Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2022; 10(1): 163-171

Received: 22-11-2021
Accepted: 27-12-2021

Maha Kalboussi
Department of Agricultural Production Systems and Sustainable Development (LR03AGR02), Higher School of Agriculture of Mograne (ESAM), Mograne, Zaghouane, University of Carthage, Tunisia

Mohamed Elimem
Department of Agricultural Production Systems and Sustainable Development (LR03AGR02), Higher School of Agriculture of Mograne (ESAM), Mograne, Zaghouane, University of Carthage, Tunisia

Thameur Bouslama
LR21AGR03-Production and Protection for a Sustainable Horticulture, University of Sousse, 10 Regional Research Centre on Horticulture and Organic Agriculture, BO. 57, 4042, Chott-11 Mariem, Tunisia

Chaima Lahfef
1. Department of Agricultural Production Systems and Sustainable Development (LR03AGR02), Higher School of Agriculture of Mograne (ESAM), Mograne, Zaghouane, University of Carthage, Tunisia
2. Deparment of Plant Protection, National Agronomic Institute of Tunisia, 43 Charles Nicolle avenue, Mahrajène City, 1082 Tunis, Tunisia

Essia Limem-Sellemi
General Directorate of Agricultural Protection, Ministry of Agriculture of Water Resources and Fisheries, 30, Alain Savary Street, 1002-Tunis le Belvedere, Tunisia

Slim Rouz
Department of Agricultural Production Systems and Sustainable Development (LR03AGR02), Higher School of Agriculture of Mograne (ESAM), Mograne, Zaghouane, University of Carthage, Tunisia

Corresponding Author:
Mohamed Elimem
Department of Agricultural Production Systems and Sustainable Development (LR03AGR02), Higher School of Agriculture of Mograne (ESAM), Mograne, Zaghouane, University of Carthage, Tunisia

A preliminary study of the biodiversity and bio-ecological parameters related to aphid's species in an organic citrus orchard in Northeastern Tunisia

Maha Kalboussi, Mohamed Elimem, Thameur Bouslama, Chaima Lahfef, Essia Limem-Sellemi and Slim Rouz

DOI: https://doi.org/10.22271/j.ento.2022.v10.i1b.8943

Abstract
The Aphididae family contains many polyphagous species. Four species were identified in an organic Citrus orchard in Northeastern Tunisia in the current study. These species are *Aphis gossypii, A. spiraecola, Macrosiphum euphorbiae,* and *Toxoptera aurantii*. The most important and abundant species was *A. gossypii* followed respectively by *A. spiraecola, M. euphorbiae*, and *T. aurantii.* Monitoring species dynamic population showed that aphids began to occur in February and reached then high levels from March to May. Various structure and beta diversity indexes were calculated. The obtained results demonstrated that there was a high dominance of a few or one species. The evenness index was high and had a significant positive correlation with the Berger-Parker index. The Equitability index was low. The richness index had a strong positive correlation with Margalef's richness index and the number of species. However, Menhinick's diversity index had a weak positive relationship with the Specific richness.

Keywords: Aphids, *Citrus*, biodiversity, structure indexes, beta diversity indexes

1. Introduction

Biodiversity is one of the elemental properties of nature and a source of immense potential for economical use. It is fundamental for agricultural activities, livestock, forestry, fishing, and industry [1]. Biological diversity or biodiversity are expressions interesting in the variability of life on the earth or to the property of living systems to be distinct. It includes plants, animals, microorganisms, ecosystems, and ecological processes during a functional unit [2]. It is considered a sign of the well-being of the ecosystem [3]. Biological diversity may be a central theme of ecological theory and has been the topic of many discussions. Researchers have currently developed an outsized number of parameters for measuring biodiversity as an indicator of the state of ecological systems, with practical applicability for conservation, management, and environmental monitoring [4]. Whittaker [5] has defined three levels of Biodveristy indexes: the alpha diversity indexes, which is the within-habit or intracommunity diversity, the Beta or between-habitat diversity that describes the complementarity among and between biological habitats and the Gamma diversity that is the diversity of the whole landscape.

Insects form a particular diversified class of great importance in ecosystems [6]. They are helpful in evaluating various environmental disturbances [7, 8]. Aphids are a group of insects extremely widespread in the world. They are reported in the tropics and subtropical, temperate regions and steppes [9]. Aphids belong to the order of Homoptera, sub-order of Sternorryncha, and super-family of Aphidoidea [10]. More than 250 species of the Aphidoidea superfamily are crop pests [11]. *Citrus* aphids are serious pests causing damage directly by sap-feeding resulting in leaf deformation, underdeveloped shoots, and honey residues causing sooty mold, or indirectly by virus transmission [12]. Many studies have been carried out in Tunisia to identify different aphids' species on other crops, thus on *Citrus.* Those studies have mentioned that almost all the identified species of *Citrus* belong to the family of Aphididae and the subfamily of Aphidinae. They are mainly *Aphis gossypii, Aphis spiraecola, Toxoptera aurantii,* and *Myzus persicae* [13, 14, 15].

This work aims to assess different beta diversity indexes of aphids' species identified in an organic *Citrus* orchard in Northeastern Tunisia and to study the different relationships between them through correlation analysis.

2. Materials and Methods
2.1 Experimental site
The study was carried out in an organic *Citrus* orchard located in the region of Mograne within the Higher School of Agriculture of Mograne in the governorate of Zaghouan (36 ° 25'46.05"N 10 ° 05'37.00"E, elevation 146 m) in Northeastern Tunisia (Figure 1) from January to June 2021. The orchard has an area of approximately 66330 m² (6.63 ha), it is divided into 10 plots (micro-plots) of 6630 m² containing 10 lines; each line contains 20 trees. There are multiple varieties in the different plots like Thomson's navel, Valencia late, Maltese, clementine, mandarins, and pomelo with a spacing of 3m x 3m.

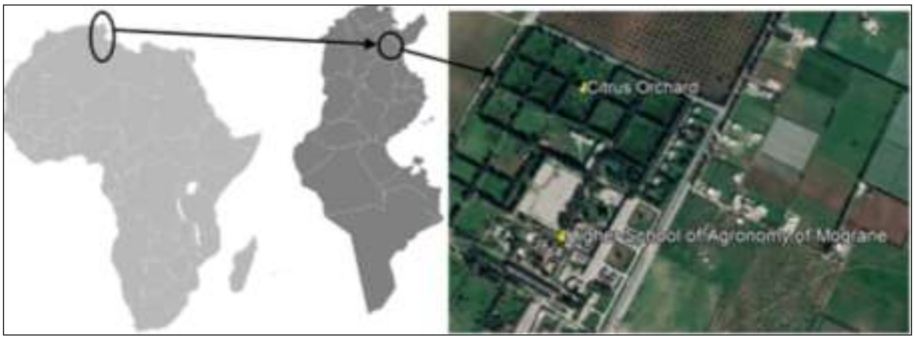


Fig 1: Geographical localization of the experimental site

2.2 Sampling method
Aphids were monitored weekly from January 13th until June 16th, 2021. From each micro-plot, ten trees were chosen randomly thus making a total number of 100 sampled trees per week from the orchard. From each tree, four twigs of 30 cm in length were sampled weekly and randomly from the five quadrants of each tree. All samples were taken to the laboratory of Entomology of the Higher School of Agriculture of Mograne for further examination and identification. The second sampling way consisted of beating branches of the same chosen *Citrus* trees on a white tissue. The fallen specimens were aspirated using a simply manufactured aspirator and conserved in small vials containing a solution of 70% alcohol for further identification.

2.3 Bio-ecological parameters
Two structure indexes and nine beta diversity indexes were used for the study (Table 1)

Table 1: Structure and diversity indexes were used for the study

Index	Formula
Structure indexes	
The number of Occurrence Index or frequency [16, 17]	$NOI = \left(\frac{C}{D}\right) * 100$ Where C is the number of individuals of each species in the sample and D is the number of individuals of all species in the sample.
The specific density of species [15]	$Dm = n/A0$ Where n is the number of individuals of each species and A0 is the surface
Diversity indexes	
Specific Richness [5, 18]	*Rs* = The number of species or taxa, and it is the simplest and most commonly applied index used to represent diversity.
Margalef's richness index [19]	$MR = (S - 1)/\ln(n)$ Where S is the specific richness and n is the total number of individuals
Menhinick's richness index [20]	$DMn = S/\sqrt{n}$ Where S is the specific richness and n is the total number of individuals
Simpson's/Gini-Simpson's diversity index [21]	$GSDI = \sum pi^2$ Where pi is the proportion of the species i obtained by dividing the number of individuals of the targeted species (ni) by the total number of individuals of the species that have been found (n).
Simpson's dominance index [21]	$SDI = 1 -$ GSDI Where GSDI is the Simpson's/Gini-Simpson's diversity index
Berger-Parker's dominance index [22]	$d = Nmax/N$ Where Nmax is the number of individuals of the most abundant species and N is the number of individuals of all the species that have been found.
Shannon Weaver's diversity index [23]	$H' = -\sum pi * Ln(pi)$ Where pi is the proportion of the species i obtained by dividing the number of individuals of the targeted species (ni) by the total number of individuals of the species that have been found (n).
Equitability index [24, 25]	$J = Hs/S$ Where Hs = - Σ pi ln(pi) with pi the proportion of the species i obtained by dividing the number of individuals of the targeted species (ni) by the total number of individuals of the species that have been found (n); and S the observed number of species.

Evenness index [26]	$E = e^{H/S}$ Where H is the observed diversity and S is the observed number of species

2.4 Statistical analysis
The different indexes have been measured by the statistical software PAST® version 3.24 (2019): Paleontological Statistics software package for education and data analysis [27]. A one-way ANOVA followed by a Student Newman and Keuls (SNK) Post Hoc test was used to compare the cumulative means of aphid species during the study period. Pearson correlation was performed on the different calculated indexes. The ANOVA, Post Hoc test and the correlation analysis were done with IBM SPSS (Statistical Package for the Social Sciences) version 23 Edition 32 bits.

3. Results
3.1 Aphid's fauna found in the citrus orchard
The aphid fauna found on citrus has been identified according to several identification keys [28, 29, 30, 31]. The identification led to four species (Table 2); are the cotton aphid *Aphis gossypii* Glover (1877) (Figure 2. A), the green citrus aphid *Aphis spiraecola* Patch (1914) (Figure 2. B), the black orange aphid *Toxoptera aurantii* Boyer de Fonscolomb (1841) (Figure 2. C), the green and pink potato aphid *Macrosiphum euphorbiae* Thomas (1878) (Figure 2. D).

Table 2: Different species of aphids identified in the *Citrus* orchard

Order	Sub-order	Family	Sub-family	Genus	Species
				Macrosiphum	*euphorbiae*
Hemiptera	Sternorryncha	Aphididae	Aphidinae	*Aphis*	*gossypii*
					spiraecola
				Toxoptera	*aurantii*

Fig 2: Different Aphid species collected in the *Citrus* orchard (A: *A. gossypii*, B: *A. spiraecola*, C: *T. aurantia*, D: *M. euphorbiae*)

3.2 Structure indexes
Monitoring populations' dynamics
Monitoring of the total population of each species has revealed that the emergence of the majority of aphid's species took place from late February reaching high levels from March to May (Figure 3).
The maximum averages of the different recorded species have been observed in April when spring shoots reached their peaks. The survey showed that *A. gossypii* is the most abundant species throughout the study period. However, no significant difference ($p < 0.05$) was observed between the maximum averages of *A. spiraecola*, *T. aurantii*, and *M. aurantii* (Figure 4).

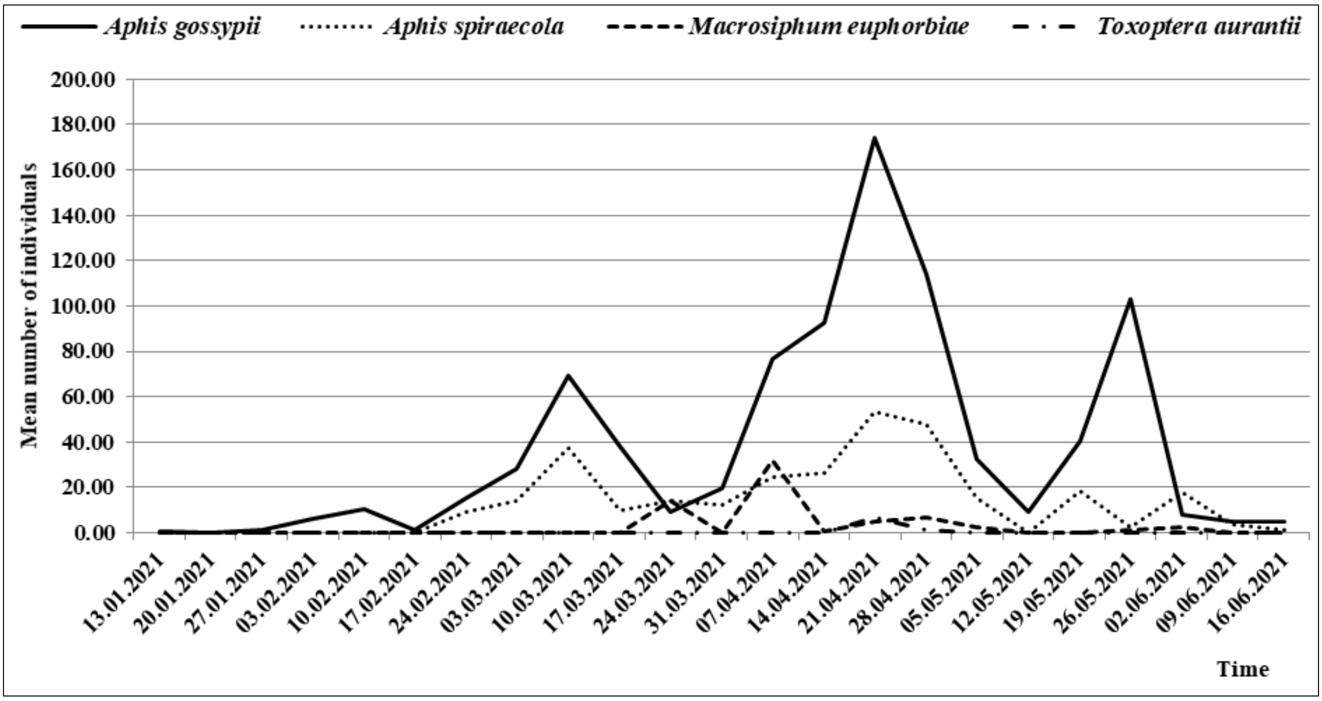
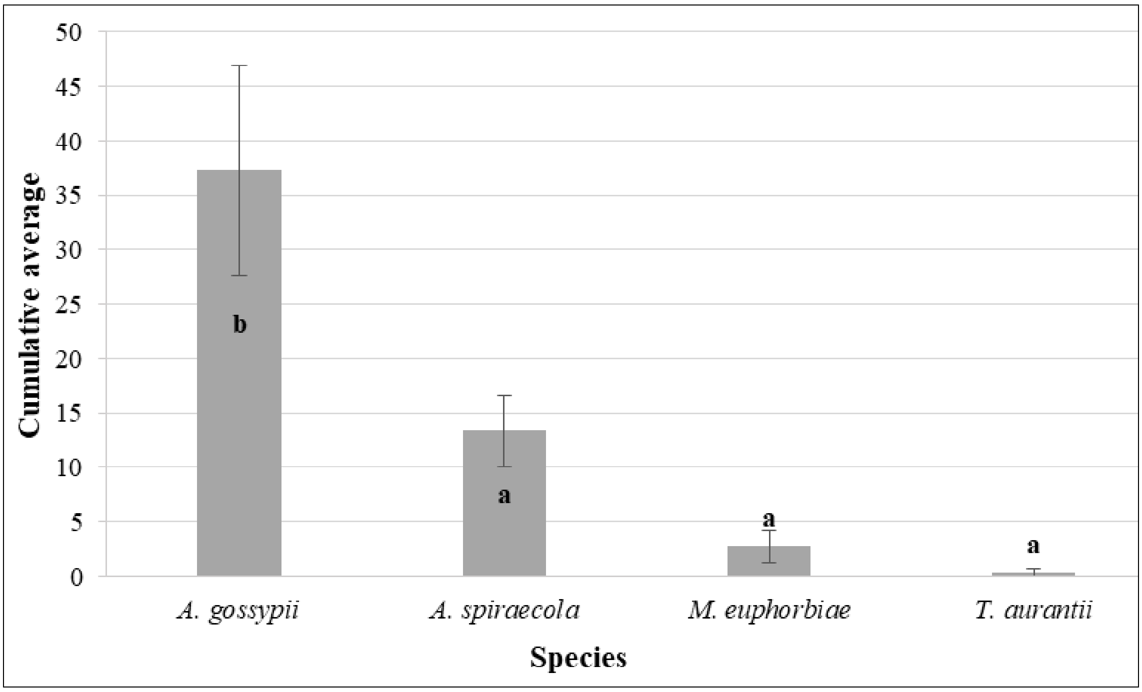


Fig 3: Monitoring populations' dynamics of the different aphid species in the *Citrus* orchard



*Means with different alphabetic letters (a, b) are statically different (p <= 0.05) according to the Student Newman and Keul (SNK) PostHoc test.
* Bars represent the standard error

Fig 4: Cumulative mean values of aphids' species throughout the study period in the *Citrus* orchard

Occurrence index or Frequency

The distribution of frequency of the various species identified in the citrus orchard is represented in Figure 5. *A. gossypii* and *M. euphorbiae* were the most abundant species (62% and 27% respectively) followed by *A. spireacola* and *T. aurantii* (9% and 2% respectively).

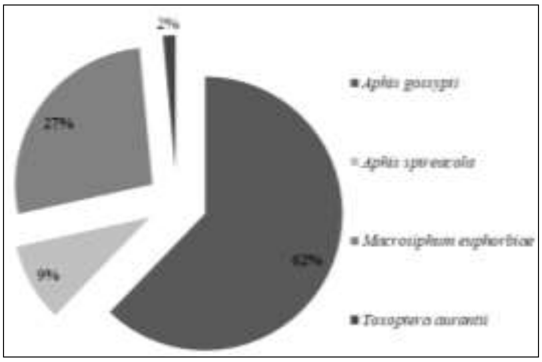


Fig 5: Distribution of the frequency of the different species of aphids in the *Citrus* orchard

Specific density

The results of the specific density of the different species revealed low values. The maximum value slightly exceeds 0.15 recorded by the most abundant and frequent species *A. gossypii* (Figure 6). That means that the number of individuals is very low compared to the total area of the orchard. That may be explained by the presence of aphids in some micro plots and their absence in others due to their preference towards some varieties of *Citrus* trees.

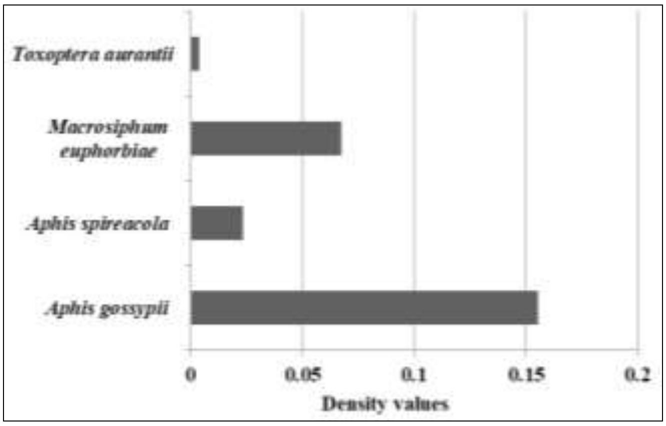


Fig 6: The specific density of the different species of aphids in the *Citrus* orchard

3.3 Diversity indexes

Nine diversity indexes have been studied (Table 3). The different obtained indexes showed high values of dominance indexes with 0.81 and 0.85 for Simpson Dominance index and Berger Parker dominance index respectively. This is due to the high dominance and abundance of *A. gossypii* compared to the other species. Consequently, the other registered diversity indexes are very low with 0.14 for Simpson diversity and 0.24 for Shannon diversity. In addition, the equitability showed a low value of about 0.26 (less than 0.6) indicating thus a disturbing environment. For richness indexes, Margalef's and Menhinick's richness indexes did not exceed 1 (respectively 0.16 and 0.18) and species richness was about 4.

Table 3: Values of the diversity indexes in the organic *Citrus* orchard

Diversity index	value
Specific richness (Rs)	4
Simpson Dominance (SDI)	0,81
Simpson diversity (GSDI)	0,14
Shannon index (H')	0,24
Evenness index (E)	0,78
Margalef's richness index (MR)	0,16
Menhinick's richness index (DMn)	0,18
Equitability index (J)	0,26
Berger Parker dominance index (d)	0,85

Diversity indexes evaluation in the organic citrus orchard

Monitoring Simpson Dominance and Equitability indexes revealed that dominance reached its maximum (SDI=1) almost during all the study period. Moreover, Berger Parker's dominance index was always high.

The index reached its maximum (d=1) almost during all the study periods indicating that the proportion of the abundance of one species in the field is high. The maximum-recorded levels of Simpson dominance and Berger Parker dominance indexes have been associated with maximum levels of Evenness (Figure 7).

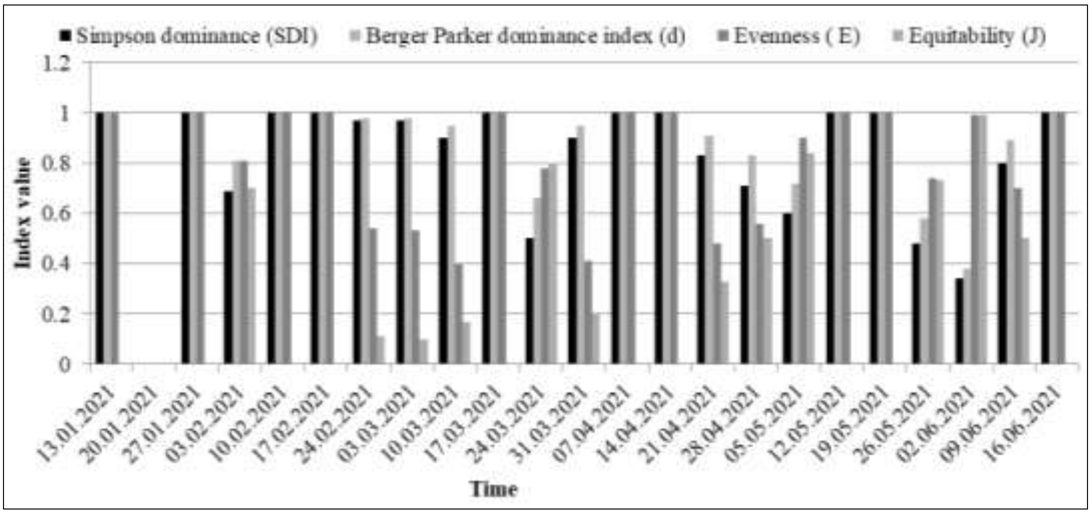


Fig 7: Monitoring Dominance, Evenness, and Equitability indexes in the *Citrus* orchard

As a consequence of the high level of dominance observed in the *Citrus* orchard, the diversity was very low or absent throughout the study period. The Simpson diversity index (GSDI) ranged between 0.3 and 0.65 recorded on February 03rd and June 02nd, 2021, respectively. The Shannon index (H') ranged from 0.5 to 1.1 recorded on the same dates (Figure 8).

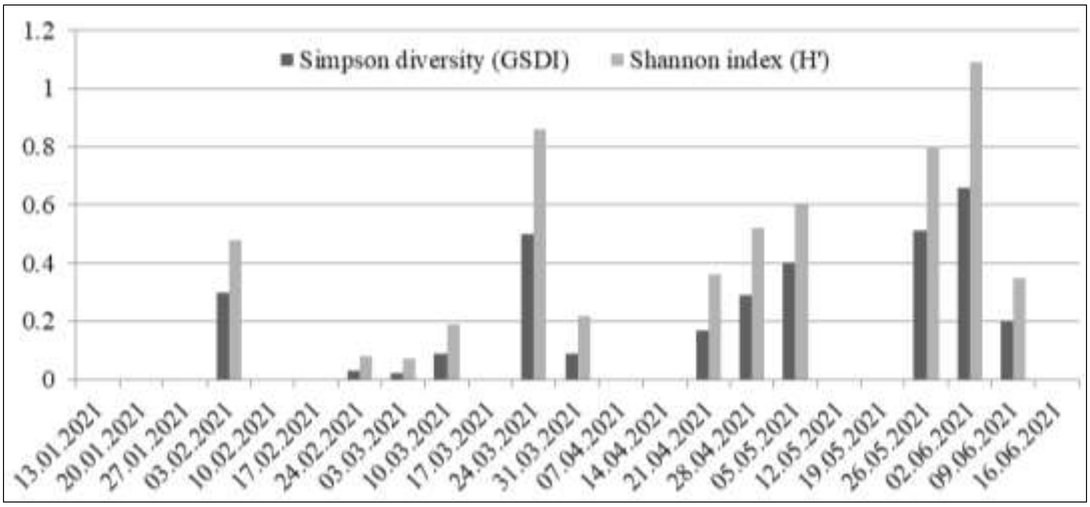


Fig 8: Monitoring Simpson diversity and Shannon indexes in the *Citrus* orchard

Regarding richness indexes, they were relatively low. Menhinick's richness index (DMn) ranged from 0.23 to 0.67 recorded between January 13th and June 09th, 2021, respectively. Margalef's richness index (MR) ranged from 0.35 to 0.5 registered between February 03rd and May 26th, 2021, respectively (Figure 9).

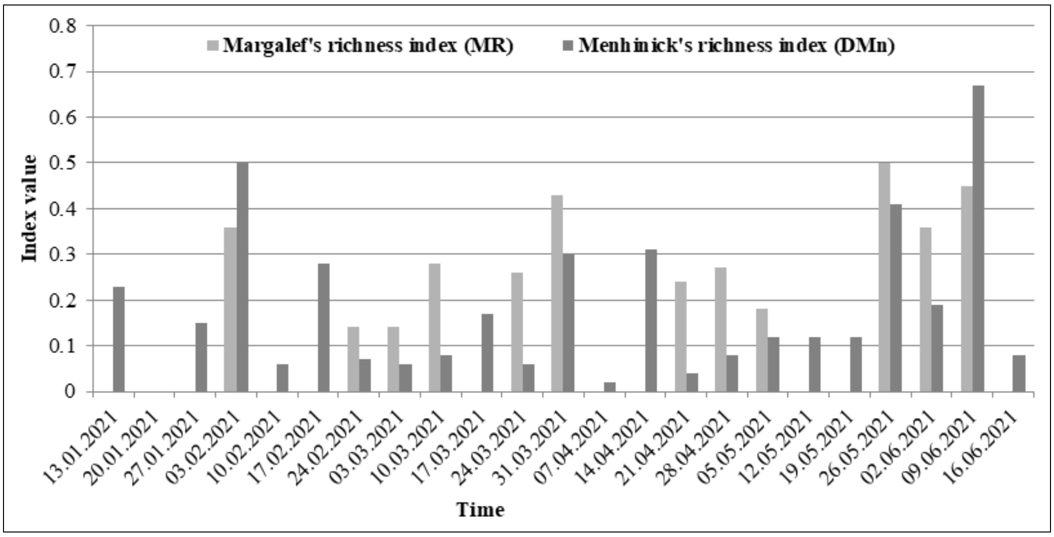


Fig 9: Monitoring richness indexes in the *Citrus* orchard

Correlation between diversity indexes

Relationships between diversity indexes have been studied using the Pearson correlation. There was a strong positive correlation between diversity indexes and richness indexes. For instance, that was observed between the Specific richness index (Rs) and Shannon index (H') (r= 0.761; $p< 0.01$), Margalef's richness index (MR) and Shannon index (H') (r=0.758; $p< 0.01$) and between Simpson diversity index (GSDI) and Margalef's richness index (MR) (r=0.729; $p< 0.01$) (Table 3). However, Menhinick's richness index (DMn) had a weak positive correlation with diversity indexes such as Simpson and Shannon diversity indexes (r=0.24 and r=0.23, respectively). Furthermore, Margalef's richness index (MR) had a strong positive correlation with specific richness (r=0.850; $p< 0.01$), however, Menhinick's richness index (DMn) had a weak correlation with specific richness (r=0.15).

On the other hand, the Berger Parker dominance index (d) has a negative correlation value with Specific richness (Rs) (r=-0.09). However, it had a significant correlation with the Evenness index (E) (r=0.483; $p< 0.05$).

For the Evenness (E), it had a negative correlation with diversity indexes such as Specific richness (Rs) (r=-0.3), Simpson diversity index (GSDI) (r=-0.02), Shannon index (H') (r=-0.07), and Equitability index (J) (r=-0.055). Regarding Equitability (J), it had a strong significant correlation with Margalef's richness index (MR) (r=0.767; $p< 0.01$) and Simpson diversity index (GSDI) (r=0.975: $p< 0.975$). Moreover, this parameter had a significant negative correlation with Berger Parker dominance index (d) (r=-0.479: $p< 0.05$) and Simpson dominance index (SDI) (r=-0.610: $p< 0.01$).

Table 4: Intra-correlation between various indexes using Pearson coefficient

	Specific richness (Rs)	Number of individuals (N)	Simpson dominance (SDI)	Simpson diversity (GSDI)	Shannon index (H')	Equitability (E)	Berger Parker index (d)
Evenness (E)	-0,30	-0,28	0,492*	-0,02	-0,07	-0,05461708	0,483*
Margalef's richness index (MR)	0,850**	0,14	-0,41	0,729**	0,758**	,767**	-0,28285726
Menhinick's richness index (DMn)	0,15	-,441*	-0,01	0,24	0,23	0,31670621	0,05523366
Equitability (E)	,711**	0,15	-0,610**	0,975**	0,970**		-0,479*
Berger Parker dominance index (d)	-0,09	0,06	0,982**	-0,527**	-0,513*	-,479*	
Simpson dominance index (SDI)	-0,23	-0,01		-0,641**	-0,631**	-,610**	0,982**
Simpson diversity index (GSDI)	0,711**	0,15	-,641**		0,996**	0,975**	-0,527**
Shannon index (H')	0,761**	0,21	-,631**	,996**		0,970**	-0,513*
Number of individuals (N)	0,458*		-0,01	0,15	0,21		

* Correlation at 0.05 (2-tailed), ** Correlation at 0.01 (2-tailed)

4. Discussion

The study occurred on a Citrus orchard in the region of Mograne from the governorate of Zaghouane in Northeastern Tunisia. The field contains various trees of *Citrus spp.*

The species identified in the study were *Aphis spiraecola*, *Aphis gossypii*, *Toxoptera aurantii*, and *Macrosiphum euphorbiae.* These species were found on Citrus in Tunisia by other researchers [12, 14, 32, 33, 34]. Indeed, Ben Halima-Kamel and Ben Hammouda [14] found that the species *Aphis spiraecola* was the most abundant in the fields of *Citrus* spp during the second push that is the spring push, and that infestations depend on the development of young stems. Our results coincide with the results of Ben Halima-Kamel and Ben Hamouda [14]. Indeed, *Aphis gossypii*was the most dominant species with less abundance of *Toxoptera aurantii* in the orchard. The same authors added that these species are the main species that cause significant damage in the Cap Bon region. *Aphis gossypii* and *Toxoptera aurantii* are species that havean important economic incidence in the Mediterranean region [35]. *Aphis sipraecola*, *Aphis gossypii*, and *Toxoptera aurantii* are vectors of Tristeza [36].

The emergence of the different species had been staggered over time. *Aphis gossypii* emerged first, which was around the beginning of February, followed by *Aphis spiraecola*. Moreover, according to Sellami *et al.* [15], the various specimens identified are divided into three groups according to their number of occurrences. Species with frequency fi ≥ 20% are called frequent represented by *A.*

gossypii and *A. spiraecola* during this study. The second group of insects is within 20% ≤ fi ≤ 10% refers to moderately frequent species. The third group of insects contains rare species with fi <10%. That was the case of *M. euphorbiae* and *T. aurantia* with 9 and 2% respectively. These results coincide with a study in Japanmade by Komazaki [37] affirming that*A. gossypii* is a polyphagous species possessing thus primary hosts to settle down during winter. Blackman and Eastop [11] reported that *A. gossypii* is also parthenogenetic in the Mediterranean basin and *A. spiraecola* is parthenogenetic on *Citrus* spp. In addition, the two species had a parallel temporal evolution from the end of February until the end of the study. Indeed, a study on clementine gave the same results except that *A. spiraecola*was more abundant than *Aphis gossypii*, this is explained by the fact that this species is influenced by the excessive production of proline that begins around the beginning of April and during June and September [38]. Our results confirm those of Marroquin *et al.* [39] who indicated that *Aphis gossypii* is more abundant on young shoots of Clementine than *Aphis spiraecola* with percentages of 53% and 32% respectively, *Toxoptera aurantii* stands at 11%. In Tunisia, Ben Halima-Kamel and Ben Hamouda [14] signaled that *Aphis spiraecola* and *Aphis gossypii* cause major damage to clementine trees with the sporadic presence of *T. aurantii*. *A. spiraecola* is the most abundant especially during summer.

According to Roger [16], diversity indexes represent the amount of information of a given sample. These indexes describe how individuals are distributed among various species. Diversity cannot be estimated by one index [40, 41]. So, nine diversity indexes have been used in our study: Simpson dominance, Simpson diversity, Shannon index, Evenness, Margalef's and Menhinick's richness indexes, Equitability, and Berger Parker dominance index.

Gorelick [42] affirms that the most used diversity indexes in ecological studies are Shannon and Simpson indexes. Our results showed that the mean value of the Shannon index was about 0.24 indicating a polluted environment [43, 44]. Indeed, the value of the Shannon index ranging between 1 and 2 describes a moderately polluted environment while values above 3 exhibit a stable ecosystem. Kanieski *et al.* [1] have shown that a value of 1.54 in an arboreal field indicates a low diversity. In addition, Dash [45] says that Simpson diversity values close to zero indicate that ecosystems are under stress conditions and low diversity. In our study, the mean value of the Simpson index was low (about 0.14). According to Brower and Zar [46], this low diversity is due to a few numbers of species registered or to the abundance of few species so that the number of species identified in our study is low (Rs=4) and the dominance is high (SDI=0.81, d=0.85) (Table 3). Another study on Simpson diversity has demonstrated that the Simpson index reaches its maximum values when specific richness reaches a value from 10 to 12 [47]. In addition, the low diversity registered has been combined with a low mean value of equitability (J=0.26) (Table 3) which confirms the findings of Peet [48] affirming that diversification of species is higher in a community when there are more species and when the species are equally abundant.

The correlation between indexes has revealed that the Berger Parker index has a negative correlation with Specific richness (r=-0.09).That confirms the findings of Magurran [18] and Magurran and Phillip [49] who plotted the negative relationship between Species richness and Berger Parker index. In our study, the number of aphids' species was low (four species) and the mean value of Berger Parker dominance index was about 0.85 (Table 3). However, the Berger Parker index had a significant positive correlation with the Evenness index (r=0.483: $p < 0.05$). That explainsthese indexes' parallel temporal evolution (Table 4, Figure7).These results confirm the findings of Shah and Pandit [50] who revealed that the Berger Parker index depends totally on Evenness.

The correlation between Equitability (J) and Evenness (E) was weak and negative (r=-0.055), indicating probably that these two indexes do not always refer to the same term as noticed in the literature. The existence of a few or one dominant species reduces the Equitability, regarding that, there was a significant negative correlation between Berger-Parker index and Equitability (r=-0.479: $p < 0.05$) and a positive significant correlation between Simpson dominance and Equitability (r=-0.610, $p < 0.01$). Moreover, the Equitability and Evenness had the same values when the dominance was low (Figure 7). In our study, the Evenness index has shown a weak and negative correlation with the Simpson index (r=-0.02). Shah and Padit [50] mentioned in their works that there was a significant negative correlation between these two indexes (r=-0.54; $p < 0.05$).However, Watling *et al.* [51] had found a positive correlation between them (r=0.54; $p < 0.05$). The evenness had shown also a negative correlation with the Shannon index (r=-0.07) which is in contrast with the findings of Shah and Padit [50] who found that there was a strong significant relationship (r=0.771; $p < 0.01$) between the two indexes. Our findings reject the confirmation that evenness is a component of the diversity in ecosystems [52].

Concerning the richness indexes, they have a highly significant ($p < 0.01$) correlation with Simpson and Shannon indexes, except for Menhinick's richness index that has a weak positive correlation with those indexes confirming then the findings of Ricotta [53] and Liu *et al.* [54] that the richness is a component of the diversity. Moreover, Ravera [55] affirmed that a reduced number of species is considered a factor of low diversity. Furthermore, Margalef's richness index has a highly positive correlation ($p < 0.01$) with the Specific richness index. That confirms the findings of Shah and Pandit [50] affirming that Margalef's richness index depends on the number of species and it has no limit value so that it is sensitive to the sample's size. Kocatas [56] had demonstrated that this index is used to compare between sites. Kanieski *et al.* [1] confirmed also that Margalef's index depends on the sample's size. Therefore, Menhinick's richness index had a weak positive correlation that explains the affirmation of Kanieski *et al.* [1]. Indeed, Menhinick's richness does not consider the size of the sampledarea; it represents the real diversity even in a small area.

Schaaf *et al.* [57] found that values of 6.52 and 7.02 of the Margalef index reveal medium to high diversity and values of 1.1 and 1.7 of Menhinick indexes show a medium diversity. A value of 1.96 of Menhinick's index denotes high diversity Kanieski *et al.* [1].

5. Conclusion

Four Aphid species were identified in an organic *Citrus* orchard in northeastern Tunisia. These species are *Aphis spiraecola*, *Aphis gossypii*, *Toxoptera aurantii*, and *Macrosiphum euphorbiae*. *A. gossypii* was the most abundant species, followed by *M. euphorbiae*. *A. spireacola* and *T. aurantii* were rarely found on the orchard. Two structure indexes and nine beta diversity indexes were calculated.

Results showed that few or one species was dominant. Correlation between the different indexes showed that the evenness index had a significant positive correlation with the Berger-Parker index; the richness index had a strong positive correlation with Margalef's richness index and the number of species, and the Menhinick's diversity index had a weak positive relationship with the Specific richness. Other studies will be carried out on other locations and for longer periods.

Appendices Table 1: Descriptive statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A. gossypii	23	37.3039	46.26566	9.64706	17.2971	57.3107	.00	174.23
A. spiraecola	23	13.3361	15.58158	3.24898	6.5981	20.0741	.00	53.47
M. euphorbiae	23	2.7591	7.10253	1.48098	-.3122	5.8305	.00	31.87
T. aurantii	23	.3565	1.44841	.30201	-.2698	.9829	.00	6.88
Total	92	13.4389	28.37114	2.95790	7.5634	19.3144	.00	174.23

Appendices Table 2: Anova

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19659.377	3	6553.126	10.761	.000
Within Groups	53588.496	88	608.960		
Total	73247.873	91			

Appendices Table 3: PostHoc test

Student-Newman-Keuls[a]			
Species	N	Subset for alpha = 0.05	
		1	2
T. aurantii	23	.3565	
M. euphorbiae	23	2.7591	
A. spiraecola	23	13.3361	
A. gossypii	23		37.3039
Sig.		.181	1.000

Means for groups in homogeneous subsets are displayed
a. Uses Harmonic Mean Sample Size = 23,000

6. References

1. Kanieski MR, Longhi SJ, Soares PRC. Methods for biodiversity assessment: case study in an area of Atlantic Forest in Southern Brazil. Selected Studies in Biodiversity. 2018.
2. Dias BFS, Coradin L. Biological diversity and its importance for Brazil. EDn 3, Freeman, New York. 1990, 456.
3. Ricklefs RE. Seabird life histories and the marine environment: some speculations. Colonial Waterbirds. 1990, 1-6.
4. Magurran M. Ecological Diversity and its Measurement. Cambridge University Press, Cambridge, UK, 1988.
5. Whittaker RH. Evolution and measurement of species diversity. Taxon. 1972;21:213-51.
6. Finnamore AT. The advantages of using arthropods in ecosystem management. Biological Survey of Canada (Terrestrial Arthropods) for Canadian Museum of Nature and Entomological Society of Canada, Ottawa. 1996.
7. Lehmkuhl DM, Danks HV, Behan-Pelletier VM, Larson DJ, Rosenberg DM and Smith IM. Recommendations for the appraisal of environmental disturbance: some general guidelines, and the value and feasibility of insect studies. A brief. Bulletin of the Entomological Society of Canada. 1984;16(3):8.
8. Rosenberg DM, Danks HV and Lehmkuhl DM. Importance of insects in environmental impact assessment. Environmental Management. 1986;10:773-783.
9. Accodji. Bio-écologie de pucerons en culture maraîchères, El Harrach. 1982, 108.
10. Gullan PJ, Martin JH. Sternorrhyncha: (jumping plant-lice, whiteflies, aphids, and scale insects). In Encyclopedia of insects, Academic Press. 2009, 957-967.
11. Blackman RL, Eastop VF. Aphid on the world'scrops: an identification information guide. EDn 2. Chichester, John Wiley & Sons. 2000.
12. Kavallieratos NG, Tomanović Ž, Athanassiou CG, Starý P, Žikić V, *et al*. Aphid parasitoids infesting cotton, citrus, tobacco, and cereal crops in southeastern Europe: aphid-plant associations and keys. The Canadian Entomologist. 2005;137(5):516-531.
13. Ben Halima-Kamel M, Ben Hamouda MH, Rabasse JM. Les pucerons desagrumes et leurs ennemis en Tunisie. Tropicultura. 1994;12(4):145-147.
14. Ben Halima-Kamel M, Ben Hamouda MH. A propos des pucerons des arbresfruitiers de Tunisie. Notes fauniques de Gembloux. 2005;58:11-16
15. Sellami EL, Meurgey F, Barbouche N, Romdhane MS. Odonates dans les principaux cours d'eau du parc national de l'Ichkeul (Tunisie). Entomologie Faunistique – Faunistic Entomology. 2015;68:93-100.
16. Roger J. Collection d'écologie: Paléoécologie. Masson Edition, Paris. 1977.
17. Olawusi-Peters OO, Ajibare AO. Species richness, diversity and abundance of some Decapod Crustaceans in coastal waters of Ondo State, South West, Nigeria. International Journal of Fauna and Biological Studies. 2014;1(5):44-51.
18. Magurran AE. Measuring biological diversity, EDn 2. Blackwell Science Ltd, Oxford, U.K. 2004.
19. Margalef R. Information theory in ecology. General Systematics. 1958;3:36-71
20. Menhinick EF. A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology. 1964;45:859-61.
21. Simpson EH. Measurement of diversity. Nature. 1949;163:688.
22. Berger WH, Parker FL. Diversity of Planktonic foraminifera in deep sea sediments. Science. 1970;168:1345-1347.
23. Shannon CE, Weaver W. The mathematical theory of communication. Science. 1949;185:27-39.
24. MacArthur RH. On the relative abundance of bird species. Proceedings of the National Academy of Sciences USA. 1957;43:293-29.
25. Lloyd M, Ghelardi RJ. A table for calculating the equitability component of species diversity. Journal of Animal Ecology. 1964;33:217-225.
26. Sheldon AL. Equitability Indices: Dependence on the Species Count. Ecology. 1969;50(3):466-467.

27. Hammer Ø, Harper DAT, Ryan PD. PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica. 2001;4(1):9.
28. Blackman RL, Eastop VF. Aphids on the World's Trees. CAB International, Wallingford, 1994, 987.
29. Blackman RL, Eastop VF. Aphids on the World's Herbaceous Plants and Shrubs. II, Wiley, Chichester, 2006, 1439.
30. Hullé M, Chaubet B, Turpeau E, Simon JC. Encyclop' Aphid: a website on aphids and their natural enemies. Entomologia generalis. 2020. DOI: 10.1127/entomologia/2019/0867
31. Brightwell R, Dransfield RD. Influential Points. Services for ecologists, medics and veterinarians. http://influentialpoints.com/Gallery/Aphid genera.htm. 2021.
32. Bouhachem S. Aphid enemies reported from Tunisian citrus orchards. Journal of Plant Protection. 2011;6:21-27.
33. Albouchi F, Ghazouani N, Souissi R, Abderrabba M, Boukhris-Bouhachem S. Aphidicidal activities of Melaleuca styphelioides Sm. essential oils on three citrus aphids: Aphis gossypii Glover; Aphis spiraecola Patch and Myzus persicae (Sulzer). South African Journal of Botany. 2018;117:149-154.
34. Sellami EL, Delvare G, Chermiti B. Parasitoids and hyperparasites of citrus aphids in northern east of Tunisia (Cap Bon). Integrated Control in Citrus Fruit Crops IOBC-WPRS Bulletin. 2013;95:131-139.
35. Tena A, Garcia-Marí F. Current situation of citrus pests and diseases in the Mediterranean basin. International Organization for Biological Control Bulletin. 2011;62:365-368.
36. Portillo MM, Benateña HN. Transmission of Psorosis from citrus to citrus by Aphids. Revista de la Sociedad Entomológica Argentina. 2018;45:1-4.
37. Komazaki S. Ecology of citrus aphids and their importance to virus transmission. World. 1994;2(4):13.
38. Mostefaoui H, Allal-Benfekih L, Djazouli ZE, Petit D, Saladin G. Why the aphid Aphis spiraecola is more abundant on clementine tree than Aphis gossypii? Comptes rendus biologies. 2014;337(2):123-133.
39. Marroquín C, Olmos A, Gorris MT, Bertolini E, Martınez MC, Carbonell EA, *et al*. Estimation of the number of aphids carrying Citrus tristeza virus that visit adult citrus trees. Virus Research. 2004;100(1):101-108.
40. Hayek LC, Buzas MA. Surveying Natural Populations. Columbia University Press, New York. 1997.
41. Purvis A, Hector A. Getting the measure of biodiversity. Nature. 2000;405:212-219.
42. Gorelick R. Combining richness and abundance into a single diversity index using matrix analogues of Shannon's and Simpson's indices. Ecography. 2006;29:525-530.
43. Staub R, Appling JW, Hofstetter AM, Haas IJ. The effects of industrial wastes of Memphis and Shelby County on primary planktonic producers. Bioscience. 1970, 905-912.
44. Mason CF. Biology of freshwater pollution. Pearson Education. 2002.
45. Dash MC. Fundamental of Ecology. EDn2, Tata McGrawHill publishing company limited, New Delhi. 2003.
46. Brower JE, Zar JH. Field and laboratory methods for general ecology. MA: Wm. C. Brown Company Publishers, Boston. 1977.
47. Loya Y. Community structure and species diversity of hermatypic corals at Eilat, Red Sea. Marine Biology. 1972;13(2):100-123.
48. Peet RK. The measurement of species diversity. Annual Review of Ecology, Evolution, and Systematics. 1974;5:285-307.
49. Magurran AE, Phillip DAT. Implications of species loss in freshwater fish assemblages. Ecography. 2001;24:645-650.
50. Shah JA, Pandit AK. Application of diversity indices to crustacean community of Wular Lake, Kashmir Himalaya. International Journal of Biodiversity and Conservation. 2013;5(6):311-316.
51. Watling L, Bottom D, Pembroke A, Maurer D. Seasonal variations in Delaware Bay phytoplankton community structure. Marine Biology. 1979;52(3):207-215.
52. Omernik JM. The misuse of hydrologic unit maps for extrapolation, reporting, and ecosystem management 1. JAWRA Journal of the American Water Resources Association. 2003;39(3):563-573.
53. Ricotta C. On parametric evenness measures. Journal of Theoretical Biology. 2003;222(2):189-197.
54. Liu Z, Liu G, Fu B, Zheng X. Relationship between plant species diversity and soil microbial functional diversity along a longitudinal gradient in temperate grasslands of Hulunbeir, Inner Mongolia, China. Ecological Research. 2008;23(3):511-518.
55. Ravera O. A comparison between diversity, similarity and biotic indices applied to the macroinvertebrate community of a small stream: The Ravella river (Como Province, Northern Italy). Aquatic Ecology. 2001;35:97-107.
56. Kocataş A. Ekoloji ve Çevre Biyolojisi, Ege Üniv. Matbaası, İzmir. 1992, 564.
57. Schaaf LB, Figueiredo Filho A, Franklin G, Sanqueta CR, Longhi SJ. Modifcações florístico-estruturais de um remanescente de floresta ombrófla mista montana no período entre 1979 e 2000. Ciência Florestal. 2006;16(3):271-291.