera: Chalcidoidea) of *Anophococcus abaii* (Hemiptera: Eriococcidae), with description of *Metaphycus anophococcosi* Lotfalizadeh, n. sp. *Annales de la Société entomologique de France* (N. S.), 55 (4): 317-326. DOI: 10.1080/00379271.2019.1621204.
- Mercet, R. G. 1929. Los generos *Prochiloneurus* y *Achrysoophagus*. *Eos*, 5: 359-363.
- Moghadam, M. and Bagheri, N. A. 2010. A new record of mealybug pest in the South Iran, *Phenacoccus solenopsis* (Hemiptera: Coccidea: Pseudococcidae). *Journal of Entomological Society of Iran*, 30 (1): 67-69.
- Moravvej, S. A., Lotfalizadeh, H. and Shishehbor, P. 2018. A contribution to the study of Encyrtidae (Hymenoptera: Chalcidoidea) of Khuzestan in southwestern Iran. *Journal of Insect Biodiversity and Systematics*, 4 (1): 13-23.
- Mossadegh, M. S., Vafaei, S., Farsi, A., Zarghami, S., Esfandiari, M., Dehkordi, F. S., Fazlinejad, A. and Seyfollahi, F. 2015. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Pseudococcidae), its natural enemies and host plants in Iran. *1st Iranian International Congress of Entomology*, August, Tehran, Iran, pp: 159-167.
- Nagrare, V. S., Kranthi, S., Kumar, R., Dhara, B., Amutha, M., Deshmukh, A. J., Sone, K. D. and Kranthi, R. 2011. *Compendium of cotton mealybugs*. CICR Publication.
- Nalini, T. and Manickavasagam, S. 2011. Records of Encyrtidae (Hymenoptera: Chalcidoidea) parasitoids on mealybugs (Hemiptera: Pseudococcidae) from Tamil Nadu, India. *Check List*, 7 (4): 509-515. <https://doi.org/10.15560/7.4.510>
- Novin, M. 2000. The biology and population fluctuations of *Nipaecoccus viridis* (News.) and its natural enemies in citrus orchards of Dezful. (Unpublished master's Dissertation). Shahid Chamran University of Ahvaz, Ahvaz, Iran.
- Novin, M., Mossadegh, M. S., Karami Nejad, M. and Ghasemi Nejad, M. 2000. Natural enemy of *Nipaecoccus viridis* in the North of Khuzestan. *Proceedings of the 14th Iranian Plant Protection Congress*, September. Isfahan, Iran, p. 264.

- Noyes, J. S. 2000. Encyrtidae of Costa Rica (Hymenoptera: Chalcidoidea), 1. The subfamily Tetracneminae, parasitoids of mealybugs (Homoptera: Pseudococcidae). *Memoirs of the American Entomological Institute*, 62: 1-355.
- Noyes, J. S. 2019. Universal Chalcidoidea Database. The Natural History Museum, London. Available from: <http://www.nhm.ac.uk/chalcidoids> (Accessed 17th March 2019).
- Noyes, J. S. and Hayat, M. 1994. Oriental mealybug parasitoids of the Anagyrini (Hymenoptera: Encyrtidae). CAB International, Oxon.
- OILB. 1971. Liste d'identification des entomophages. Vol. 8. OILB, Genève.
- Rajabi Mazaher, N. and Sadeghi, S. E. 2006. Studying biology of *Psyllopsis repens* Log. and identification of its natural enemies in Hamadan province. *Proceedings of 17th Iranian Plant Protection Congress*, September. Karaj, Iran, p. 236.
- Seyfollahi, F., Esfandiari, M., Mossadegh, M. S. and Rasekh, A. 2016. Life table parameters of the coccinellid *Hyperaspis polita*, a native predator in Iran, feeding on the invasive mealybug *Phenacoccus solenopsis*. *Journal of Asia-Pacific Entomology*, 19: 835-840.
- Spodek, M., Ben-Dov, Y., Mondaca, L., Protasov, A., Erel, E. and Mendel, Z. 2018. The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Israel: pest status, host plants and natural enemies. *Phytoparasitica*, 46 (1): 45-55.
- Suroshe, S., Gautum, R. D. and Fand, B. 2013. Natural enemy complex associated with the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) infesting different host plants in India. *Journal of Biological Control*, 27 (3): 204-210.
- Talebi, A. A., Ameri, A., Fathipour, Y. and Rakhshani, E. 2008. Natural enemies of cypress tree Mealybug, *Planococcus vovae* (Nasonov) (Hem., Pseudococcidae), and their parasitoids in Tehran, Iran. *Journal of Agricultural Science and Technology*, 10: 123-133.
- Timberlake, P. H. 1919. Revision of the parasitic chalcidoid flies of the genera *Homalotylus* Mayr and *Isodromus* Howard, with descriptions of two closely related genera. *Proceedings of the United States National Museum*, 56: 133-194. <https://doi.org/10.5479/si.00963801.56-2293.133>.
- Wang, Y., Watson, G. W. and Zhang, R. 2010. The potential distribution of an invasive mealybug *Phenacoccus solenopsis* and its threat to cotton in Asia. *Agriculture for Entomology*, 12: 403-416.
- Wei, J., Zhang, H., Zhao, W. and Zhao, Q. 2017. Niche shifts and the potential distribution of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) under climate change. *PLoS One*, 12 (7): e0180913. <https://doi.org/10.1371/journal.pone.0180913>.
- Yazdani, A. and Mehrnejad, M. R. 1993. The first record of psyllid species and several Hymenoptera parasitoids on pistachio psyllid from Iran. *Proceedings of 11th Iranian Plant Protection Congress*, September, Rasht, Iran, p. 211.

زنبورهای بالاخانواده Chalcidoidea (Hymenoptera)، مرتبط با شپشک آردآلود پنبه *Phenacoccus solenopsis* در جنوب غربی ایران

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چکیده: یازده گونه زنبور از بالاخانواده Chalcidoidea (Hymenoptera) متعلق به خانواده‌های Aphelinidae، Encyrtidae، Eriaporidae و Signiphoridae مرتبط با شپشک آردآلود پنبه *Phenacoccus solenopsis* (Hemiptera, Pseudococcidae) طی سال‌های ۲۰۱۷ و ۲۰۱۸ میلادی از استان خوزستان واقع در جنوب غربی ایران، جمع‌آوری و شناسایی شدند. زنبور *Prochiloneurus rex* (Encyrtidae) گزارش جدیدی از فون ایران است. هم‌چنین ارتباطات زیستی گونه‌های *Bothriothorax* (Encyrtidae) *L. mayri* و *Leptomastix dactylopii serratellus* (Encyrtidae) به‌عنوان پارازیتوئید و گونه‌های *Marietta picta* (Aphelinidae)، *P. rex* و *Chartocerus kurdjumovi* (Signiphoridae) به‌عنوان هیپرپارازیتوئید شپشک آردآلود پنبه *Phenacoccus solenopsis*، جدید بودند.

واژگان کلیدی: شپشک آردآلود پنبه، Chalcidoidea، پارازیتوئیدها، استان خوزستان، جنوب غربی ایران