



The population density of biocontrol agents of common pistachio psylla, *Agonoscena pistaciae* (Hemiptera: Aphalaridae) in non-sprayed orchards in pistachio plantation areas of Kerman and Yazd provinces

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Information	Abstract
<p>Article Type: Original Article</p> <p>Article History:</p> <p>Received: 14.05.2021 Accepted: 26.07.2021</p> <p>Doi: 10.22123/PHJ.2021.286058.1099</p> <p>Keywords: Pistachio Predators parasitoid wasps</p> <p>Corresponding Author: Mehdi Basirat</p> <p>Email: mbasirat2000@yahoo.com</p> <p>Tel: +98-9131939011</p>	<p>Background: The common pistachio psylla, <i>Agonoscena pistaciae</i> Burckhardt & Lauterer (Hemiptera: Aphalaridae), is known as the key pest of pistachio trees in Iran. This study was surveyed to the population density of natural enemies of <i>A. pistaciae</i>.</p> <p>Materials and Methods: This study was conducted in pistachio plantations in Kerman and Yazd province through 2006-2008. Three pistachio orchards were sampled in each pistachio plantations where managed under no spraying condition. By monthly sampling, population density of predators and parasitoids were recorded.</p> <p>Results: Totally, eight ladybirds' species, <i>Anthochoris minki pistaciae</i>, <i>Anystis baccarum</i>, <i>Chrysoperla lucasina</i>, <i>Psyllaephagus pistaciae</i> were collected as psyllophagous. <i>Oenopia conglobata contaminata</i> and <i>Adalia bipunctata</i> were found in all experimental sites. The two spotted ladybird <i>A. bipunctata</i> was found as the dominant species in Rafsanjan, Ravar, Kerman and Shahr-e Babak areas. <i>O. conglobata contaminata</i>, <i>Hippodamia variegata</i>, <i>Exochomus nigripennis</i> and <i>Coccinella septempunctata</i> were dominant in some areas of Kerman and Yazd provinces. Population density of psyllophagous ladybirds in spring and autumn were considerably higher than summer. 26% of the wasps emerging from psyllids mummies were the primary parasitoid <i>Psyllaephagus pistaciae</i>, and the remaining were hyperparasitoids.</p> <p>Conclusion: This information can be used in the integrated management of this pest.</p>

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1. Introduction

Common pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer (Hemiptera: Aphalaridae) is a key pest of pistachio trees in Iran that feeds on plant sap during the nymph and adult stage, and causes economic damage to pistachio trees [1]. This pest with high reproductive and several generations per year causes that in most years, the population outbreak on one or more happen. High densities of insect populations, simultaneously with the beginning of pistachio kernel growth and after Disrupts the process of Completed pistachio kernel. As a result, irreparable damage is caused to the pistachio crop; sometimes it reduces the crop in the following two years [2, 3].

Common pistachio psylla has several natural enemies in pistachio plantation areas of Iran. Mehrnejad has reported more than 23 species of natural enemies for this pest [2, 4, 5]. Eggs and nymphs of Common pistachio psylla are suitable food for eight species of active ladybirds in pistachio orchards. In addition to ladybirds, which are considered to be the most important natural control agents for common pistachio psylla in pistachio orchards, *Psyllaephagus pistaciae* Ferrier, predatory bugs, common green lacewing and predatory mites are also considered as natural enemies of common pistachio psylla in Iran [1, 2, 4].

The *P. pistaciae* is known as the primary parasitoid of this insect. This useful wasp has a dispersal in pistachio-growing areas of Iran as well as those of the neighboring countries [4, 6, 7]. In his studies, Mehrnejad [6] has investigated various aspects of the life of this wasp such as hosting behaviors, host selection, host identification, laying eggs, and ecological and biological characteristics; he has considered this wasp as a valuable biological control factor for

common pistachio psylla. This wasp attacks all stages of host nymphs and is able to complete the growth period in all five stages of host nymphs [8, 9, 10]. This insect overwinters as a pupa inside the host mummy nymphs [7, 8]. Mehrnejad [7] has discussed the habitats and wintering conditions, the time of emergence of this wasp in spring, and the factors that result in the reduced population of this wasp. Investigating the parasitoid population of this pest has shown that 46% of mummified nymphs belong to the primary parasitoid wasp i.e. *P. pistaciae* and the remaining 54% belong to 6 secondary parasitoid species (hyperparasitoid) [11]. The wasp *Syrphophagus aphidivorus* Mayr is the predominant hyperparasitoid for *P. pistaciae*, and the wasps including *Marietta picta* Andre, *Chartocerus kurdjumovi* Nikolskaja, *Psyllaphycus diaphorinae* Hayat and *Pachyneuron* spp. act as secondary parasitoids [2, 12, 13].

A group of important predators of pistachio psylla are predatory ladybird. ladybirds such as *Oenopia conglobata contaminata* Menteries, *Adalia bipunctata* Linnaeus, *Coccinella undecimpunctata aegyptica* Rieche, *Coccinella septempunctata* Linnaeus, *Exochomus nigripennis* Erichson and *Hippodamia variegata* Goeze attack the eggs and nymphs of psylla [14].

One of the most important common pistachio psylla predators is the ladybird *O. conglobata contaminata*. This ladybird prefers laying eggs on pistachio trees to laying eggs on weeds infested with aphids in pistachio orchards [14, 15]. In his study, Hassani [16] collected as many as 9 species of ladybirds from *Pistacia atlantica* trees, where the dominant species was *O. conglobata cotaminata*. In this regard, Salehi et al. [17] have reported as many as 20 species of

ladybirds from pistachio trees, and 15 species from *Pistacia atlantica* trees in pistachio orchards and wild pistachio habitats in Shahr-e Babak. The two-spot ladybird *A. bipunctata* was also collected on pistachio trees and weeds. This ladybird also prefers laying eggs and living on pistachio trees to laying eggs and living on weeds infested with aphids [18, 19]. This insect has a significant ability to feed on psylla and reproductive. The ladybird *E. nigripennis* is widely found in pistachio growing areas, feeding on pistachio scale insects and pistachio psylla nymphs. This ladybird lives simultaneously on pistachio trees as well as aphid-infested weeds. The ladybird *H. variegata* is present on aphid-infested weeds in pistachio orchards in early spring and is active in aphid colonies with a significant density. After a while, with a relative decrease in the population of aphids on weeds, samples of this species are also seen on pistachio trees. The eleven-spot ladybird *C. undecimpunctata aegyptica* migrates to pistachio trees in early spring and is found in abundance in common pistachio psylla colonies. The larvae and adult of this ladybird feed on the eggs and nymphs of common pistachio psylla. The seven-spot ladybird *C. septempunctata* is abundant on pistachio trees and feeds on common pistachio psylla nymphs, but adult insects are unable to lay eggs by feeding on common pistachio psylla nymphs [1, 15, 18, 19]. The studies conducted by Jalali [15] and Mehrnejad [1] indicated that the ladybird *Chilocorus bipustulatus* Linnaeus is present on pistachio trees and adult insects feed on a small amount of psylla nymphs, yet they do not lay eggs with this diet. Moreover, eight species of ladybirds have also been reported in Greek pistachio orchards [20], and as many as 22 species have been found in pistachio trees in

Turkey [21], but there is no report on their feed status on common pistachio psylla.

In addition to the listed natural enemies, the predatory lacewing larvae of *Chrysoperla lucasina* Lacroix attack eggs and nymphs of common pistachio psylla [2, 22]. Predatory bugs and mites are also considered as natural enemies of this pest [2]. Several predatory mites, including *Anystis baccarum* Linnaeus, *Phytoseius corniger* Wainstein, and *Paraseiulus porosus* Kolodochka, attack common pistachio psylla [23]. The predatory bug *Anthochoris minki pistaciae* Wagner is one of the active predators of this pest [15, 24].

Identifying and protecting native populations of natural enemies and rearing and increasing their population is one of the goals of reducing pesticide use [25]. The present study has been conducted to investigate the population density of natural enemies of common pistachio psylla in pistachio plantation areas of Kerman and Yazd provinces.

2. Materials and methods

Sampling was conducted in 15 pistachio plantation areas of Kerman province and 2 pistachio plantation areas of Yazd province in from 2006 to 2008. In each area, 3 pistachio orchards with an Ohadi cultivar and an area of at least half a hectare were selected that had not been sprayed during the growing season.

In pistachio plantation areas of Kerman province, sampling was conducted in Rafsanjan (suburbs of Rafsanjan), Hydarabad, Faizabad, Saadatabad, Ferdowsieh Azadegan, Mehdiabad, and Station Number 2), the first part of Noq (Shamsabad, Kamalabad, Chah Jafar), Part 2 of Noq (Bahrman, Najmabad, Javadieh Fallah), Koshkoeih (Vakilabad, Behjatabad and Abbasabad), Anar (Golshan, Hosseinabad and Ahmadabad) Kabotarkhan (three orchard), Raviz (Riseh, Hassanabad and Shahabiyeh),

Sirjan (Malekabad, Mafoun and Hassanabad), Kerman (Kazemabad, Zangiabad and Kerman station), Zarand (Rouhbad, Mohammadabad and Abbasabad), Ravar (Sharifabad, Dehouj and Talkelaghi), Rayen (Deh Mirza and Jahadabad), Bardsir (Mohmenabad), Shahrabak (Manzelabad, Hosseinabad and Khatonabad). In Yazd province, the sampling was conducted from the pistachio plantation areas of Ardakan (Kachib and Mortin) and Bahadaran (Moradabad, Mehdiabad and Aliabad). The selected orchards were visited once a month from late May to late November; the population of predators and parasitoid bees was estimated via sampling

Investigating the population of predators

In each experimental orchard, 10 trees were randomly selected and from each tree, four branches in four different tree directions were sampled by limb tapping method [26, 27]. Then the species of ladybirds and their number were recorded separately and their larvae were transferred to the laboratory for rearing and emergence of adult insects. In this regard, the number of adult insects and lacewing larvae, predatory bug, and predatory mites were recorded. In addition, the total number of *P. pistaciae* was recorded in this method. In order to compare the population density of natural enemies in different areas, the average population of natural enemies in each of the sampling areas was calculated. The identification and confirmation of the scientific names of the ladybirds was conducted by Helmut Fursch (Bayerwaldstr. 26, D-94161 Ruderting, Germany).

Population study of parasitoid and hyperparasitoid wasps.

At each sampling time, 10 trees were randomly selected in the orchard, and 5 leaflets were picked from different parts in each tree. In

the laboratory, 150 psyllid mummy psylla nymphs were isolated from the leaves and placed individually in 5 ml glass jars. Mummy nymphs were kept in laboratory conditions (25 ± 5 ° Celsius, a relative humidity of 40-50%, and light period of 16: 8 (darkness: light). After keeping them for one month, the parasitoid and hyperparasitoid wasps were investigated; their number was counted and recorded separately by species.

3. Data analysis

After conducting the sampling process in the pistachio-growing areas, the average population of natural enemies and the percentage of parasitoid and hyperparasitoid wasps and their standard error were measured using excel. Population density charts of natural enemies, their frequency during a season, and the percentage of parasitoid and hyperparasitoid wasps were drawn using excel.

4. Results

Among the ladybirds collected from pistachio trees, there were as many as 15 species of unknown species and species whose scientific names were not confirmed. The species were identified and named as follows:

1. Four forms of the species *Menochilus sexmaculatus* (Fabricius)
2. Two forms of species *Hippodamia (Adonia) variegata* (Goeze)
3. *Scymnus (Pullus) syriacus* Marseul
4. *Psyllobora vigintiduomaculata* Linnaeus
5. *Coccinula elegantula* Weise
6. *Exochomus nigripennis* (Erichson)
7. *Adalia bipunctata revelierei* Mulsant
8. *Oenopia oncina* Olivier
9. *Brumus undulatus* Weise

10. *Hyperaspis polita* Weise

11. *Hyperaspis* sp

Population density of predators of the *A. pistaciae* in pistachio plantation areas

1. Ladybirds

The average number of ladybirds on pistachio trees in different regions of Kerman and Yazd provinces is shown in Table 1. Ladybirds *O. conglobata contaminata* and *A. bipunctata* were present in all pistachio plantation areas of Kerman and Yazd provinces. The ladybird, *A. bipunctata* was the most populated ladybirds in Rafsanjan, Ravar, Kerman and Shahr-e Babak areas (Table 1). Ladybirds *C. septempunctata*, *C. undecimpunctata aegyptica*, *E. nigripennis* and *H. variegata* were found in most pistachio plantation areas of Rafsanjan, Kerman and Yazd provinces (Table 1). From among the collected ladybirds, *A. bipunctata* and *H. variegata* had the highest and lowest relative frequencies, respectively (Table 1 and Figure 1). The relative frequency of ladybirds on pistachio trees in different areas of Kerman province (except Rafsanjan) and Yazd province are shown in Figures 2 and 3, respectively. The relative frequency of the ladybird *H. variegata* in pistachio plantation areas of Kerman province (except Rafsanjan) was the highest among ladybirds, being 4 in each sampling. The ladybird *O. conglobata contaminata* was also ranked second in terms of population density among the collected ladybirds (Figure 2). In the pistachio plantation areas of Yazd province, the ladybird *O. conglobata contaminata* had the highest frequency among all ladybirds (Figure 3).

The frequency of *O. conglobata contaminata*, *A. bipunctata*, *C. septempunctata*, *C. undecimpunctat aegyptica*, *E. nigripennis* and *H. variegata* in different months is shown in Figure 4. The population of *O. conglobata*

contaminata was low in August, but gradually increased in September, October and November, reaching its highest density in November. The ladybird *A. bipunctata* had the lowest population in July, but its population increased in the following months (Figure 4). The population of the seven-spot ladybird *C. septempunctata* was high in June, and gradually decreased until September, but the highest population was observed in October. The population of the ladybird *C. undecimpunctat aegyptica* was relatively small from June to September and increased in October and November (Figure 4). The ladybird *E. nigripennis* had the lowest population in June, and its population gradually increased in the following months. The population of the ladybird *H. variegata* was high in June, but decreased in July to September and increased significantly in October and November; it reached its maximum in November (Figure 4).

2. Larvae and adults of Lacewing

The green lacewing larvae and adult of *C. lucasina* were found in all pistachio plantation areas of Rafsanjan, Kerman and Yazd provinces (Table 1). The relative frequency of green lacewing larvae and adults in pistachio plantation areas of Rafsanjan, Kerman (except Rafsanjan) and Yazd provinces are shown in Figures 1, 2 and 3 respectively.

3. The predatory bug, *Anthochoris minki pistaciae*

The predatory bug *A. minki pistaciae* was present in most areas of Kerman and Yazd provinces (Table 1). The relative frequency of this predatory bug in pistachio plantation areas of Rafsanjan, Kerman (except Rafsanjan) and Yazd provinces are shown in Figures 1, 2 and 3, respectively. The relative frequency of this predatory bug in different months is shown in Figure 5; its population was lower June than that

of the other months and had a significant increase in September (Figure 5).

4. The predatory mite, *Anystis baccarum*

The predatory mite, *A. baccarum* was present in most pistachio plantation areas of Kerman and Yazd provinces (Table 1). The relative frequency of this mite on pistachio trees in

different pistachio plantation areas of Kerman and Yazd provinces is shown in Figures 1, 2 and 3, respectively. The relative frequency of this mite in different months showed that the population of this mite decreased from late May to August and had an upward trend in September and October; the highest population was observed in October (Figure 5).

Table 1. Average population number (SE ±) of natural enemies of common pistachio psylla in each sampling (on 10 trees, 4 branches from each tree) in pistachio plantation areas of Kerman and Yazd provinces from 2006 to 2008

Natural enemy	Areas									
	Rafsanjan	Ravar	Kerman	Zarand	Shahr-e Babak	Rayen	Sirjan	Bardsir	Bahadara	Ardakan
<i>Oenopia conglobata contaminata</i>	0.37±0.14	1±0.61	1.06±0.32	0.43±0.18	0.03±0.05	1.25±0.051	5.93±2.60	0.20±0.4	1±1.10	9±3.85
<i>Adalia bipunctata</i>	1.1±0.46	1.06±0.37	1.44±0.76	0.33±0.21	0.87±0.41	0.92±0.31	0.79±0.71	2±1.74	0.10±0.2	1±0.42
<i>Coccinella septempunctata</i>	0.33±0.10	0.89±0.36	0.28±0.14	0.76±0.27	0.7±0.34	0.5±0.22	0.57±0.27	1.4±0.98	0.05±0.1	0±0
<i>Coccinella undecimpunctata</i>	0.39±0.20	0.11±0.07	0.11±0.11	0.38±0.16	0.33±0.19	0.92±0.43	0.36±0.19	0.40±0.40	0.10±0.20	0±0
<i>Exochomus nigripennis</i>	0.49±0.32	0.06±0.55	0.44±0.21	0.33±0.08	0.03±0.03	0±0	0.07±0.10	0±0	0±0	1±0.45
<i>Hippodamia variegata</i>	0.03±0.02	0±0	0±0	0±0	0.33±0.30	3.50±1.14	4.79±1.56	19.20±6.45	1.24±1.59	0.20±0.22
<i>Chrysoperla lucasina</i> (adult)	0.70±0.21	0.83±0.27	1.33±0.32	1.14±0.32	2.27±0.65	2.33±0.63	7.21±1.63	2.60±0.73	1.14±0.63	3.20±0.85
<i>Chrysoperla lucasina</i> (larva)	0.76±0.21	0.67±0.99	1.22±1.13	0.57±1.11	1.93±1.41	0.92±0.67	2.57±1.98	1±0.73	1.19±0.93	0.40±0.32
<i>Anthocoris minki pistaciae</i>	0.43±0.34	0±0	5.67±4.92	0±0	1.73±0.54	7.5±2.55	12.21±5.17	4.4±3.23	1.19±1.80	31.60±14.27
<i>Anystis baccarum</i>	0.93±0.30	0±0	1.61±0.77	0.24±0.13	0.80±0.13	0.17±0.08	2.71±2.20	1.20±1.20	7.10±4.64	9±6.30

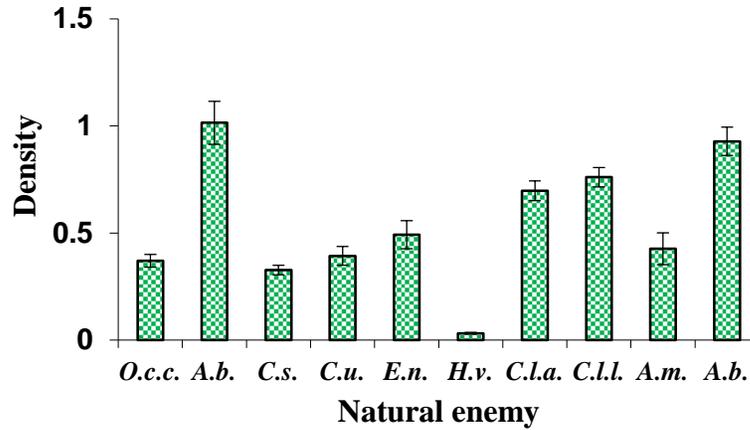


Figure 1. The mean frequency of natural enemies of common pistachio psylla on pistachio trees (on 10 trees 4 branches from each) in different areas of Rafsanjan from 2006 to 2008

(O.c.c.: *Oenopia conglobata contaminata*, A.b.: *Adalia bipunctata*, C.s.: *Coccinella septempunctata*, C.u.: *Coccinella undecimpunctata*, E.n.: *Exochomus nigripennis*, H.v.: *Hippodamia variegata*, C.l.(a.): *Chrysoperla lucasina* (adult), C.l.(l.): *Chrysoperla lucasina* (larva), A.m.: *Anthocoris minki pistaciae*, A.b.: *Anystis baccarum*).

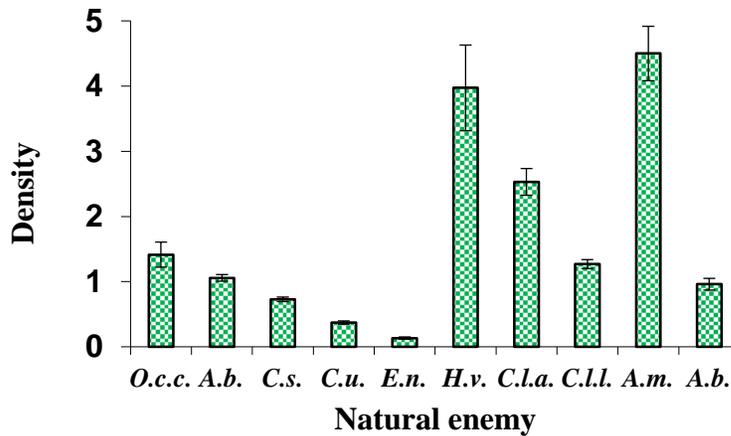


Figure 2. The mean frequency of natural enemies of common pistachio psylla on pistachio trees (on 10 trees, 4 branches from each) in different areas of Kerman province (except Rafsanjan) from 2006-2008

(O.c.c.: *Oenopia conglobata contaminata*, A.b.: *Adalia bipunctata*, C.s.: *Coccinella septempunctata*, C.u.: *Coccinella undecimpunctata*, E.n.: *Exochomus nigripennis*, H.v.: *Hippodamia variegata*, C.l.(a.): *Chrysoperla lucasina* (adult), C.l.(l.): *Chrysoperla lucasina* (larva), A.m.: *Anthocoris minki pistaciae*, A.b.: *Anystis baccarum*).

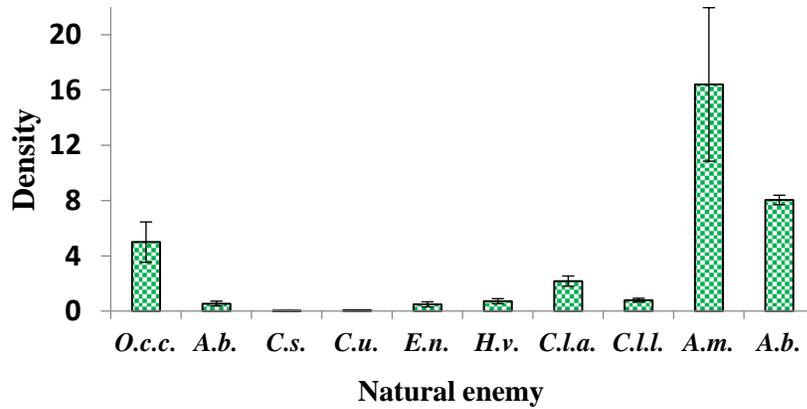


Figure 3. The mean frequency of natural enemies of common pistachio psylla on pistachio trees (on 10 trees, 4 branches from each) in different areas of Yazd province from 2006 to 2008

(O.c.c.: *Oenopia conglobata contaminata*, A.b.: *Adalia bipunctata*, C.s.: *Coccinella septempunctata*, C.u.: *Coccinella undecimpunctata*, E.n.: *Exochomus nigripennis*, H.v.: *Hippodamia variegata*, C.l.(a.): *Chrysoperla lucasina* (adult), C.l.(l.): *Chrysoperla lucasina* (larva), A.m.: *Anthocoris minki pistaciae*, A.b.: *Anystis baccarum*).

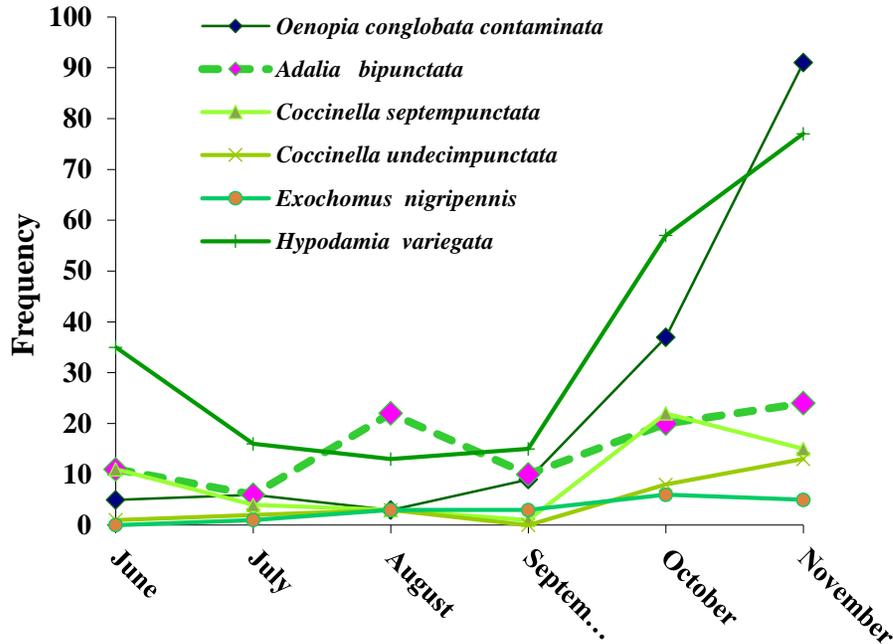


Figure 4. Mean number of ladybirds *Oenopia conglobata contaminata*, *Adalia bipunctata*, *Coccinella septempunctata*, *Coccinella undecimpunctata*, *Exochomus nigripennis* and *Hippodamia variegata* on pistachio trees (on 10 trees, 4 branches from each, in different regions) per month Yazd from 2006-2008.

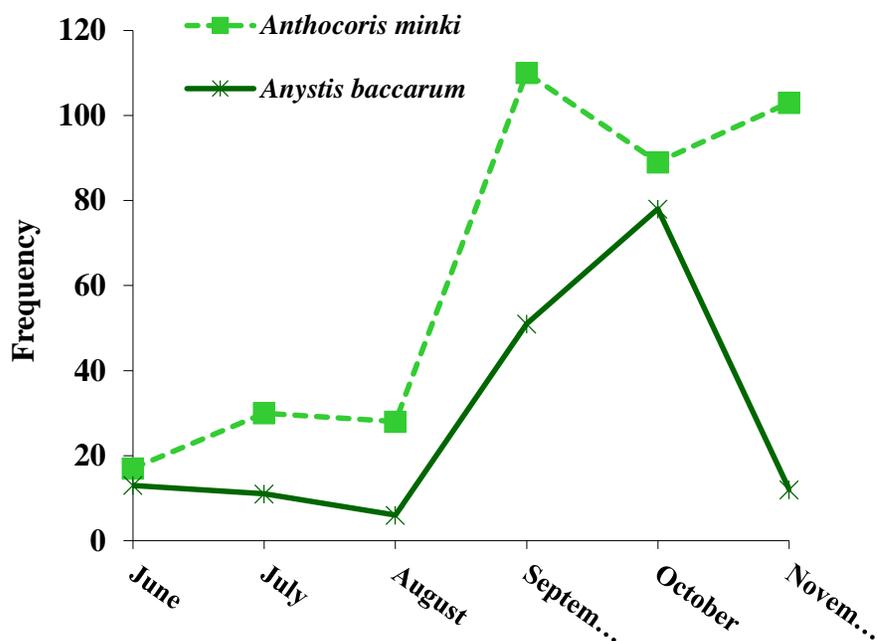


Figure 5. Mean number of predatory bug, *Anthocoris minki pistaciae* and predatory mite, *Anystis baccarum* on pistachio trees (on 10 trees, 4 branches from each) in different months in different areas of Kerman and Yazd provinces from 2006 to 2008.

Population density of parasitoid and hyperparasitoid wasp of common pistachio psylla

The Mean frequency of *P. pistaciae* wasp and hyperparasitoid wasps including *S. aphidivorus*, *M. picta*, *C. kurdjumovi*, *P. diaphorinae* and *Pachyneuron* spp in Rafsanjan pistachio plantation areas and Kerman and Yazd provinces are shown in Figures 6, 7 and 8, respectively. In these areas, the population of the

wasp *P. pistaciae* was ranked second only following the hyperparasitoid wasp *S. aphidivorus*. The frequency of *S. aphidivorus* was higher than other hyperparasitoid wasps as well as the wasp *P. pistaciae*. The frequency of hyperparasitoid *M. picta* wasp was ranked second following *S. aphidivorus* among hyperparasitoid wasps. The hyperparasitoid wasp *P. diaphorinae* had the lowest population among the hyperparasitoid wasps in pistachio plantation areas (Figures 6, 7 and 8).

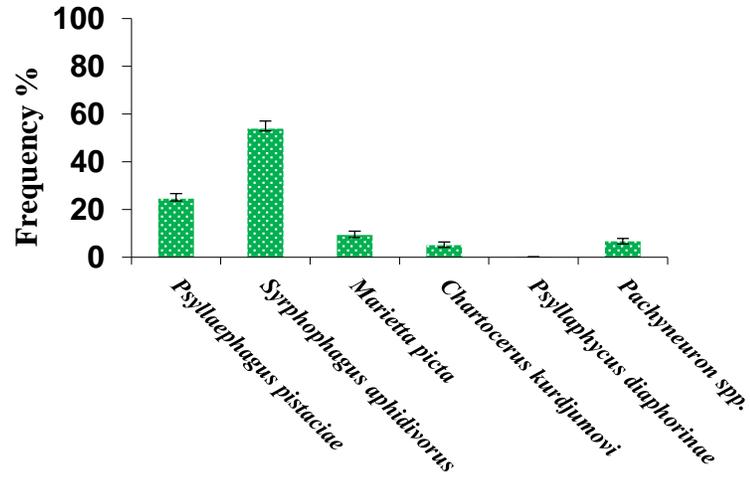


Figure 6. Mean percentage of frequency of parasitoid and hyperparasitoid wasps of common pistachio psylla in sampling of pistachio plantation areas of Rafsanjan in 2006-2007

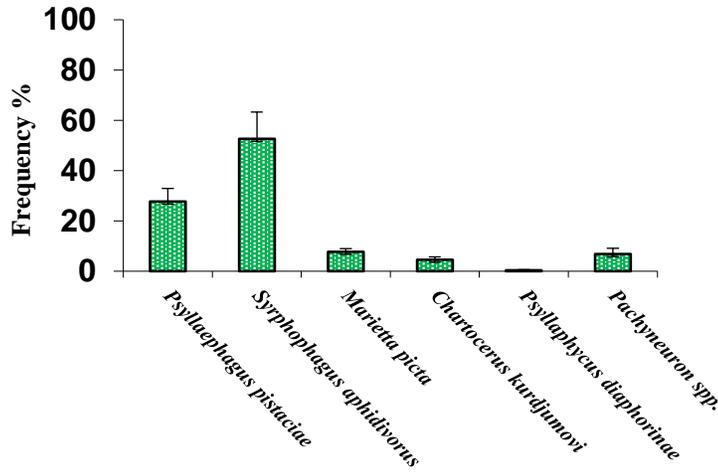


Figure 7. Mean percentage of frequency of parasitoid and hyperparasitoid wasps of common pistachio psylla in the sampling conducted in Kerman province in 2006-2008

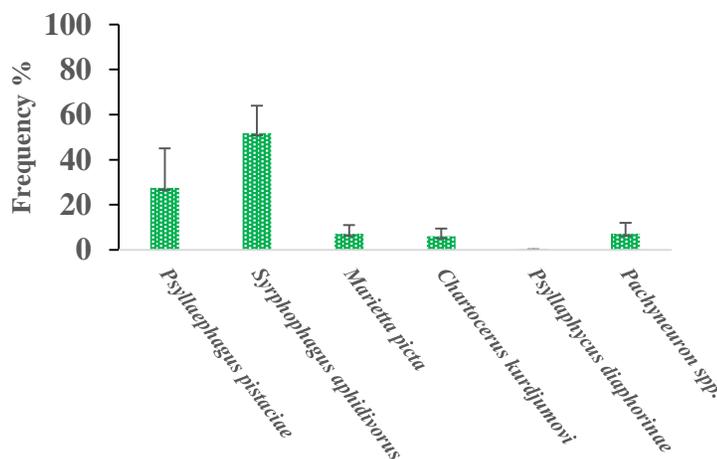


Figure 8. Mean percentage of frequency of parasitoid and hyperparasitoid wasps of common pistachio psylla in the sampling conducted in Yazd province in 2006-2008

5. Discussion

The two species of ladybirds *O. conglobata contaminata* and *A. bipunctata* are the most important species of psyllophagous species and prefer feeding from common pistachio psylla to aphids in pistachio orchards [2, 14, 15, 18, 19]. The present study has indicated that these two species of ladybirds are present in all pistachio plantation areas and *A. bipunctata* ladybird had the highest population among psyllophagous species in Rafsanjan, Ravar, Kerman and Shahr-e Babak pistachio plantation areas; it is the dominant species.

In their studies, Salehi *et al.* [17, 28] have also found that the two-spot ladybird has a high frequency in wild pistachio habitats of Kerman province and eight forms of this ladybird have been reported in trees of *Pistacia atlantica* subsp. *Mutica* Fischer & Meyer. There are other reports that this ladybird prefers hosts on trees and shrubs [29]. It has also been reported that the ladybird *A. bipunctata* prefers to lay eggs at a height of 150 cm on pistachio trees [19, 30]. The ladybird *O. conglobata contaminata* had the

highest population in Sirjan and Ardakan areas, and it was rank second in Ravar, Kerman, Zarand, Rayen and Bahadaran areas. Hassani [16] has collected as many as 9 species of ladybirds from *Pistacia atlantica* trees in his study, of which *O. conglobata contaminata* was the dominant species. Therefore, since the ladybird *O. conglobata contaminata* prefers feeding on psylla to feeding on aphids in pistachio orchards (14, 31) and since it is ranked the second place in the sampling conducted in Kerman province (in terms of population), this species is thus of high significance as a predator of pistachio psylla.

The ladybird *H. variegata* was the most population in Rayen, Bardsir and Bahadaran pistachio plantation orchards, but had the lowest population density in Rafsanjan pistachio plantation areas. The largest population of this ladybird was seen in pistachio plantation areas of Bardsir. The ladybird *H. variegata* settles on aphid-infested weeds in pistachio orchards from early spring [2, 15, 32]. Thus, it can be concluded that the population of this ladybird in

pistachio orchards is highly dependent on the weeds existing in the orchard.

The presence and population density of psyllophagous ladybirds varies on pistachio trees during in three seasons i.e. spring, summer and autumn [2]. This study has indicated that the population of most ladybirds species reaches a minimum in mid-summer and reaches a maximum in late summer and early autumn. Since psyllophagous ladybirds of pistachio orchards have a minimal population in mid-summer, it is necessary to carry out chemical control of psyllids more carefully; in early spring, late summer, and early fall, it is important to avoid indiscriminate spraying.

The wasp *P. pistaciae* is known as the primary parasitoid of common pistachio psylla. This beneficial insect has a biological dispersal in pistachio plantation areas of Iran as well as the neighboring countries of Iran [4, 6, 7, 33]. This study has also indicated that this wasp is present in all pistachio plantation areas of Kerman and Yazd provinces. This useful wasp accounted for 24.6% of the parasitoid wasp population in Rafsanjan pistachio plantation areas, and secondary parasitoid wasp accounted for the remaining 75.4%. In Kerman and Yazd provinces, to *P. pistaciae* accounted for 26% and 27.5% of the population of parasitoid wasps, respectively, and secondary parasitoid wasps accounted for the remaining number of wasps. However, in study conducted by Emami [12] in 2001, the frequency of primary parasitoid wasp *P. pistaciae* was reported to be 46%. It can be stated that some factors may have increased the population of hyperparasitoid wasps and thus reduced the population of this wasp. In this regard, the decrease in primary parasitoid efficiency of citrus psylla in Taiwan was reported to be owing to the activity of several

species of hyperparasitic wasps [34]. There are numerous reports on the effect of secondary parasitoid wasps on the reduction of primary parasitoid wasp population in different crops [35, 36, 37]. Among the factors that increase the population of hyperparasitoid wasps on common pistachio psylla is the presence and activity of several species of aphids, including *Aphis gossypii* Glover on weeds such as *Chenopodium album* Linnaeus, *Glycyrrhiza glabra* Linnaeus, and *Alhagi camelorum* Fisch is found in pistachio orchards [11]. According to Mehrnejad [2], hyperparasitoid wasps of common pistachio psylla also attack parasitic aphids on weeds and have common hosts in pistachio orchards. Thus, in early spring, the population of hyperparasitoids on weeds increases very sharply, and as the weather warms and the population of aphids decreases, this group of wasps turn into parasitic psylla nymphs, i.e. they attack *P. pistaciae* wasps [11]. Thus, weed control is necessary to increase the efficiency of *P. pistaciae* wasps and reduce the population of hyperparasitoid wasps. *P. pistaciae* wasps spends winter inside psylla mummy nymphs in pupal stage [1, 10]. Therefore, grazing of pistachio orchards in fall reduces the population of this wasp [1, 7].

According to the results of this study, several natural enemies are active on pistachio psylla and their population is significant in the early and late seasons. Therefore, in order to protection the natural enemies of this pest, it is necessary to avoid indiscriminate spraying against this pest at the beginning and end of the season. As two ladybirds i.e. *A. bipunctata* and *O. conglobata contaminata* are present in all pistachio plantation areas and since they prefer feeding on pistachio psylla to aphids in pistachio orchards, since the evaluation of the biological and ecological parameters of these two species

of ladybirds have indicated that they can be used against the psylla on a large scale [14, 18, 19, 30, 32, 41]) Therefore, it is suggested that mass rearing and evaluation of their efficiency in the control of common pistachio psylla be considered.

6. Conclusion

The results of this study indicated that several natural enemies are active on common pistachio psylla and their population at the beginning and end of the season is significant. Therefore, in order to protect of the natural enemies of this pest, it is necessary to avoid indiscriminate spraying against this insect at the beginning and end of the season. Also, to control common pistachio psylla during the season, use harmless and slightly harmful pesticides for natural enemies. Given the presence of two ladybirds

i.e. *A. bipunctata* and *O. conglobata contaminata* in all pistachio plantation areas, it is suggested that mass rearing and evaluation of the efficiency of these two ladybirds be considered in controlling common pistachio psylla.

Conflict of interest

The authors acknowledge that they have no conflict of interest in publishing this study and no significant financial support has been provided for this study (to influence the findings)

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