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Local distribution and diversity of Cynipid-induced galls in oak forests of Sardasht, Iran

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Abstract. Oak gall wasp species (Hymenoptera: Cynipidae) were collected from the oak forests of West-Azerbaijan province in the regions such as: Ghabre-hossein, Mir-abad, Vavan, Shalmash, Rabat and Dar-ghabr in 2010. The optimum number of samples was determined to be 40 trees. Number of galls on 50 cm sampled branches from four directions on each tree was counted. Species richness of oak gall wasps was estimated and also parameters such as Simpson's index, Shannon's H', and Sorensen similarity quotient were calculated. In this survey, 7 and 28 species of oak gall wasp were identified in spring and fall, respectively. The most galls occurred on *Q. infectoria*. All of the collected oak gall wasps belong to seven genera as were *Andricus*, *Cynips*, *Neuroterus*, *Chilaspis*, *Pseudoneuroterus*, *Biorhiza* and *Aphelonyx*. The *Andricus* species group had the highest abundance among other species group collected from oaks. There were differences among sites; Dar-ghabr and Ghabre-hossein had the highest diversity and abundance of gall wasps among study sites. The highest amount of Simpson and Shannon index were recorded in Rabat and Dar-ghabr area in fall, respectively. Naturally some species overlap between sites. The highest amount of Sorensen similarity was recorded about the spring's galls (sexual generation) and summer-fall's galls (asexual generation) between Ghabre-hossein vs Mir-abad, and Ghabre-hossein vs Dar-ghabr, respectively. The most important point is that the role of oak subspecies and climate, in distribution of oak gall wasps should not be ignored.

Keywords: population, species diversity, gall wasps, forest, Iran.

Introduction

Differences in terms of community composition and diversity of different animal species, plant and environmental ecology is named biodiversity. Biological diversity is usually considered at three different levels: genetic diversity, species diversity and ecosystem diversity. In an environment with a greater diversity, the sustainable environment and its condition have more regularity. Thus, biodiversity in each region should be a key health and environmental sustainability of the region (Schowalter 1996, Magurran 2004). Species diversity refers to the variety of species. Aspects of species diversity can be measured by different ways, which can be classified into three groups of measurements: species richness, species abundance and taxonomic diversity (Magurran 1988).

There are the methods for evaluating species diversity and one of them is general index of diversity. A number of these indexes proposed by the relative frequency of the species are known as Heterogeneity indexes. One of the used indicators is the Shannon diversity index that involves predicting an individual randomly from a set of S species with N selected individuals (Magurran, 1988, 2004). This index is usually between 1.5 and 4.5 and the low level of this index represents the destruction of the environment (Schowalter 1996). The Shannon index (also called Shannon-Wiener index) is an entropy measure adapted from information theory. Another index is Simpson index that is based on abundance and evenness of species. These indicators are strongly related to dominant species found in the samples, but have little sensitivity to species richness. Simpson's Index calculates the probability that two organisms sampled from a community will belong to different species (the more even the abundance of individuals across species, the higher the probability that the two individuals sampled will belong to different species). This index value is between zero to one and the numbers nearly to one have showed a high diversity (Simpson 1949). Beta diversity is measured by important indicators such as Sorensen which are used to show the variation trends in different localities (Schowalter 1996). Local richness is the number of species associated with a host population or clump at a single site and the influence of local richness on certain oak species is independent of regional richness (Cornell 1985).

The Zagros Mountains in Iran are divided into the northern Zagros and southern Zagros. West-Azerbaijan province is located in the northern Zagros that is the main habitat of *Quercus infectoria* Oliv. (Sagheb-Talebi et al. 2004). Iran lies at the eastern limit of the Western Palaearctic, and recent surveys confirm that its cynipid fauna includes widespread Western Palaearctic species (such as *Andricus kollari* and *Cynips quercusfolii*) (Melika et al. 2004). About 80 percent of the oak gall wasp species, on oak trees make diverse galls in terms of structure and form (Short & Castner 1997, Liljeblad & Ronquist 1998). The nutrition theory is the most important one in relation to diversity and the cause of gall formation. This theory is based on the gall wasp larvae feeding on the gall tissue and which in turn causes gall formation (Stone et al. 2002). Cynipid gall formation is an extremely complex interaction between cynipid gall wasps and the host plant, in which the wasp communicates with the host plant to redirect normal plant development by providing nutrients and protection for the developing larva in the form of a gall (Stone et al. 2002, Nylander 2004). Sexual and Asexual generation of oak gall wasps produce the galls in the spring and early summer, and in the summer and autumn, respectively (Schonrogge et al. 1999). Oak gall wasp species have a high richness in the West-Azerbaijan province. Shojai (1980) has reported 36 oak gall wasp species associated with oak *Q. infectoria* from Iran. The recent surveys were conducted about

the Cynipids fauna in Iran (Zargaran et al. 2006, Azizkhani et al. 2007, Tavakoli et al. 2008) and according to the latest results, so far 82 species of oak gall wasps have been introduced in the oak forests of Iran whereas 25 species are reported in the world for the first time (Sadeghi et al. 2010) but the oak cynipid gall wasps diversity remains little-studied. In this study, the oak gall wasp species diversity and their distribution in West-Azerbaijan of Iran were carried out in 2010.

Material and Methods

At first, some stations were determined in west-southern region of West-Azerbaijan province, Sardasht and Piranshahr city. Sampling was performed in the Ghabre-hossein, Mir-abad, Vavan, Rabat, Dar-ghabr, and Shalmash regions (Table 1), Iran, in 2010. Oak cynipid galls were collected from oak forests. In our studied area, sampling of cynipid galls took place in the mid and the end of spring for the spring's gall wasps and also in the end of summer and the mid fall for other gall wasps. The optimal number of samples was determined according to Southwood and Henderson's formula (2000) that is $N=(t\times s / D\times m)^2$, where t is student's T-test of standard statistical tables, D is the predetermined confidence limit for the estimation of the mean expressed as a decimal, m is sampling mean and s is the standard deviation. The best number of samples was determined to be 40 trees. In this study, we have counted 960 trees in six sites (40 trees per each site). Species diversity refers to the variety of species. Aspects of species diversity can be measured in different ways. Measuring the species richness involves counting the number of species in a defined area. Measuring the species abundance requires sampling the relative numbers among species. Measures of species diversity that simplify information on species richness and relative abundance into a single index are of extensive use (Magurran 1988). Also the parameters such as Shannon's H', Simpson's index and also Sorensen similarity coefficient were calculated with the Ecological Methodology 6.0 software.

Similarity coefficients are the methods for directly comparing diversity of different sites; usually compare the number of species common to all areas. Sørensen similarity index is calculated from this formula as: $C_s = 2a / (2a + b + c)$,Where a is the number of species common to both sites, b is the number of species in site B, but not in A and c is the number of species in site A, but not in B (Magurran 2004). Also, abundance, diversity, oak gall wasp fauna and their distribution were identified in West-Azerbaijan.

Results

In this research, six sites were studied in spring, summer and fall seasons. The identified gall wasps were 35 species that were classified in seven genera. These species were: *Andricus* (23 species), *Cynips* (three species), *Neuroterus* (four species), *Pesudoneuroterus* (one species), *Chilaspis* (one species), *Biorhiza* (one species) and *Aphelonyx* (two species). The genus *Andricus* was the richest species of the collected oak gall wasps. Distribution of oak gall wasps among study sites was different. We collected 21 oak gall wasps species from Ghabre-hossein, 12 species from Mir-abad, 12 species from Vavan, 14 species from Rabat, 21 species from Dar-ghabr and 13 species from Shalmash regions. The highest oak gall wasp species' richness was recorded in Ghabre-hossein and Dar-ghabr regions and, Mir-abad region had the lowest species richness among the stations. The highest number of species of the genus *Andricus* was obsereved in Dar-ghabr area with 17 species and the lowest number of species was five species in Vavan area. *Cynips* was found in all areas and the maximum number of three species belong to *Cynips* was collected from Ghabre-hossein. All species of the genus *Neuroterus* sp. (total four species), were obtained from the station Vavan. Meanwhile, this genus was not observed in any of Shalmash and Mir-abad areas. The two genera *Pseudoneuroterus* and *Chilaspis* with one species were found only in the Rabat area. *Biorhiza pallida* Olivier was obtained from Ghabre-hossein, Mir-abad and Shalmash but *Aphelonyx* was observed in all of the study regions. Figure 1 presents the percent of oak gall wasp species among the regions. Stem gall wasps were more abundant (23) than leaf gall wasp (8) and catkin gall wasp (4). All stem gall wasps belong to the genera, *Andricus*, *Aphelonyx*, *Biorhiza* and *Plagiotrochus*. Leaf-causing gall wasps were members of *Cynips* and *Neuroterus*.

All species of oak gall wasps were gathered on three species of oak *Q. infectoria*, *Q. brantii* and *Q. libani* and Figure 2 presents the species-rich fauna of oak gall wasp species in West-Azerbaijan that occurred on *Q. infectoria*. But the highest number of the spring's species has been established on *Q. brantii*. As observed in Table 1, minimum and maximum of the Simpson index for the spring's galls was in Mir-abad (0.236) and Shalmash (0.512), respectively. Also, minimum and maximum of Simpson index for summer-fall's galls were recorded in Dar-ghabr (0.090) and Rabat (0.314), respectively. The only collected species from Dar-ghabr in spring was *Andricus cecconi* Kieffer that produced the galls on *Q. brantii*. With only one species, calculating the diversity

Table 1. Oak gall wasp species diversity in different regions of West-Azerbaijan, 2010.
[S: Spring, F: Fall, *: Not calculated (only one species was collected)]

Characteristic		Regions					
		Ghabre-hossein	Mir-abad	Rabat	Vavan	Dar-ghabr	Shalmash
Host (*Quercus*)		*Q. infectoria* *Q. brantii* *Q. libani*	*Q. infectoria* *Q. brantii*	*Q. infectoria* *Q. brantii*	*Q. infectoria* *Q. brantii*	*Q. infectoria* *Q. brantii* *Q. libani*	*Q. infectoria* *Q. brantii* *Q. libani*
Latitude		36° 28′N	36° 15′N	36° 14′N	36° 16′N	36° 11′N	36° 07′N
Longitude		45° 18′W	45° 22′W	45° 33′W	45° 28′W	45° 24′W	45° 30′W
Climate		Very humid and cold	Very humid and cold	Humid Mediterranean	Very humid Mediterranean	Humid Mediterranean	Very humid Mediterranean
		Diversity index					
Simpson	S	0.3142	0.2361	0.3788	0.3629	*	0.5121
	F	0.0910	0.1860	0.3147	0.1564	0.0907	0.1404
Shannon's H'	S	1.2496	1.5248	1.0195	1.0534	*	0.6765
	F	2.5634	1.7926	2.1735	1.9671	2.6340	2.1586
No. of species (Spring+Fall)		21(4+17)	12(5+7)	14(3+11)	12(3+9)	21(1+20)	13(2+11)

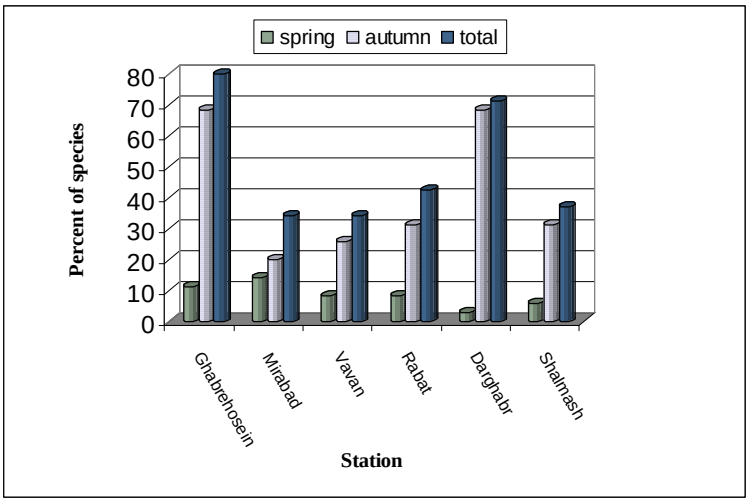

Figure 1. Percent and distribution of oak gall wasp species in West-Azerbaijan, 2010.

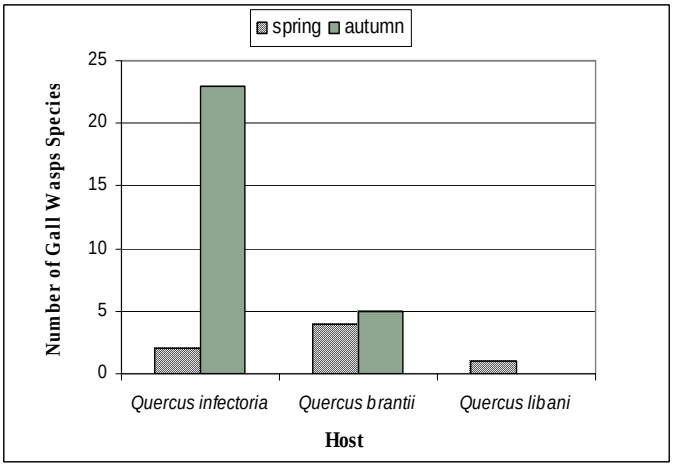

Figure 2. Host plant of oak gall wasps species in West-Azerbaijan.

indexes will be impossible in Dar-ghabr. The highest value of Shannon index for summer-fall's galls were recorded in Dar-ghabr and Ghabre-hossein regions and the high level of this index in these regions indicate that oak gall wasp species have the highest species richness and abundance in these regions. The highest of Shannon index in spring's galls was observed in Mir-abad (1.524) area. Beta diversity, which indicates a change of habitat to other habitats or along a geographical axis or the line size, is obtained by the measurement of similarity index. One of the most important indexes of similarity is Sorensen similarity quotient. Of spring's galls, the highest similarity was between Mir-abad and Ghabre-hossein and the lowest recorded index of similarity was between two regions, Rabat and Mir-abad (Table 2). Pair wise regions such as Rabat and Ghabre-hossein, Dar-ghabr and Ghabre-hossein, Dar-ghabr and Mir-abad, Dar-ghabr and Vavan, Shalmash and Rabat do not share any species; therefore, the similarity value was zero and this means that the areas considered together have no similarity in the presence of oak gall wasps' sexual generation. The highest and lowest similarity index of the fall's gall were observed between Dar-ghabr and Ghabre-hossein (% 76), and between Vavan and Mir-abad (% 25), respectively, (Table 2). Due to higher species richness in the summer-fall galls and their distribution in all regions, the level indicators of Sorensen similarity was not zero.

Table 2. Sorensen similarity quotient (percent) in different regions of West-Azerbaijan.
(* means: for the spring's galls and other are the fall's galls)

Region	Ghabre-hossein	Mir-abad	Vavan	Rabat	Dar-ghabr	Shalmash
Ghabre-hossein	-	* 88	* 57	* Not similar	* Not similar	*66
Mir-abad	27	-	* 75	* 25	* Not similar	* 40
Vavan	54	25	-	* 33	* Not similar	* 40
Rabat	50	44	50	-	* 50	* Not similar
Dar-ghabr	76	37	41	45	-	* Not similar
Shalmash	36	56	30	36	52	-

Discussion

Cynipid-genera can be large about 1000 species are distributed in 41 genera, with a mean of 24 species per genus. Some genera are very large, with 300 species in *Andricus*, 150 species in *Callirhytis*, and 100 species in *Neuroterus* (Price 2005). In this survey, thirty-five oak gall wasp species from studied areas in West-Azerbaijan province were identified to belong to seven major genera of the family Cynipidae. We have collected thirty-five oak gall wasp species from these six sites and Ghabre-hossein had the highest number of species among sites, in 2009. Meanwhile, we collected 21 oak gall wasp species from this region in 2010. There was a slight decline in species abundance from 2009 to 2010 (Unpublished data).

Andricus, *Cynips* and *Neuroterus* with 64, 16 and 10 abundance, respectively, were distributed in all of the areas. *Andricus* on the three oak species, *Cynips* on *Q. infectoria* and *Q. brantii*, and *Aphelonyx* only on *Q. brantii* should make the galls. Considering the different studied climatic regions, at the first stage it did not appear that these species' distribution will be affected by climate change. According to the distribution of *Q. infectoria* in all regions, the highest number of galls (25 galls) was also recorded on this oak species. Comparison of oak gall wasp fauna of *Q. infectoria* with *Q. brantii* and *Q. libani* had showed more variety. Meanwhile, the numbers of nine and one species of gall wasps were active on *Q. brantii* and *Q. libani*, respectively, and the galls were produced on these oak species. Oak gall wasp fauna of the Lorestan province of Iran on *Q. brantii* compared with *Q. infectoria* diversity was higher (Azizkhani et al. 2007). Nazemi et al. (2008) reported species richness of oak gall wasps from Kurdistan, Ilam and Kermanshah provinces of Iran. *Pseudoneuroterus* and *Chilaspis* produced the galls on *Q. brantii* and only have been collected from Rabat. According to the *Q. brantii* presence in both areas and similar climate between Rabat and Dar-ghabr regions, which appear to be of other factors involved in the distribution of these two species and very possibly the presence of different subspecies of oak trees will be investigated as the first important factor in this relationship. A total of 35 species of oak gall wasps, seven spring galls and 28 summer galls were identified. Most of spring's galls (four galls) have been created by sexual generation of oak gall wasp species on *Q. brantii*. In contrast, most summer galls (28 species) were made by asexual generation of oak gall wasps on *Q. infectoria*. Based on climatic similarity in the Ghabre-hossein and Mir-abad regions and also presence of *Q. brantii* as a dominant species, the highest similarity was found in the spring whereas the lowest similarity was registered between Rabat and Mir-abad regions. Oak species of these two regions are the same but their climates are different. It seems that presence of oak gall wasp species were affected by climate or oak subspecies. Due to a lower species richness in spring (seven species) and lack of equal distribution in various regions, the rate similarity index was zero in many areas that showed dissimilarity in the desired areas (Table 2). Stone et al. (2002) believe geographical differences in the oak gall wasp fauna are related to oak distribution patterns in different regions. The highest similarity of asexual generation of oak gall wasp was observed between the Ghabre-hossein and Dar-ghabr. The two acorn covering is the same area but have different climates. Species richness of oak gall wasps in Mexico was reviewed and the results showed that species richness between insects and host plants have positive correlations (Cuevas-Reyes et al. 2004). Gall traits (such as structure, location, and phenology) may play important roles in community diversity, but there is little empirical evidence of this (Hayward & Stone 2005). The lowest similarity was observed between Mir-abad and Vavan in fall. Probably the presence of oak subspecies was affected and led to different richness of oak gall wasp and a minimum similarity between these two regions has been recorded. Some results in relation to galling-insect distribution showed that the effect of humidity on the distribution of these insects is minor and leads to the lower species richness (Fernandes & Price 1992). Price et al. (2004) studied the oak gall wasps demographic population changes and also the relationship between host plant and gall wasps species richness. It shall be believed that gall wasps are skilled plant taxonomists and because all of the galling insects are usually host-specific, generation and maintenance of gall wasp species richness have been often related to plant species richness (Wright & Samways 1998). Adaptation in gall wasp species in different regions was studied and the host plant distribution as the most important factor has been noted (Price 2005). Oak gall wasps are skilful plant taxonomists and mostly form their galls on the different species of oak. Reducing the oak gall wasps diversity will be an alarm for environmental health of oak forests.

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