

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 swarms 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

Handling Editor: George Japoshvili

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Received: 9 June 2016, Accepted: 26 May 2017

Published online: 14 July 2017

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. Lalezar 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.

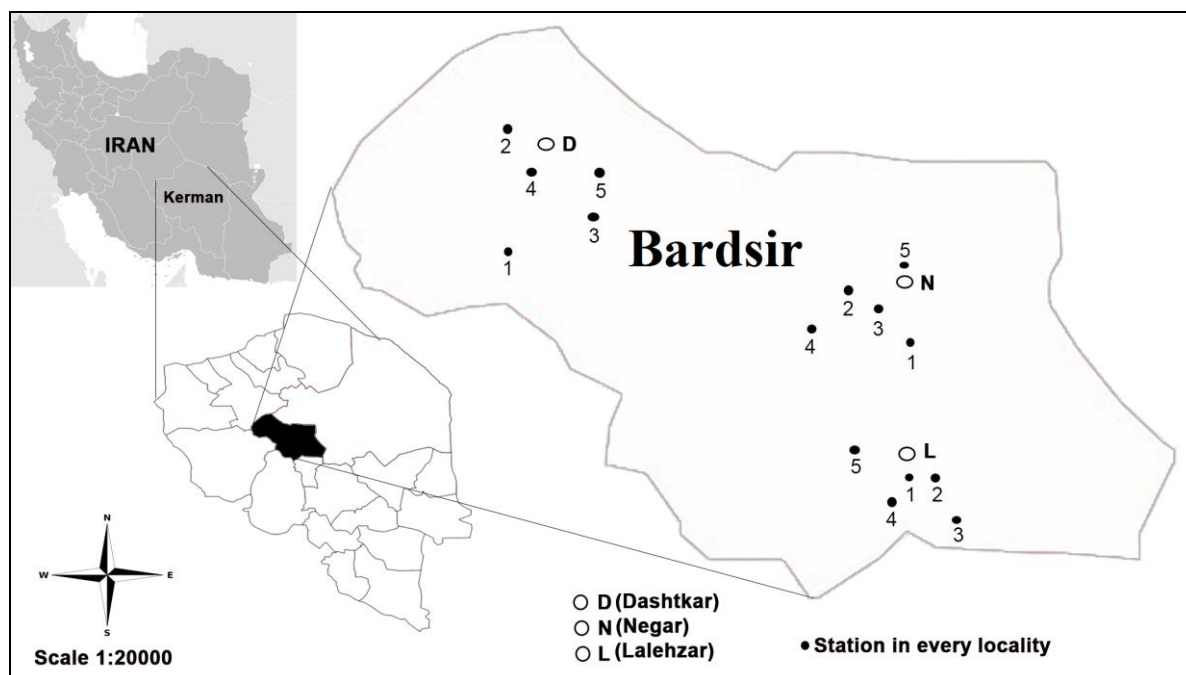


Figure 1 Map of Bardsir city indicating collecting sites.

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 L₅ station (N = 36), followed by the N₁ station (N = 31) and also the least number of specimens were found in D₅, but the host plants in three locations was the same (L₅, N₁ and D₅) (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 follow: 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	<i>Medicago sativa</i>	<i>Aphidius smithi</i> , <i>A. ervi</i> , <i>Trioxys complanatus</i> , <i>Praon volucre</i>	31
	N ₂	<i>Medicago sativa</i>	<i>A. smithi</i> , <i>P. volucre</i> , <i>T. complanatus</i> , <i>Lysiphlebus fabarum</i>	12
	N ₃	<i>Medicago sativa</i>	<i>A. uzbekistanicus</i> , <i>A. ervi</i> , <i>P. volucre</i> , <i>Diaeretiella rapae</i> , <i>A. smithi</i>	15
	N ₄	<i>Medicago sativa</i>	<i>A. smithi</i> , <i>A. ervi</i> , <i>D. rapae</i> , <i>P. volucre</i> , <i>A. matricariae</i> , <i>T. complanatus</i>	11
	N ₅	<i>Medicago sativa</i>	<i>P. exoletum</i> , <i>T. complanatus</i>	9
Dashtkar (D)	D ₁	<i>Medicago sativa</i>	<i>A. uzbekistanicus</i> , <i>A. smithi</i> , <i>P. volucre</i> , <i>L. fabarum</i>	14
	D ₂	<i>Medicago sativa</i>	<i>P. exoletum</i> , <i>T. complanatus</i>	8
	D ₃	<i>Medicago sativa</i>	<i>P. volucre</i> , <i>T. complanatus</i>	18
	D ₄	<i>Mentha longifolia</i>	<i>L. fabarum</i> , <i>T. complanatus</i>	8
	D ₅	<i>Medicago sativa</i>	<i>T. complanatus</i>	4
Lalehzar (L)	L ₁	<i>Medicago sativa</i>	<i>A. smithi</i> , <i>A. ervi</i>	14
	L ₂	<i>Triticum aestivum</i>	<i>A. matricariae</i> , <i>A. uzbekistanicus</i> , <i>P. volucre</i> , <i>D. rapae</i>	23
	L ₃	<i>Latirus cf. sativus</i>	<i>A. smithi</i> , <i>A. ervi</i> , <i>P. volucre</i>	7
	L ₄	<i>Medicago sativa</i>	<i>A. smithi</i> , <i>A. matricariae</i>	7
	L ₅	<i>Medicago sativa</i>	<i>A. smithi</i> , <i>A. ervi</i> , <i>P. volucre</i> , <i>D. rapae</i> , <i>T. complanatus</i> , <i>P. exoletum</i>	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 to site 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.

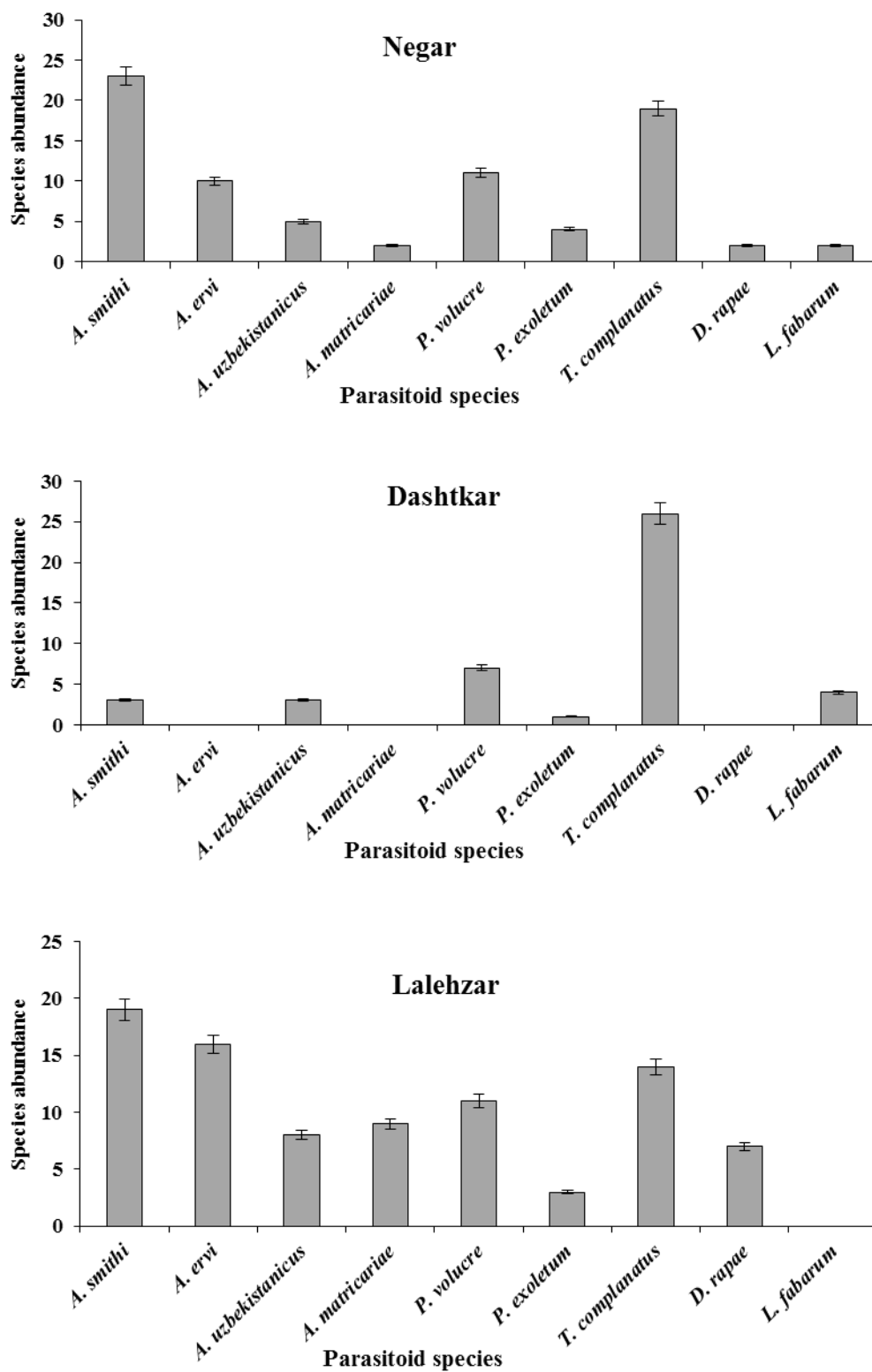


Figure 2 Abundance of parasitoid wasps in different locations (A: Negar, B: Dashtkar, C: Lalehzar).

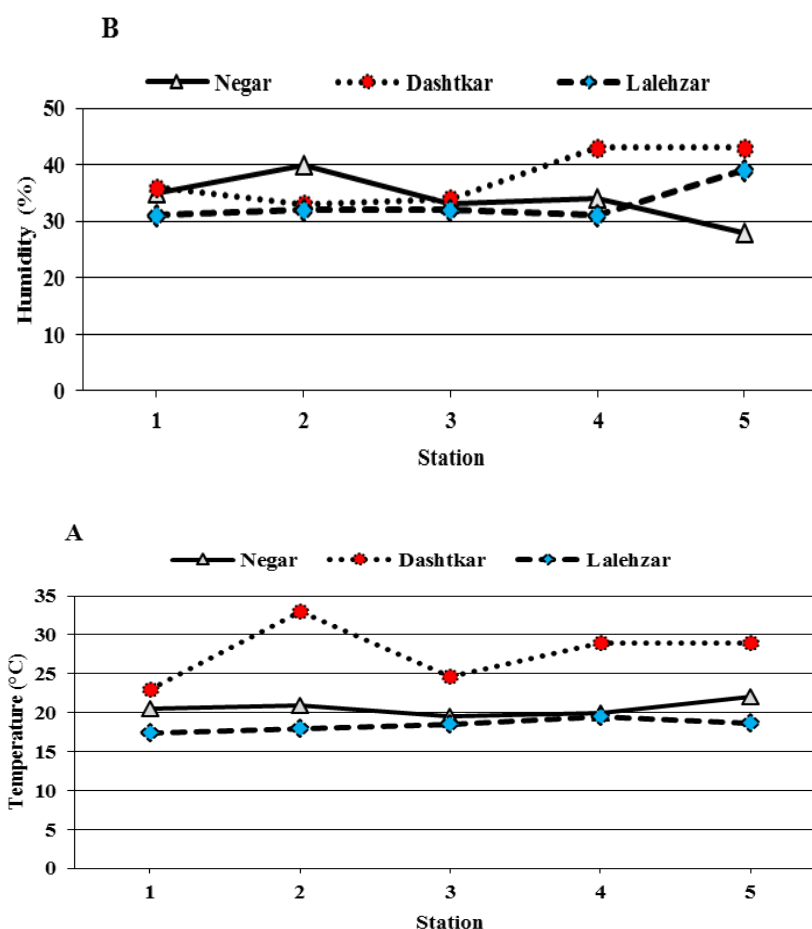


Figure 3 Environmental factors in Negar, Dashtkar and Lalehzar, (A: Temperature and B: Humidity).

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, the highest 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 highest 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 Shannon, 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).

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

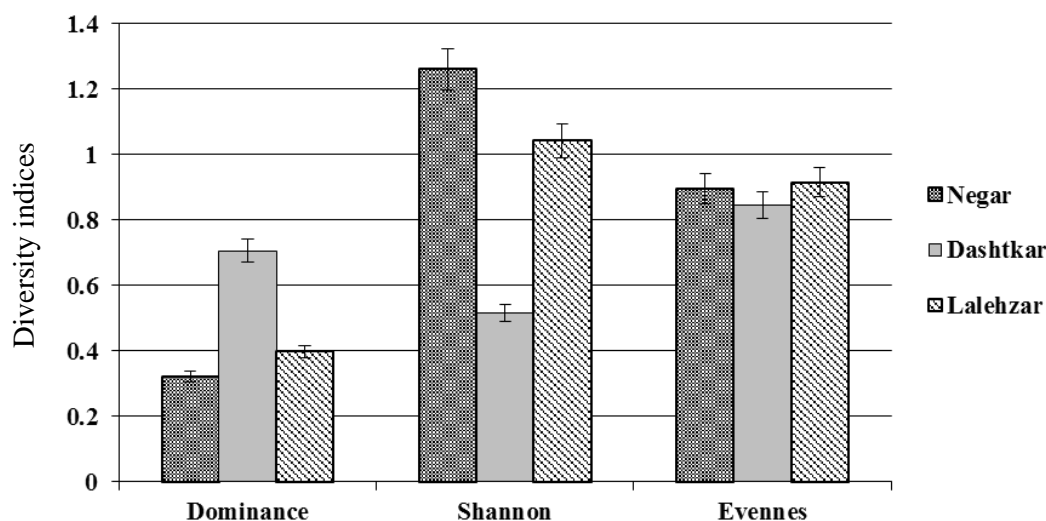


Figure 4 Diversity indices for Aphidiinae species in Negar (N = 78), Dashtkar (N = 44) and Lalehzar (N = 87).

Discussion

The maximum density of parasitoid wasps was observed in the humidity 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 N₄ and L₅ (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 D₂ and D₄ (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 N₅ 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, Aydagnum, 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 (Aydagnum, 2007).

In the present study *Aphidius uzbekistanicus* was collected from alfalfa 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 parasitoids 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 (Chanotis *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.

Acknowledgements

This research was supported by the Department of Biology, Shahid Bahonar University of Kerman, Iran, which is greatly appreciated. The authors are grateful to Mr. H. Barahoei for identification and confirmation of the species.

References

- Aydagnhum, T. 2007. Study on Insect Diversity of Menagesha Forest and Bihera Tsige Public Park in wet and dry seasons using sweeping net. Msc Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 61 pp.
- Barahoei, H., Rakhshani, E., Madjdzadeh, S. M., Alipour, A., Taheri, S., Nader, E., Bogdanović, A. M., Petrović-Obradović, O., Starý, P., Kavallieratos, N. G. and Tomanović, Ž. 2013. Aphid parasitoid species (Hymenoptera: Braconidae: Aphidiinae) of central submountains of Iran. *North-Western Journal of Zoology*, 9 (1): 70-93.
- Barahoei, H., Rakhshani, E., Nader, E., Starý, P., Kavallieratos, N. G., Tomanović, Ž. and Mehrparvar, M. 2014. Checklist of Aphidiinae parasitoids (Hymenoptera: Braconidae) and their host aphid associations in Iran. *Journal of Crop Protection*, 3 (2): 199-232.
- Boinski S., Fowler, N. L. 1989. Seasonal patterns in a tropical lowland forest. *Biotropica*, 21: 223-233.
- Boinski, S. and Scott, P. E. 1988. Association of birds with monkeys in Costa Rica. *Biotropica*, 20: 136-143.
- Brodeur, J., McNeil, J. N. 1989. Biotic and abiotic factors involved in diapause induction of the parasitoid, *Aphidius nigripes* (Hymenoptera: Aphidiidae). *Journal of Insect Physiology* 35 (12): 969-974.
- Campbell, A., Fraser, B. D., Gilbert, N., Gutierrez, A. P. and Mackauer, M. 1974. Temperature requirements of some aphids and their parasites. *Journal of Applied Ecology*, 11: 431-438.
- Carriere, Y. and Boivin, G. 2001. Constraints on the evolution of thermal sensitivity of foraging in *Trichogramma*: genetic trade-offs and plasticity in maternal selection. *Journal of American Naturalist*, 157: 570-581.
- Chanotis, B. N., Neely, J. M., Correa, M. A., Tesh, R. B. and Johnson, K.M. 1971. Natural population dynamics of phlebotomine sand flies in Panama. *Journal of Medical Entomology*, 8: 339-352.
- Chima, U. D., Omokhua, G. E. and Iganibo-Beresibo E. 2013. Insect species diversity in fragmented habitats of the University of Port Harcourt, Nigeria. *ARPN Journal of Agricultural and Biological Science*, 8 (2): 160-168.
- Christiansen-Weniger, P. and Hardie, J. 1999. Environmental and physiological factors for diapause induction and termination in the aphid parasitoid, *Aphidius ervi* (Hymenoptera: Aphidiidae). *Journal of Insect Physiology*, 45 (4): 357-364.
- Denlinger, D. L. 1980. Seasonal and annual variation of insect abundance in the Nairobi National Park, Kenya. *Biotropica*, 12: 100-106.
- Dobzhansky, T. and Pavan, C. 1950. Local and seasonal variations in relative frequencies of species of *Drosophila* in Brazil. *Journal of Animal Ecology*, 19: 1-14.

- Elzinga, R. J. 1978. Fundamentals of Entomology. Prentice-Hall, Inc. New Jersey.
- Frith, D., Frith, C. 1990. Seasonality of litter invertebrate populations in an Australian upland tropical rain forest. *Biotropica*, 22: 181-190.
- Godfray, H. C., Lewis, O. T. and Memmot, J. 1997. Studying insect diversity in the tropics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 354: 1811-1824.
- Janzen, D. H. 1973. Sweep samples of tropical foliage insects, vegetation types, elevation, time of day and insularity. *Ecology*, 54: 687-708.
- Jimenez-Peydro, R. and Peris-Felipo, F. J. 2014. Diversity and Community Structure of Opiinae (Hymenoptera, Braconidae) in Mediterranean Landscapes of Spain. *Journal of Entomological Research Society*, 16: 75-85.
- Ju, R. T., Wang, F. and Li, B. 2011. Effects of temperature on the development and population growth of the sycamore lace bug, *Corythucha ciliata*. *Journal of Insect Science*, 11:16
- Kavallieratos, N. G., Lykouressis, D. P., Sarlis, G. P., Stathas, G. J., Sanchis-Segovia, A. and Athanassiou, C. G. 2001. The Aphidiinae (Hymenoptera: Ichneumonoidea: Braconidae) of Greece. *Phytoparasitica*, 29: 306-340.
- Kavallieratos, N. G., Tomanovic, Z., Starý, P., Athanassiou, C. G., Sarlis, G. P., Petrovic, O., Niketic, M. and Veroniki, M. A. 2004. A survey of aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) of Southeastern Europe and their aphid-plant associations. *Journal of Applied Entomology and Zoology*, 39: 527-563.
- Leather, S. R., Walters, K. F. A. and Bale, J. S. 1993. *The Ecology of Insect Overwintering*. Cambridge University Press, Cambridge.
- Lotfalizadeh, H., Pourhaji, A. and Zargaran, M. R. 2015. Hymenopterous parasitoids (Hymenoptera: Braconidae, Eulophidae, Pteromalidae) of the alfalfa leafminers in Iran and their diversity. *Far Eastern Entomologist*, 288: 1-24.
- Lotfalizadeh, H., Zargaran, M. R., Taghizadeh, M. 2014. Species diversity of Coccoidea parasitoids wasps (Hym.: Chalcidoidea) in the northern parts of East-Azərbayjan province, Iran. *North-Western Journal of Zoology*, 10: 60-66.
- Mackauer, M. and Starý, P. 1967. Index of entomophagous insects. In Delucchi V. and Remaudiere G. (Eds): *Hymenoptera: Ichneumonoidea, World Aphidiidae*. Le Francois, Paris.
- Magurran, A. 2004. *Measuring Biological Diversity*. Blackwell, Cornwall, UK.
- Malina, R. and Praslicka, J. 2008. Effect of temperature on the developmental rate, longevity and parasitism of *Aphidius ervi* Haliday (Hymenoptera: Aphidiidae). *Plant Protection Science*, 44: 19-22.
- Nautiyal, S., Bhaskar, K., Imran Khan, Y. D. 2015. Biodiversity of Semiarid Landscape Baseline Study for Understanding the Impact of Human Development on Ecosystems, Springer, AG Switzerland, pp. 13-37.
- Noorman, N. and Den Otter, C. J. 2002. Effects of relative humidity, temperature, and population density on production of cuticular hydrocarbons in housefly *Musca domestica* L. *Journal of Chemical Ecology*, 28 (9): 25-33.
- Pinheiro, F., Diniz, I. R., Coelho, D. and Bandeira, M. P. S. 2002. Seasonal pattern of insect abundance in the Brizilian Cerrod. *Austral. Ecology*, 27: 132-136.
- Polgár, L., Mackauer, M., Völk, W. 1991. Diapause induction in two species of aphid parasitoids: The influence of aphid morph. *Journal of Insect Physiology*, 35 (12): 969-974.
- Powell, W. 1994. Nemeč and Starý's "Population diversity centre" hypothesis for aphid parasitoids re-visited. *Norwegian Journal of Agricultural Science Supplement*, 16: 163-169.
- Rajabi, G. 2008. *Insect Ecology Applied and Considering the Conditions of Iran*. Agriculture Ministry of Iran, Tehran, (In Persian).

- Rakhshani, E., Kazemzadeh, S., Starý, P., Barahoie, H., Kavallieratos, N. G., Četković, A., Popović, A., Bodlah, I. and Tomanović, Ž. 2012. Parasitoids (Hymenoptera: Braconidae: Aphidiinae) of northeastern Iran: Aphidiine-aphid-plant associations, key and description of a new species. *Journal of Insect Science*, 12: 143.
- Rakhshani, E., Talebi, A. A., Manzari, S., Tomanović, Ž., Starý, P. and Rezwani, A., 2007. Preliminary taxonomic study of the genus *Praon* (Hymenoptera: Braconidae: Aphidiinae) and its host associations in Iran. *Journal of Entomological Society of Iran* 26 (2): 19-34.
- Rakhshani, E., Tomanović, Ž., Starý, P., Talebi A. A., Kavallieratos, N. G., Zamani, A. A and Stanković, S. 2008. Distribution and diversity of wheat aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) in Iran. *European Journal of Entomology*, 105: 863-870.
- Rehman, A. and Powell, W. 2010. Host selection behaviour of aphid parasitoids (Aphidiidae: Hymenoptera). *Journal of Plant Breeding and Crop Science*, 2: 299-311.
- Ricklefs, R. E. 1975. Seasonal occurrence of night-flying insects on Barro Colorado Island, Panama Canal Zone. *Journal of New York Entomological Society*, 83: 19-32.
- Shelly, T. 1988. Relative abundance of day-flying insects in trefall gaps vs shaded understory in a neotropical forest. *Biotropica*, 20: 114-119.
- Starý, P. 1966. *Aphid Parasites of Czechoslovakia. A Review of the Czechoslovak Aphidiidae (Hymenoptera)*. 1st edition, Springer.
- Starý, P. 1970. *Biology of Aphid Parasites (Hym. Aphidiidae) with respect to Integrated Control*. Dr. W. Junk, The Hague.
- Starý, P. 1973. A review of *Aphidius*-species (Hymenoptera: Aphidiidae) of Europe. *Annotationes Zoologicae et Botanicae*, 84: 1-85.
- Starý, P. 1976. *Aphid Parasites (Hymenoptera, Aphidiidae) of the Mediterranean area*. Transactions of the Czechoslovak Academy of Sciences, Series of Mathematical and Natural Sciences Dr. W. Junk b. v., The Hague, 86 (2): 1-95.
- Starý, P. 1988. Aphidiidae. In: Minks, A. K. and Harewijn, P. (Eds.), *Aphids, Their Biology, Natural Enemies and Control*. Elsevier Publisher, Amsterdam.
- Tanka, L. K. and Tanka, S. K. 1982. Rainfall and seasonal changes in arthropod abundance on tropical Oceanic Island. *Biotropica*, 14: 114-123.
- Tomanović, Ž., Kavallieratos, N. G., Athanassiou, C. G., Petrović, O., 2003. A review of the West Palearctic aphidiines (Hymenoptera: Braconidae: Aphidiinae) parasitic on *Uroleucon* spp., with the description of a new species. *Annales de la Societe Entomologique de France* 39 (4): 343-353.
- Wolda, H. 1978a. Seasonal fluctuations in rainfall, food and abundance of tropical insects. *Journal of Animal Ecology*, 47: 369-381.
- Wolda, H. 1978b. Fluctuations in abundance insects. *Journal of American Naturalist*, 112: 1017-1045.
- Wolda, H. 1980. Seasonality of tropical insects. *Journal of Animal Ecology*, 49: 277-290.
- Yu, D. S., van Achterberg, C. and Horstmann, K. 2012. *World Ichneumonidea 2011. Taxonomy, Biology, Morphology and Distribution*. Taxapad (Scientific Names for Information Management), Interactive Catalogue, Ottawa.

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

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دریافت: ۱۷ خرداد ۱۳۹۵؛ پذیرش: ۵ خرداد ۱۳۹۶

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 $18/5 \pm 1/13$ 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. به‌طور کلی دما و رطوبت تأثیر بسزایی بر تنوع گونه‌ای و الگوی پراکنش زیرخانواده Aphidiinae دارند.

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