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Research Article

Species diversity and distribution pattern of Aphidiinae (Hym.: Braconidae) in Kerman province, Iran

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Abstract: Aphidiinae is one of the most important subfamilies of Braconidae, species of which play an important role in biological control of aphids (Hemiptera: Aphidoidea). In this study, the effects of humidity and temperature on the density and dispersal of different species of the subfamily Aphidiinae were investigated in three different ecological areas of Bardsir (Kerman province), located in southeast Iran. Specimens were collected by a hand net on field crops in three stations (Bardsir, Lalehzar and Negar) during March to November 2013. Altogether nine species belonging to five genera (*Aphidius*, *Praon, Diaeretiella, Trioxys* and *Lysiphlebus*) were recorded from these areas. The results revealed that the majority of species were found in the area with temperature between 18 to 20 °C and/ or with humidity rate of 34 to 39%, 40.1 and 50.6 percent of specimens respectively. Most of the collected members of this subfamily were found in the average temperature of 18.5 ± 1.13 °C. *Trioxys complanatus* Quilis, 1931 was the dominant species. According to biodiversity and ecological indices, species diversity and dispersal were different in the three stations. In conclusion, temperature and humidity have great impact on species diversity and distribution pattern of Aphidiinae.

Keywords: humidity, temperature, diversity, ecological indices

Introduction

Aphidiinae is one of the most important subfamilies of the Braconidae. All known species are exclusively solitary endoparasitoids of aphids (Starý, 1970; Kavallieratos *et al*., 2001, 2004; Rakhshani *et al*., 2007; Tomanović *et al*., 2003; Barahoei *et al*. 2013, 2014).

This parasitic swamps has great impacts on reduction of aphid populations (Mackauer and Starý, 1967; Starý, 1970, 1988; Kavallieratos *et al*., 2001, 2004). The Aphidiinae includes about 60 genera and 400 species worldwide (Starý, 1973; Starý, 1988; Yu *et al*., 2012). Seventy eight species and 17 genera of Aphidiinae are listed in Iran (Barahoei *et al*., 2014). Species of this subfamily play an important role in biological control of aphid pests, therefore study on their taxonomy and ecology is important and helpful (Powell 1994; Rehman and Powell, 2010).

Climatic factors, especially temperature and humidity affect the life cycles and activities of Aphidiinae. Temperature plays a key role in the regulation of population growth in different seasons (Starý, 1966; Malina and Praslikca, 2008). It also affects population dynamics of insects mainly by influencing developmental time (Campbell *et al*., 1974), longevity (Starý, 1970), mortality (Leather *et al*., 1993) and reproduction (Carriere and Boivin, 2001). In the same way, humidity has also important role in

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distribution and duration of different stages of development of insects (Noorman and Den Otter, 2002). As in other insects also in the aphids, a certain ideal developmental temperature may be experimentally recognized. The optimal temperature varies in different species. In general, it seems to be lower in the forest-type than in the steppe-type habitats that are occupied by parasitic species (Wolda, 1978b). Below a certain low temperature, the parasitoid does not develop, while higher temperatures can be detrimental. Sometimes the diapause may be also induced experimentally, if the parasitoid is transferred to a high but not lethal temperature (Brodeur and McNeil, 1989; Polgár *et al*., 1991; Christiansen-Weniger and Hardie, 1999). This is also the response of some parasitoids to high temperature in the field (Starý, 1966). Studies on the effects of environmental factors on Aphidiinae biodiversity are very few. Considering the significant regulatory effect of these parasitoids on the population of pest aphids, it is important to survey the effect of environmental factors on their efficiency as parasitoids. The aim of this study was to identify the Aphidiinae species and also to investigate the effects of microclimatic factors (humidity and temperature) on their population density and distribution patterns of this group and to record the ecological indices in their dispersal and diversity.

Materials and Methods

Study areas

Sampling was conducted during March to November 2013 in three locations including Negar, Dashtkar and Lalezar (5 sites in each location) situated around Bardsir county in Kerman province (Fig. 1), southeast Iran. Bardsir is located in semi dried, temperate to cool climatic region. The mean annual rainfall is 91.95mm. Negar covers an area of 125ha which is located about 29km southeast of Bardsir County. It is located in semi dried, temperate to cool climatic region. Dashtkar is located about 8 km southeast of Bardsir County. It has a plain situation with warm and dry to temperate climate. Lalehzar is located about 75km southeast of Bardsir County. It has a foothill plain situation with temperate and semi dried climate. Data of elevation and geographical positions of the stations are shown in table 1.

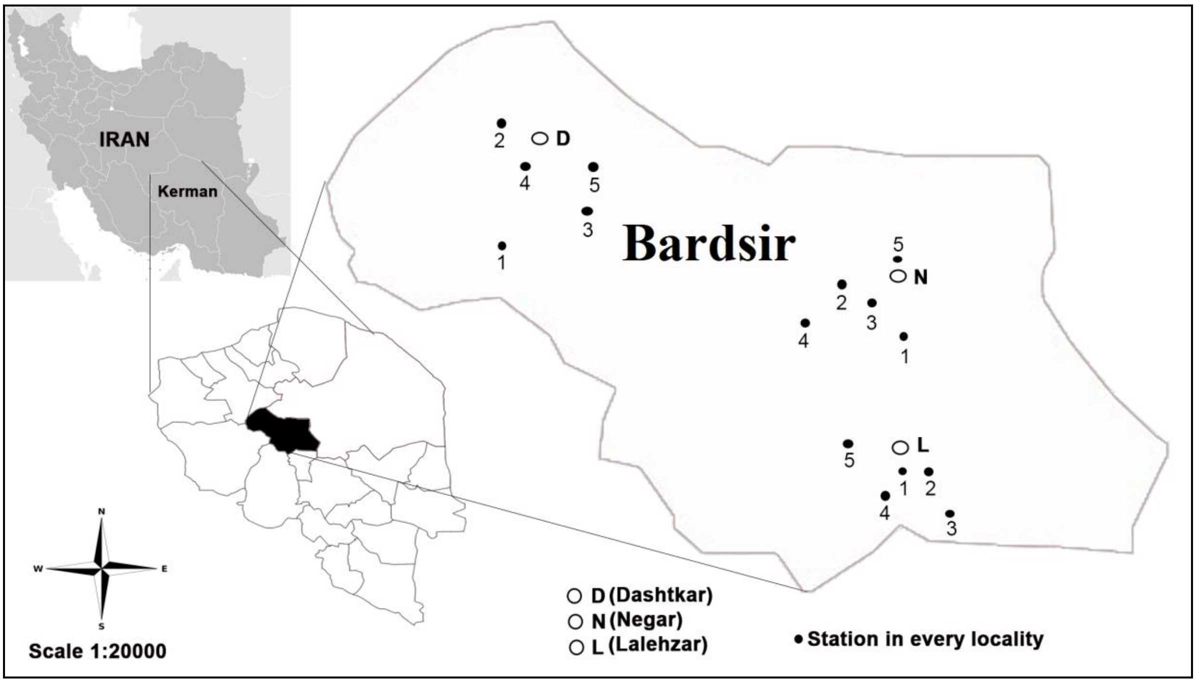

Figure 1 Map of Bardsir city indicating collecting sites.

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Table 1 Geographical positions of the stations.

Station	Position	Elevation (m)	Rainfall (mm/y)
Negar	29°51′ N 56°47′ E	2087	80.7 ± 15.3
Dashtkar	29°55′ N 56°40′ E	2111	95.91 ± 25.2
Lalehzar	29°32′ N 56°50′ E	2865	197.5 ± 17.8

Sampling

Specimens were collected by insect net from arable lands of alfalfa (the most common cultivated plant). They were captured using an aspirator to be dropped directly inside 75% ethyl alcohol for later studies. The specimens were then softened in laboratory using AXA method and mounted on triangular point card. The external morphology of specimens was examined using a Nikon SMZ800 stereomicroscope and Lumini-microscope Olympus CH-2. Specimens were identified to genus and species level based on female specimens using identification keys of Starý (1976), Rakhshani *et al*. (2012) and Kavallieratos *et al.* (2001).

Statistical Analyses

Ecological indices were calculated using PAST (PAlaeontological STatistics, version 1.81) and all indices variables analyzed using SPSS 21.00. The t-test was applied to determine if the indices of variables were different within different localities. One-way ANOVA with Duncan Post-hoc test ($P < 0.05$) was used to test the significance of indices of variables. By analyzing the recorded data (temperature and humidity) for all stations, and using the ecological indices including, Shannon-Weiner, Simpson, Margalef (Magurran, 2004; Chima *et al*., 2013), Evenness, Equitability and Fisher-alpha (Magurran, 2004; Nautiyal *et al*., 2015) the relationship between the density and climatic conditions was emerged.

Results

In this study nine species: *Aphidius smithi* Sharma and Subba Roa, 1959, *A. ervi* Haliday, 1834, *A. matricariae* Haliday, 1834, *A. uzbekistanicus* Luzhetski, 1960, *Trioxys complanatus* Quilis, 1931, *Praon volucre* (Haliday, 1833), *P. exoletum* Nees, 1811, *Lysiphlebus fabarum* (Maeshall 1896) and *Diaeretiella rapae* (M'Intosh, 1855) were identified. Majority of specimens were collected from alfalfa fields. The maximum density of specimens, 40.1 and 50.6 percent, was captured in the range of humidity 34% to 39% and temperature 18 °C to 20 °C respectively. The greatest number of specimens of this subfamily were found in the average temperature of 18.5 ± 1.13 °C. Captured species and their distribution in each station on different host plants are shown in Table 2. *Aphidius smithi* was most frequently in Negar and Lalehzar stations (23 and 19 respectively), while *Trioxys complanatus* had the most frequency in Dashtkar station (Fig. 2). The greatest numbers of Aphidiinae was observed in L_5 station ($N = 36$), followed by the N_1 station ($N = 31$) and also the least number of specimens were found in D_5, but the host plants in three locations was the same (L_5, N_1 and D_5) (Table 2).

According to environmental parameters in three stations (Fig. 3), the highest temperature and relative humidity ratio were 22 °C and 40% in sites 5 and 2 respectively in Negar, while in Dashtkar were 33 °C in site 2 and 43% in sites 4 and 5. These parameters were 19.5 °C and 39% in sites 4 and 5, respectively in Lalehzar. The lowest value of temperature and humidity were 19.5 °C and 28% in sites 3 and 5, respectively in Negar. In Dashtkar, it was 23 °C in site 1 and 33% in site 2, while in Lalehzar station it was 17.4 °C in site 1 and 31% in sites 1 and 4.

According to acquired data from ecological indices (Table 3, 4 and 5), the maximum and minimum value of each index in all sites (Negar, Dashtkar, Lalehzar) were as fallow: In Negar location (Table 3), the maximum and the minimum value of Dominance index belonged to site 5 (0.5062) and site 4 (0.2231). The value of Simpson index in all sites was about the same, the maximum and the minimum ratio observed in sites 4 and 5 were (0.7769) and (0.4938). Shannon index in all sites except site 5 (0.687), was more than site 1, and the highest value belonged to site 4 (1.642). The least ratio of Evenness index was observed in site 3 (0.8236) and the maximum was in site 5 (0.9938). Margalef index in different sites was variable, the maximum belonged to site 4 (2.083) and the minimum was in site 5 (0.4551). Equitability index in site 5 had the highest value (0.9911) and the least belonged to site 3 (0.8794).

Table 2 Parasitoid wasp species, abundance values (N) and host plants from three locations in Kerman province.

Location	Station	Host Plant	Species	N
Negar (N)	N_1	*Medicago sativa*	*Aphidius smithi, A. ervi, Trioxys complanatus, Praon volucre*	31
	N_2	*Medicago sativa*	*A. smith, P. volucr, T. complanatus, Lysiphlebus fabarum*	12
	N_3	*Medicago sativa*	*A. uzbekistanicus, A. ervi, P. volucre, Diaeretiella rapae, A. smithi*	15
	N_4	*Medicago sativa*	*A. smithi, A. ervi, D. rapae, P. volucre, A. matricariae, T. complanatus*	11
	N_5	*Medicago sativa*	*P. exoletum, T. complanatus*	9
Dashtkar (D)	D_1	*Medicago sativa*	*A. uzbekistanicus, A. smithi, P. volucre, L. fabarum*	14
	D_2	*Medicago sativa*	*P. exoletum, T. complanatus*	8
	D_3	*Medicago sativa*	*P. volucre, T. complanatus*	18
	D_4	*Mentha longifolia*	*L. fabarum, T. complanatus*	8
	D_5	*Medicago sativa*	*T. complanatus*	4
Lalehzar (L)	L_1	*Medicago sativa*	*A. smithi, A. ervi*	14
	L_2	*Triticum aestivum*	*A. matricariae, A. uzbekistanicus, P. volucre, D. rapae*	23
	L_3	*Latirus cf. sativus*	*A. smithi, A. ervi, P. volucre*	7
	L_4	*Medicago sativa*	*A. smithi, A. matricariae*	7
	L_5	*Medicago sativa*	*A. smithi, A. ervi, P. volucre, D. rapae, T. omplanatus, P. exoletum*	36

Different values were obtained in different sites for Fisher-alpha index. The maximum and minimum values were observed in sites 4 (5.403) and 5 (0.7972), respectively (Table 3).

In Dashtkar station the maximum and minimum value of Dominance index belonged to site 5 (1.00) and site 1 (0.2551) respectively, however in other sites were about the same (Table 4). The maximum and minimum ratio of Simpson index observed in site 1 (0.7449) and site 5 (0.00) and also Shannon index were in site 1 (1.376) and site 5 (0), respectively, however in the other sites had about the same ratio. The Evenness index values in all sites were almost the same, the maximum belonged to site 5 (1.00), and the minimum tosite 1 (0.9899). Margalef index was highest in site 1 (1.137) and least in site 5 (0.00). The maximum and minimum values of Equitability and Fisher_ alpha indices belonged to site 1 (0.9926), site 5 (0.00) and site 1 (1.871), site 5 (0.4279), respectively.

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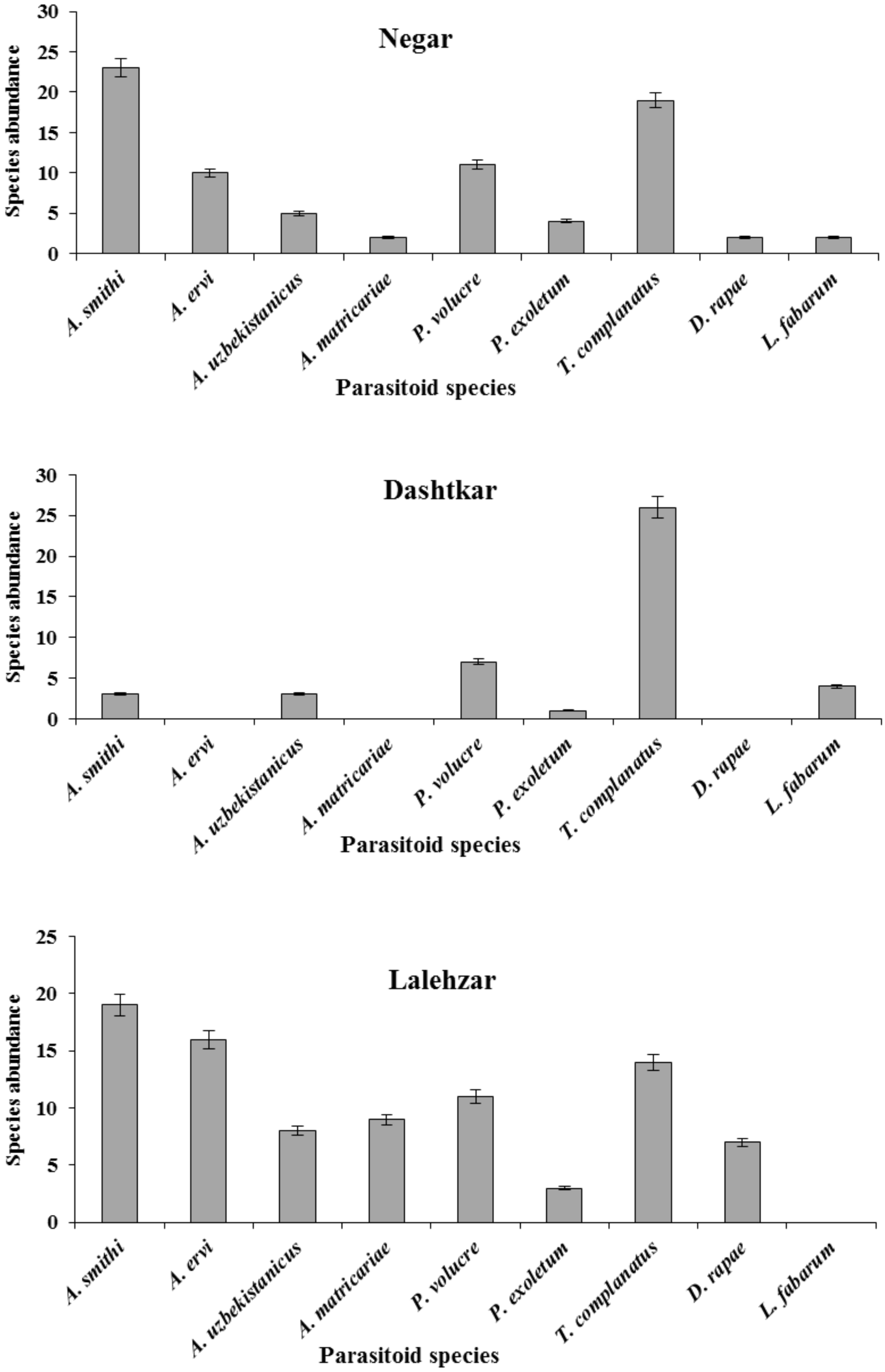

Figure 2 Abundance of parasitoid wasps in different locations (A: Negar, B: Dashtkar, C: Lalehzar).

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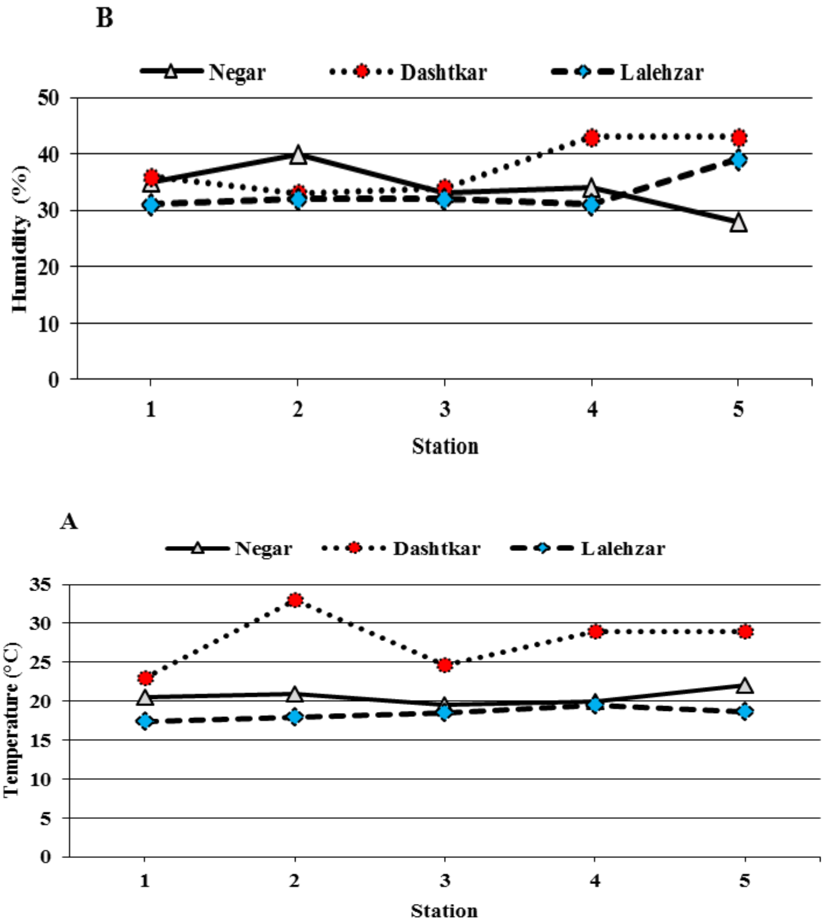

Figure 3 Environmental factors in Negar, Dashtkar and Lalehzar, (A: Temperature and B: Humidity).

In Lalehzar station, the maximum and minimum ratio for Dominance index belonged to site 4 (0.5918) and site 5 (0.2392) respectively. Simpson index belonged to site 5 (0.7608) and site 4 (0.4082), for Shannon index depended on site 5 (1.596) and site 4 (0.5983). Evenness indices in all sites were close to each other, thehighest ratio belonged to site 1 (1.00) and the least belonged to site 5 (0.8223). Margalef index in different sites showed different values. The hifhest was on site 5 (1.395) and the least belonged to site 1 (0.3789). Equitability indices in all sites were close, in site 1 (1.00) had the highest ratio and site 5 (0.8908) had the least. The highest value of Fisher_alpha index was shown in site 5 (2.056) and the least belonged to site 1 (0.6385).The highest abundance value was in Lalehzar (N = 87), followed by Negar (N = 78) and Dashtkar (44) but the highest Shanon, Margalef and Fisher-Alpha indices ratios were observed in Negar, followed by Lalehzar and Dashtkar. However the highest ratio of dominance index was in Dashtkar, Lalehzar and Negar, respectively. ANOVA analysis (Duncan, $\alpha = 0.05$) between all localities (Table 6) showed that there was significant differences between Dashtkar with Negar and Lalehzar, for some ecological indices. Dominance, Simpson and Equitability indices, abundance and temperature as in other ecological indices and humidity there were significant differences between all localities ($P < 0.05$). But the Evenness index ratio was almost similar in all localities and no significant differences were observed between the three localities (Table 6, Fig. 4).

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Table 3 Ecological indices for Negar stations.

Station	Dominance	Simpson	Shannon	Evenness	Margalef	Equitability	Fisher_alpha
N_1	0.2820	0.7180	1.321	0.9370	0.8736	0.9530	1.2230
N_2	0.3333	0.6667	1.242	0.8660	1.2070	0.8962	2.1010
N_3	0.2711	0.7289	1.415	0.8236	1.4770	0.8794	2.6260
N_4	0.2231	0.7769	1.642	0.8607	2.0850	0.9163	5.4030
N_5	0.5062	0.4938	0.687	0.9938	0.4551	0.9911	0.7972

Table 4 Ecological indices of Dashtkar stations.

Station	Dominance	Simpson	Shannon	Evenness	Margalef	Equitability	Fisher_alpha
D_1	0.2551	0.7449	1.3760	0.9899	1.1370	0.9926	1.8710
D_2	0.7813	0.2188	0.3768	0.7288	0.4809	0.5436	0.8559
D_3	0.7222	0.2778	0.4506	0.7846	0.3460	0.6500	0.5757
D_4	0.7813	0.2188	0.3768	0.7288	0.4809	0.5436	0.8559
D_5	1	0	0	1	0	0	0.4279

Table 5 Ecological indices of Lalehzar stations.

Station	Dominance	Simpson	Shannon	Evenness	Margalef	Equitability	Fisher_alpha
L_1	0.5	0.5	0.6931	1	0.3789	1	0.6385
L_2	0.2779	0.7221	1.3270	0.9422	0.9568	0.9571	1.3990
L_3	0.3878	0.6122	1.0040	0.9099	1.0280	0.9141	1.9890
L_4	0.5918	0.4082	0.5983	0.9095	0.5139	0.8631	0.9354
L_5	0.2392	0.7608	1.5960	0.8223	1.3950	0.8908	2.0560

Table 6 Ecological indices of Aphidiinae in various localities in Bardsir City.

Index	Location	Mean ± S.D.	Min.	Max.
Dominance	N	0.3229 ± 0.10a	0.22	0.51
	D	0.7078 ± 0.27b	0.26	1.00
	L	0.3988 ± 0.14a	0.24	0.59
Simpson	N	0.6769 ± 0.10a	0.49	0.78
	D	0.2921 ± 0.27b	0.00	0.74
	L	0.6007 ± 0.14a	0.41	0.76
Shanoon	N	1.2614 ± 0.35a	0.69	1.64
	D	0.5160 ± 0.51b	0.00	1.38
	L	1.0437 ± 0.42a	0.60	1.60
Evenness	N	0.8962 ± 0.06a	0.82	0.99
	D	0.8464 ± 0.13a	0.73	1.00
	L	0.9168 ± 0.06a	0.82	1.00
Margalef	N	1.2195 ± 0.61a	0.46	2.09
	D	0.4890 ± 0.41b	0.00	1.14
	L	0.8545 ± 0.41c	0.38	1.40
Equitability	N	0.9272 ± 0.04a	0.88	0.99
	D	0.5460 ± 0.35b	0.00	0.99
	L	0.9250 ± 0.05a	0.86	1.00
Fisher-Alpha	N	2.4300 ± 1.81a	0.80	5.40
	D	0.9173 ± 0.56b	0.43	1.87
	L	1.4036 ± 0.62c	0.64	2.06
Humidity	N	34.0000 ± 4.30a	28.00	40.00
	D	37.8000 ± 4.86b	33.00	43.00
	L	33.0000 ± 3.39c	31.00	39.00
Temperature	N	20.6000 ± 0.96a	19.50	22.00
	D	27.7400 ± 3.95b	23.00	33.00
	L	18.3800 ± 0.78a	17.40	19.50

Means in a column followed by the same letters for each index are not significantly different (Duncan's multiple ragne test, $p < 0.05$).

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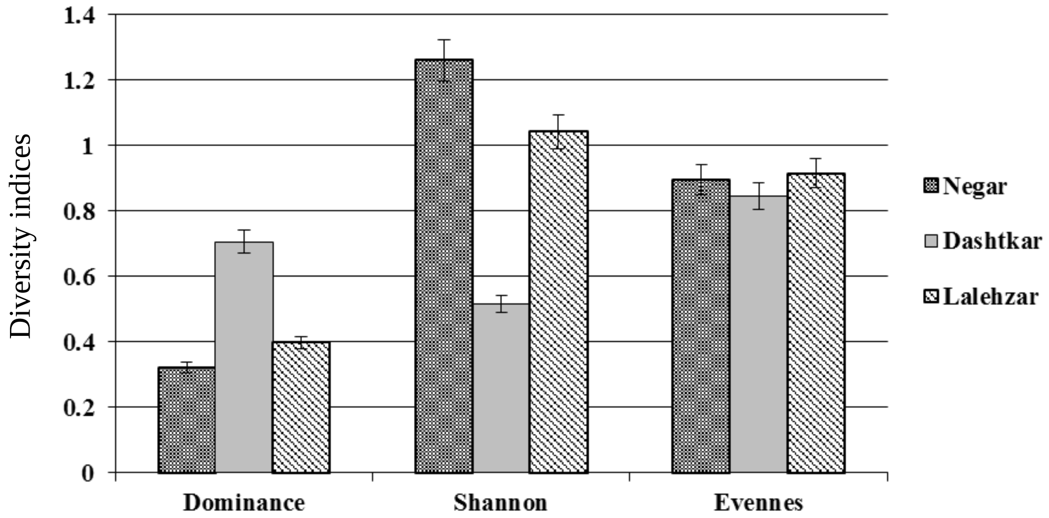

Figure 4 Diversity indices for Aphidiinae species in Negar (N = 78), Dashtkar (N = 44) and Lalehzar (N = 87).

Discussion

The maximum density of parasitoid wasps was observed in thehumidity range of 34% to 39% and temperature 18 °C to 20 °C with 40.1 and 50.6 percent, respectively. Any temperature increase or humidity decrease from this range can decrease parasitoid abundance.

In Dashtkar stations, increasing temperature up to 25 °C and high humidity (43%), caused decrease in abundance. In the two sites, 2 and 4, abundance was the same and low because in site 2 temperature was high (33 °C) and humidity was about low (33%) and also in site 4 temperature was low (29 °C) and humidity was high (43%).

Two sites 4 and 5 had the same temperature and humidity but accumulation in site 4 was more than site 5. One of the reasons could be plant cover, since *Mentha longifolia* (L.) and *Medicago sativa* L. were observed in sites 4 and 5 respectively. Nearly 50% of the insect species, especially during the immature stages, use living plant material for food (Elzinga, 1978). It is known that insect species richness correlates with plant species richness both at local and regional levels (Godfray *et al*., 1997).

In Lalehzar station, humidity had greater share than temperature in increasing the accumulation. As humidity rises to 39 %, accumulation increases. Plant covering has important role in accumulation, too. In sites 2 and 3 with the same ecological condition, site 2 (N = 23) with *Triticum aestivum* L., had more accumulation than site 3 (N = 7) with *Latirus sativus* L. These results show that it is not the habitat that determines the community structure, as the sampling area presents very specific climatic conditions and botanical and faunal composition (Jimenez-Peydro and Peris-Felipo, 2014). Both biotic and abiotic factors can be responsible for this phenomenon (Pinheiro *et al*., 2002).

In this study the most specimens were observed and collected in temperature 18.5 °C and humidity 39% (N = 36) in Lalezar followed by Negar (N = 31) in 20.5 °C and 35%. In addition, the highest value of Simpson index was observed in two sites N_4 and L_5 (Both are in optimal range respectively: 34% and 20 °C and 39% and 18.7 °C) and the lowest Simpson index was shown in two sites D_2 and D_4 (33% & 33 °C and 43% & 29 °C). So this study shows that temperature and humidity are closely related to each other and for optimal effects on dispersal and species diversity both should be in a fit range. For example in site N_5 humidity was low (28%) and temperature was high (22 °C) relatively, but they could not have a good effect on each other so, diversity and accumulation were low. Several lines of studies show that environmental factors affect insect diversity (Pinheiro *et al*. 2002, Aydagnhum, 2007). Rainfall and increasing elevation up to a normal range causes reduction in diversity and abundance, in addition to the value of temperature has different effects on insects. Food resource have positive effect on arthropod abundance (Aydagnhum, 2007).

In the present study *Aphidius uzbekistanicus* was collected from alfalafa fields in Negar, Dashtkar and Lalehzar stations. This species has not yet been collected from alfalfa fields and is considered as the most common parasitoid of the aphid, *Sitobion avenae*, in the wheat ecosystems (Rakhshani *et al*. 2008). In a study carried out by Rakhshani *et al*. (2008), *Aphidius* Nees species were the most abundant and widely distributed parasitods in wheat ecosystems of Iran. With regards to the presence of *A. uzbekistanicus* in the alfalfa fields in the present study, it seems that different parasitoids can be found in alfalfa fields using this ecosystem as a shelter or for feeding on nectar of this plant. These parasitoids may shift from adjacent plants. However in some areas the plantation of mixed alfalfa and wheat or barley is common. On the other hand some graminaceous plants may be found within alfalfa ecosystems.

Lotfalizadeh *et al*. (2014) reported that species diversity and density of Coccoidea parasitoid wasps and also their Shannon diversity index varies in different climatic conditions. In most cases the region's climate had no effect on the distribution of *Pachyneuron muscarum* (Linnaeus, 1758) which was present in two cold semi-arid climates and cold semi-arid and desert climate regions and also *Coccophagus lycimnia* (Walker, 1839) species was observed in two semi-arid climates region and also in cold semi-arid climate region (Lotfalizadeh *et al*., 2014).

Rajabi (2008) mentioned that the amount of humidity has a direct relationship to the abundance of *Eurygaster maura* L. Actually the rate of rainfall is an important factor that affects distribution of *E. maura*. Wolda (1980) gave some reasons for insect seasonality i.e., macroclimatic and microclimatic changes and variation in the availability of food resources.

Ju *et al*. (2011) indicated that increasing temperature changes the developmental time of different stages of *Corythucha ciliata* (Say, 1832) (Hemiptera: Tingidae). When the temperature was at 16 °C eggs did not hatch, and when it was 36 °C neither eggs nor nymphs developed. So, both low and high temperatures had noxious effects on the development of *C. ciliate*. Jimenez-Peydro and Peris-Felipo (2014) reported that in Opiinae (Hymenoptera: Braconidae) the number of specimens could be conditioned by a large number of factors associated with the temperatures and rainfalls characteristics, forcing the species to adapt to these strict conditions.

About the effect of climate on density, distribution and diversity of insects two hypotheses are suggested by Wolda (1978a), as most factors are climatic (humidity and temperature), seasonal variation of food and plant resources. The former suggests that population density and diversity fluctuate less in areas where the climate is more constant and predictable. The other hypothesis implies that insect density and abundance must be related to seasonal variations in the abundance of food resources and plants (Pinheiro *et al*., 2002). Previous studies conducted in some areas of the world have shown a similar increase in insect abundance in the wet areas and seasons as seen in this study for certain orders of insects. Similar to this study many insects have their highest abundance in the area with high humidity; for example, *Drosophila* in Brazil (Dobzhansky and Pavan, 1950), some insects in Costa Rica (Boinski and Scott, 1988; Boinski and Fowler, 1989), many insects in Panama (Ricklefs, 1975; Wolda, 1978b; Shelly, 1988), Granada (Tanka and Tanka, 1982), Australia (Frith and Frith, 1990), Kenya (Denlinger, 1980), Iran (Lotfalizadeh *et al.*, 2014; 2015) and Spain (Jimenez-Peydro and Peris-Felipo, 2014). Denlinger (1980) evidenced the most important factor for insect fluctuation in wet and dry seasons is rainfall and humidity ratio. Rainfall may directly affect insect populations (Janzen, 1973). It has also an indirect effect (Chaniotis *et al*., 1971). Though rainfall contributes for insect abundance and fluctuations significantly, it cannot be responsible for all of the observed fluctuations (Tanaka and Tanaka, 1982).

In conclusion, it was observed that the highest density and diversity in species of Aphidiinae were found in the average temperature of 18.5 °C and the maximum density of Aphidiinae species was for *Trioxys complanatus*. According to diversity indices, species diversity and dispersal were different in all stations. According to this study temperature and humidity were effective on the distribution, abundance and diversity of parasitoid wasps.

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الگوی پراکنش و تنوع گونه‌ای زیرخانواده Aphidiinae (Hym.: Braconidae) در استان کرمان، ایران

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چکیده: زیرخانواده‌ی Aphidiinae یکی از مهم‌ترین زیرخانواده‌های خانواده Braconidae می‌باشد که نقش مهمی در کنترل بیولوژیک شته‌ها دارد (Hemiptera: Aphidoidea). در این پژوهش اثر رطوبت و دما بر تراکم و پراکندگی گونه‌های مختلف از زیرخانواده Aphidiinae، در ۳ ناحیه اکولوژیک متفاوت در منطقه بردسیر استان کرمان مورد بررسی قرار گرفت. نمونه‌ها به‌وسیله تور دستی از ۳ ایستگاه (بردسیر، لاله‌زار و نگار) از اسفند ماه ۱۳۹۳ تا مهر ماه ۱۳۹۲ جمع‌آوری گردید. در مجموع ۹ گونه متعلق به ۵ جنس (*Aphidius, Praon, Diaeretiella, Trioxys* and *Lysiphlebus*) از این نواحی جمع‌آوری و ثبت شد. براساس نتایج، بیش‌ترین تعداد نمونه‌ها در نواحی با بازه دمایی ۱۸-۲۰ درجه سلسیوس و یا رطوبت ۳۴-۳۹ درصد به‌ترتیب به‌میزان ۴۰/۱ و ۵۰/۶ درصد یافت شد. اکثر نمونه‌ها در میانگین دمای ۱/۱۳ ± ۱۸/۵ جمع‌آوری شدند. گونه‌ی *Trioxys complanatus* Quilis، گونه غالب در بین سایر گونه‌ها بود. براساس شاخص‌های تنوع زیستی و اکولوژیکی، تنوع و پراکندگی گونه‌ها در مناطق مختلف متفاوت بود. به‌طورکلی دما و رطوبت تأثیر بسزایی بر تنوع گونه‌ای و الگوی پراکنش زیرخانواده Aphidiinae دارند.

واژگان کلیدی: رطوبت، دما، تنوع، شاخص‌های اکولوژیکی، پارازیتویید شته، کنترل بیولوژیک

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