J. Entomol. Res. Soc., 18(1): 99-111, 2016 *ISSN:1302-0250*

Species Diversity of Chalcidoidea (Hymenoptera) in the Rice Fields of Iran

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ABSTRACT

Rice (*Oryza sativa* L.) is one of the economical crops of northern Iran. It attacks by different groups of pests. Various species of the superfamily Chalcidoidea (Hymenoptera) are parasitoids on different stages of these pests. A study was conducted in the rice fields of eastern Guilan province during 2011-2012. A total of 16 parasitic wasps were collected and identified that include one Aphelinidae (*Aphelinus flaviventris* Kurdjumov, 1913); one Chalcididae (*Brachymeria tibialis* (Walker, 1834)*); four Encyrtidae (*Anagyrus diversicornis* (Howard, 1894)*, *Syrphophagus ariantes* (Walker, 1837), *Ooencyrtus telenomicida* (Vassiliev, 1904)*, *Ooencyrtus pityocampae* (Mercet, 1921)*); four Eulophidae (*Aprostocetus mycerinus* (Walker, 1839), *Aprostocetus deobensis* (Graham, 1987)*, *Elasmus phthorimaeae* (Ferriere, 1947)*, *Hemiptarsenus* sp.); one Eupelmidae (*Anastatus interruptus* (Nikol'skaya, 1952)*); two Mymaridae (*Gonatocerus longicornis* Nees, 1834*, Mymar taprobanicum* Ward, 1875*); two Pteromalidae (*Callitula ferrierei* Bouček, 1964), *Conomorium amplum* (Walker, 1835)) and one Trichogrammatidae (*Trichogramma* sp.). Two species, *Syrphophagus ariantes* and *Anastatus interruptus* are new records for Iranian fauna and marked species with an asterisk are new for rice field fauna. In this study, the species diversity indices of the identified wasps were calculated. The maximum Shannon index was calculated in Lashkajan (1.64) and Zard-Ab Mahalleh (1.45), and the minimum Shannon index was in Rahim-abad and Layalestan (with only one species). The lowest and highest frequency of superfamily Chalcidoidea was in Lahijan (34) and Roodsar (45), respectively.

Key words: Parasitoid, Fauna, New record, Ecology, Index, Frequency, Association.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the main agricultural crops in the north of Iran (southern coast of Caspian Sea). Insect fauna of this plant has not been studied in detail, except some economical important rice pests such as *Chilo suppressalis* Walker (Lep.: Pyralidae), *Pseudaletia unipuncta* Haworth (Lep.: Noctuidae), *Naranga aenescens* Moore (Lep:. Noctuidae), *Hydronomus sinuaticollis* Faust (Col:. Curculionidae), *Ephydra afghanica* Dahl (Dip.: Ephydridae) (Behdad, 2000) and *Cicadella viridis* (L.) (Hem.: Cicadellidae) (Khanjani, 2008). These pests highly damage the strategic crop annually.

Numerous natural enemies such as parasitoid wasps attack these pests. But chemical control is one of the most common control methods destroying a wide range of natural enemies and agroecosystems. Overuse of chemical pesticides can reduce biodiversity in adjacent agro-natural ecosystems especially fauna of the superfamily Chalcidoidea as one of the largest groups of biocontrol agents (Behdad, 2000).

Marashi (1991), introduced natural enemies of rice pests, of which five families of the superfamily Chalcidoidea were presented as egg parasitoids of rice pests especially Cicadellidae and Fulgoridae (Hemiptera). With aim to find economic parasitoids appropriate in biological control programs against rice pest, Narendran *et al.* (2005) studied fauna of Chalcidoidea in rice fields in south-eastern India and described a new genus of Eulophidae, *Kiggaella* Narendran.

In a study of the parasitoids of various products (including rice) in India, 62 species belonging to 4 families were reported that two families include the superfamily Chalcidoidea (Subharani *et al.,* 2010). They studied also biodiversity indices, host range, growth period, taxonomic detail and the highest activity of 36 species.

Barrion *et al.* (2010) studied Arthropod biodiversity in rice ecosystems in China by examining 816 specimens of 36 species belonging to 11 families of the superfamily Chalcidoidea. This study revealed a high diversity of parasitoids of the family Trichogrammatidae. During study of rice whitefly, *Leptocoria* (Hem.: Aleyrodidae) in the fields at South Sumatra, 27 species belonging to the genus *Ooenocyrtus* (Chalcidoidea: Encyrtidae) were reported as egg parasitoid (Riyanto *et al.*, 2010).

Gurr *et al*. (2012) during study of *Cnaphalocrocis medinalis* Guenée (Lep.: Pyralidae) in rice fields of Asia, present its parasitoids of the superfamily Chalcidoidea. Recently authors reported two chalcidoid wasps (Hymenoptera) from rice field of Iran (Bayegan *et al.,* 2014a, b; 2015). The Chalcidoidea Database listed 173 species belonging to 10 families of the superfamily Chalcidoidea from rice fields of the world (Noyes, 2015).

No study has been done on the species diversity of the superfamily Chalcidoidea in rice fields, therefore, the present study aimed to investigate the species diversity of superfamily Chalcidoidea in the rice fields of the east of Guilan province.

MATERIALS AND METHODS

Sampling

The investigations and collection of material was conducted in different localities (Fig.1), between March-September 2011-2012 in rice fields in eastern parts of Guilan province, North of Iran (on the coast of the Caspian sea). Nine points in three locations were selected to assess the parasitoid species exploiting rice (Table 1). Specimens were collected via Malaise traps set up in the rice fields. The specimens were extracted from the traps and sorted weekly, transferred to ethyl alcohol 70%. The dried specimens were card mounted and labeled. All specimens are deposited in

the insect collection of the Department of Plant Protection, East-Azarbaijan Research Center for Agriculture and Natural Resources, Tabriz, Iran.

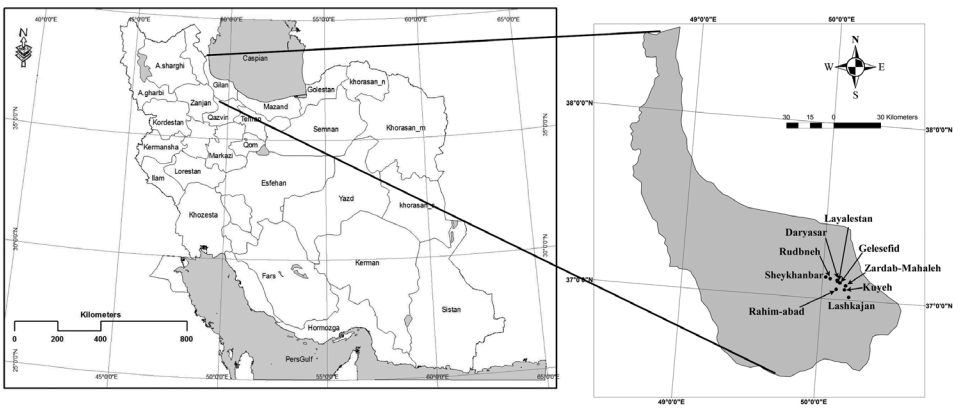

Fig. 1. Map of sampling areas in East of Guilan province (Roodsar, Langroud and Lahijan).

Table 1. Sampling localities in the rice fields of Eastern of Guilan province.

Sampling sites	Altitude (m)	Geographical Situation N	E
Kuyeh	10	37°05'85"	50°16'14"
Lashkajan	22	38°51'33"	94°47'94"
Rahim- abad	57	39°21'45"	70°57'24"
Zardab- mahalleh	14	37°08'05"	50°16'75"
Daryasar	7	37°10'71"	50°10'80"
Gelesefid	5	37°09'73"	50°12'44"
Layalestan	14	37°10'63"	50°10'93"
Rudbneh	10	37°10'63"	50°05'41"
Sheykhanbar	10	37°12'29"	50°02'21"

Species identification

Identification of specimens to genus and species level was done by second author based on available keys (Bouček, 1964; Graham, 1987, 1992, 1995; Kalina, 1981; Doutt and Viggiani, 1968; Medvedev, 1988; Springate and Noyes, 1990; Triapitsyn and Berezovskiy, 2001; Zhu and Huang, 2003; Japoshvili, 2007; Lotfalizadeh *et al*., 2012).

Statistical analysis

The Shannon-Weiner diversity index was calculated using the following formula:

$$\text{Shannon's H':} \quad H' = -\sum_{i=1}^{N_0} [p_i * \log p_i]$$

Where *Pi* is the proportion of the total number of individuals belonging to a morphotype, and N_o is the total number of morphotypes seen in that sample. Also, The Simpson's diversity index was calculated using the following formula:

$$\text{Simpson's D:} \quad D = 1 - \sum_{i=1}^{N} \frac{n_i(n_i - 1)}{N(N-1)}$$

Where n_i is the number of individuals of a particular morphotype and *N* is the total number seen in the sample (Magurran, 2004). Diversity indices like the Shannon's entropy ("Shannon-Wiener index") and the Gini-Simpson index are not in themselves diversities. The number of equally-common species required to impact a particular value to an index is called the "effective number of species". This is the true diversity of the community. Converting indices to true diversities gives them a set of common behaviors and properties. After conversion, diversity is always measured in units of the number of species (Jost, 2006). Conversion of common indices to true diversities can be achieved as described in the following term:

Index x		Diversity in terms of x	Diversity in terms of p_i
Shannon entropy:	$x \equiv -\sum_{i=1}^{S} p_i \ln p_i$	exp(x)	$\exp(-\sum_{i=1}^{S} p_i \ln p_i)$
Gini-Simpson index:	$x \equiv 1 - \sum_{i=1}^{S} p_i^2$	1/ (1-x)	$1 / \sum_{i=1}^{S} p_i^2$

Evenness, the other information-statistical index, is affected by both the number of species and their equitability or evenness compared to a community's actual diversity, and the value of E is constrained to 0-1.0. Shannon's evenness is calculated by the formula:

H'/ Hmax.

Beta diversity is generally thought of as the change in diversity among various alpha diversities (variation in species composition among sites in a geographic region) (Koleff *et al.,* 2003; Magurran, 2004). The classical Sorensen index is based on both the number of species present in the total sample and numbers only seen in each individual sample (Koleff *et al*., 2003). Sorenson's measure is regarded as one of the most effective presence/absence similarity measures. The Sorensen similarity index is calculated by

Cs= 2*a*/(2*a*+*b*+*c*)

Where *a* is the number of species common to both sites, *b* is the number of species at site B but not at A, and *c* is the number of species at site A but not in B (Magurran, 2004).

RESULTS AND DISCUSSION

Sixteen species of parasitoid wasps were collected and identified from eight families (Table 2), of which *Syrphophagus ariantes* (Walker) and *Anastatus interruptus*

(Nikol'skay) are new records for Iranian fauna. Four others were recently reported from Iran by authors (Bayegan *et al.,* 2014a, 2014b*,* 2015).

Table 2. List of collected Chalcidoidea from rice fields of east of Guilan province (2011-2012). Marked species with an asterisk are new for Iranian fauna.

Family	Genus	Species
Aphelinidae	*Aphelinus*	*A. flaviventris*
Chalcididae	*Brachymeria*	*B. tibialis*
Encyrtidae	*Anagyrus*	*A. diversicornis*
	Ooencyrtus	*O. telenomicida*
		O. pityocampae
	Syrphophagus	*S. ariantes**
Eulophidae	*Aprostocetus*	*A. deobensis*
		A. mycerinus
	Elasmus	*E. phthorimaea*
	Hemiptarsenus	*Hemiptarsenus* sp.
Eupelmidae	*Anastatus*	*A. interruptus**
Mymaridae	*Gonatocerus*	*G. longicornis*
	Mymar	*M. taprobanicum*
Pteromalidae	*Callitula*	*C. ferrierei*
	Conomorium	*C. amplum*
Trichogrammatidae	*Trichogramma*	*Trichogramma* sp.

Aphelinidae

Aphelinus flaviventris (Kurdjumov, 1913)

Material examined: Iran, Guilan province, Zardab-mahalleh, 18.7.2012, 1♀.

This species is known from Iran, Khozestan, Zanjan, Fars provinces (Bani-Hashemi *et al.,* 2014) and was reported from Palearctic region (Noyes, 2015). It is new record for Guilan province and rice field fauna.

Chalcididae

Brachymeria tibialis (Walker, 1834)

Material examined: Iran, Guilan province, Daryasar, 26.8.2012, 1♀.

This species is known from Iran, Azarbayjan, Fars, Kerman, Mazandaran provinces on two family of Lymantriidae and Zygaenidae (Lepidoptera) (Lotfalizadeh, 2012; Lotfalizadeh *et al*., 2012) but it has not been reported from Guilan province. *Brachymeria tibialis* may be parasitoid of rice pests (new association) or it may be found accidentally in rice field.

Encyrtidae

Anagyrus diversicornis (Howard, 1894)

Material examined: Iran, Guilan province, Gelsefid, 18.7.2012, 1♀.

This species is reported for the first time from Iran and has been reported from Palaearctic region (Noyes, 2015). It's association with rice is new.

***Ooencyrtus pityocampae* (Vassiliev, 1904)**

Material examined: Iran, Guilan province, Sheykhanbar, 16.7.2012, 1♀.

This species is known from Iran (Mohammadpour *et al.*, in press) and was reported from Palearctic region (Noyes, 2015). This genus is reported for the first time from the rice plant. This species is parasitoid of Hemiptera such as Scutelleridae, Pentatomidae and Coreidae families and some families from Lepidoptera such as Bombysidae, Lasiocampidae, Notodontidae and Sphingidae (Noyes, 2015). This species as secondary parasitoid of Eulophidae (Hym.: Chalcidoidea) on Pinaceae (Noyes, 2015).

***Ooencyrtus telenomicida* (Mercet, 1921)**

Material examined: Iran, Guilan province, Zardab-mahalleh, 18.7.2012, 2♀♀.

This species is egg parasitoid of Hemiptera and Lepidoptera (Noyes, 2015). This species is a common egg parasitoid in Europe, Asian and Africa (Zhang *et al.,* 2005; Japoshvili and Noyes, 2006). It's association with rice is new.

***Syrphophagus ariantes* (Walker, 1837)**

Material examined: Iran, Guilan province, Daryasar, 5.8.2012, 1♀; Gelsefid, 31.8.2012, 1♀, 9.viii.2012, 1♀; Lashkajan, 9.8.2012, 1♂.

This species is reported for the first time from Iran and was reported from Palearctic region (Noyes, 2015). *Syrphophagus ariantes* is parasitoid of Triozidae (Hemiptera) (Noyes, 2015), Aphididae and Psyllidae (Homoptera) and larva of Diptera specially Syrphidae (Noyes and Hayat, 1984). It's association with rice is new.

Eulophidae

***Aprostocetus deobensis* (Graham, 1987)**

Material examined: Iran, Guilan province, Kuyeh, 07.8.2012, 12♀♀; Zardab-mahalleh, 30.7.2012, 8♀♀ and 2♂♂; Daryasar, 9.8.2012, 1♀.

This species has been reported form rice fields of Guilan by authors (Bayegan *et al.,* 2015).

It was reported from France, Russia and Sweden as parasitoid of Tenthredinidae (Noyes, 2015).

***Aprostocetus mycerinus* (Walker, 1839)**

Material examined: Iran, Guilan province, Roudbaneh, 07.8.2012, 2♀♀; Layalestan, 30.7.2012, 4♀♀; Lashkajan, 09.8.2012, 2♀♀; Sheykhanbar, 25.8.2012, 2♀♀.

This species has recently reported from Iran (Bayegan *et al.,* 2015) and was reported from Palearctic regions and just on Salicaceae host plant (Noyes, 2015), therefore it's association with rice is new.

Elasmus phthorimaeae (Ferriere, 1947)

Material examined: Iran, Guilan province, Lashkajan, 25.6.2012, 1♀; Kuyeh, 26.8.2012, 3♀♀and 2♂♂; Lashkajan, 30.8.2012, 3♀♀ and 2♂♂.

The species of *Elasmus* are either primary external parasitoids of the larvae and pupae of Lepidoptera or hyperparasitoids on them through various Hymenoptera, such as Ichneumonidae and Braconidae (Narendran *et al.,* 2008). The *Phthorimaeae operculella* (Zeller) (Lep:. Gelechiidae) has been reported as host of *E. phthorimaeae* (Noyes, 2015), however, may attack the other lepidopterous pest in rice paddy fields. This species has been recently reported from Iran (Bayegan *et al.,* 2015) and from Europe, Spain, Turkey, United Arab Emirates, Yemen (Noyes, 2015) Asian, Africa and America (Graham, 1995).

Hemiptarsenus sp.

Material examined: Iran, Guilan province, Langroud, Gelsefid, 19.7.2012, 4♀♀.

This unknown species has recently been reported from rice field of Guilan, Langroud city (Bayegan *et al.,* 2015).

Eupelmidae

Anastatus interruptus (Nikol'skaya, 1952)

Material examined: Iran, Guilan province, Rahim-abad, 10.8.2012, 2♀♀.

This species previously been reported from Uzbekistan and is reported for the first time from Iran and rice field. No data from the host and biology of this species has been registered (Noyes, 2015). This species is a primary egg parasitoid of Lepidoptera, Orthoptera and Hemiptera (Kalina, 1981).

Mymaridae

Gonatocerus longicornis Nees, 1834

Material examined: Iran, Guilan province, Lashkajan, 1♀; Daryasar, 30.7.2012, 3♀♀; Lashkajan, 9.8.2012, 3♀♀, 2♂♂; Roudbaneh, 15.8.2012, 18♀♀; Zardab-mahalleh, 11.8.2012, 8♀♀.

This species previously been reported from Europe, India, Japan, China, Turkey, Thailand, Korea, Kyrgyzstan (Noyes, 2015) and Iran (Haghayeghi-Nosrati *et al.,* 2013; Lotfalizadeh, 2015). *Gonatocerus longicornis* was most abundant species in our samplings that may be resulted from plenty of it's host especially rice leafhoppers. This species was reported previously on rice plant and some genera of Rice leafhopper, *Tettigella, Rhytidodus* and *Cicadella* (Hemiptera: Cicadellidae) are host of G. *longicornis* (Noyes, 2015).

Mymar taprobanicum Ward, 1875

Material examined: Iran, Guilan province, Lashkajan, 10.8.2012, 3♀♀ and 2♂♂.

This species previously been reported from Russia, southern Europe, Japan, southeastern Asia, Africa, Australasia, North and Central America, Colombia (Triapitsyn and Berezovskiy, 2001), India (Hayat, 1992), the Arabian Peninsula (Jesu and Viggiani, 2004; Huber *et al*., 2009) and Iran (Bayegan *et al*., 2014b; Lotfalizadeh, 2015).

This species was reported as an egg parasitoid of Hemiptera: Delphacidae (Taguchi, 1974) and Cicadellidae (Chandra, 1980; Subba Rao and Hayat, 1983). Rice leafhopper, *Cicadella viridis* L. (Hemiptera: Cicadellidae), and *Typhlocyba avellanae* (Edwards) are two of the main pests of rice, especially in the early growth stages, in Iran (Mohammadzadeh Fard and Hodjat, 2007; Khanjani, 2008).

Pteromalidae

***Callitula ferrierei* Boucek, 1964**

Material examined: Iran, Guilan province, Zardab-mahalleh, 9.8.2012, 1♀.

Callitula ferrierei has been reported from China (Xiao *et al*., 2005), Bulgaria, Czech Republic, Germany, Moldova, Netherlands, Romania, Slovakia, Sweden, United Kingdom, England, former Yugoslavia (Noyes, 2015) and Iran (Bayegan *et al*., 2014a).

***Conomorium amplum* (Walker, 1835)**

Material examined: Iran, Guilan province, Shykhanbar, 18.8.2012, 2♀♀; Roudbaneh, 16.8.2012, 4♀♀.

This species previously been reported from Iran, Kurdestan (Alipanah *et al.,* 2011) and different region of world such as England, France, Sweden, China, Italy, Romania, Belgium, Germany and Kazakistan (Noyes, 2015). *Conomorium amplum* is reported for the first time from the rice field. This species is parasitoid of Lepidoptera such as Arctiidae, Geometridae, Lymantriidae and Notodontidae (Noyes, 2015).

Trichogrammatidae

***Trichogramma* sp.**

Material examined: Iran, Guilan province, Daryasar, 7.8.2012, 2♀♀; Lashkajan, 30.7.2012, 3♀♀; Kuyeh, 26.7.2012, 2♀♀ and 3♂♂; Sheykhanbar, 25.7.2012, 2♀♀; Zardab-mahalleh, 2.8.2012, 1♀.

All the species of *Trichogramma* are primary egg parasitoid of Lepidoptera, Diptera (Tachinidae) and Hemiptera (Cicadellidae) (Noyes, 2015).

Index Analysis

In this study, the species diversity indices of the identified parasitoids were calculated. The maximum Shannon index was calculated in Lashkajan (1.64) and Zardab- mahalleh (1.45), and the minimum was in Rahim-abad and Layalestan (with only one species). The lowest and highest frequency of superfamily Chalcidoidea was in Lahijan (34) and Roodsar (45), respectively (Table 4). In general, in an environment of diversity and stability of the two factors are correlated and complementary effects. The fact that a system must be a relative stability (balance) to rise its diversity. In such

circumstances, and despite the relative stability, increasing diversity, the situation will change in a way that preserves stability and continuity (sustainability). Therefore, the high species richness and Shannon indices, such as an area primarily reflects the stability of the region and reduce variation, possibly indicating destruction of the instability in the region.

Simpson diversity index

Simpson diversity index of the superfamily Chalcidoidea in Roudbaneh was minimum rate (0.42). It means the probability of two individuals randomly selected from Roudbaneh that belong to the same species is 42%. Low percent of Simpson diversity index indicates high uniformity and low diversity. The maximum amount of this index was calculated for Sheykhanbar with 0.86 (Table 4).

Shannon diversity index

The minimum and maximum values of Shannon diversity index were recorded 0.72 and 1.64 in Lashkajan and Roudbaneh areas, respectively. Six species of Chalcidoidea have a high frequency (almost identical) in this area (Table 4).

Evenness Simpson index

Maximum Simpson evenness index of the superfamily Chalcidoidea was recorded in Shykhanbar with 0.91, the proximity of the study area shows number of these wasps is near together (Table 4).

Evenness Sorensen index

Simpson lowest evenness index of the superfamily Chalcidoidea was recorded 0.52 (Table 4).

Evenness Shannon index

This index was calculated 0.95 for Sheykhanbar that was maximum and the uniform calculation shows that many different species of wasps collected in this area are about 95 percent similar. The lowest Shannon evenness index of the superfamily Chalcidoidea was recorded in the area Roudbaneh with 0.65 (Table 4).

Sorensen similarity index

Sorensen similarity index was 60% between Zardab mahalleh and Daryasar (Langroud city). The two regions with having three similar species were the highest similarity. *Aprostocetus mycerinus* was not collected in Langroud (Dryasr, Gelsefid and Zardab-mahalle). Therefore, any similarity between these areas and Layalestan was observed with having only one species (*A. mycerinus*).

The highest levels of species richness in Lashkajan was registered, but due to the small number of shared species in two zones, the upper bound estimate of the similarity between the two areas was estimated 33%. This area has the highest temperature and the lowest rainfall in the months of July and August, respectively. Altitude for

this area than similar areas in the city proper and the similarity in climatic conditions may create a favorable environment for the species of the same areas. Due to the presence of A. *interruptus* only Rahimabad district, the similarity between this region and other regions lack of common species were observed (Table 3).

Table 3. Sorensen's similarity quotient between pair wise in superfamily of Chalcidoidea (Hymenoptera) between different locations of Eastern of Guilan province, Iran (2011-2012).

Localities	Sheykhanbar	Roudbaneh	Layalestan	Lashkajan	Kuyeh	Rahimabad	Daryasar	Gelsefid	Zardab-mahalle
Sheykhanbar	-	57	40	50	28	0	25	0	40
Roudbaneh		-	50	22	0	0	28	0	22
Layalestan			-	28	0	0	0	0	0
Lashkajan				-	40	0	40	22	33
Kuyeh					-	0	57	0	44
Rahimabad						-	0	0	0
Daryasar							-	0	60
Gelsefid								-	0
Zardab-mahalle									-

Table 4. Species diversity indices of Chalcidoidea between different localities of Eastern of Guilan province, Iran during 2011-2012.

Locality	Heterogeneity indices			
	Simpson index	Shanon index	Shanon evenness	Simpsom evenness
Sheykhanbar	0.86	1.32	0.91	0.95
Roudbaneh	0.42	0.72	0.56	0.65
Layalestan	Not calculated (only one species collected)			
Lashkajan	0.83	1.64	0.79	0.92
Kuyeh	0.63	1.01	0.83	0.91
Rahimabad	Not calculated (only one species collected)			
Daryasar	0.81	1.27	0.82	0.92
Gelsefid	0.66	0.95	0.77	0.87
Zardabmahalle	0.71	1.45	0.52	0.67

ACKNOWLEDGMENT

We are grateful to Islamic Azad University, Tabriz Branch, and East-Azarbaijan Research Center for Agriculture and Natural Resources for supporting this research.

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Received: May 29, 2015 *Accepted: December 14, 2015*