www.biodicon.com Biological Diversity and Conservation

ISSN 1308-8084 Online ISSN 1308-5301 Print

Research article/Araştırma makalesi
DOI: 14745/biodicon.2022.1198394
15/3 (2022) 385-391

Calculation of biodiversity parameters of epigean Hexapoda species in different anise (*Pimpinella anisum* L.) and fennel (*Foeniculum vulgare* Mill.) agro-ecosystems in Burdur Province

Şükrü Erden ERGENE[1], Gökhan AYDIN [*2]
ORCID: 0000-0002-1606-344X**;** 0000-0003-2301-5195

[1] Afyonkarahisar Food Control Laboratory Management, Afyon, Turkey
[2] Isparta University of Applied Sciences, Atabey Vocational School, 32670 Atabey-Isparta, Turkey

Abstract

This study was carried out to compare the biodiversity parameters of epigean insect species in three different regions with different geographical conditions. Tefenni Plain, Beyköy (Abdülmelik) Plain and Çaylı Mountain Village, which are located at 3 different altitudes, were chosen as the study area. Pitfall traps were placed in agro-ecosystems of anise and fennel in each region and epigean insect species sampled with pitfall traps were checked weekly. A total of 2086 individuals belonging to 117 epigean insect species, mostly from the carabid (Coleoptera) family, were sampled. The highest number of individuals were sampled in fennel planted field in Tefenni Plain (*Tf*) and anise planted field in Tefenni Plain (*Ta*) with 841 and 440, respectively. The results of Shannon-Wiener diversity were found to be the highest in *Ta* with 2.7893 while the lowest was found in anise planted field in Çaylı Mountain Village (*Ca*) with 2.1775. Simpson diversity results were calculated as highest in Ta with 0.9196 and lowest in *Ca* with 0.7813. Simpson's dominance results determined that *Ca* was the highest dominant agro-ecosystem with 0.2187. According to both Shannon and Simpson Evenness; the population densities of epigean species living in fennel planted field in Beyköy (Abdülmelik) Plain (*Bf*) and anise planted field in Beyköy (Abdülmelik) Plain (*Ba*) were found to be more balanced than in other agro-ecosystems. The percentage similarity analysis shows that the regions selected in different altitudes were more similar to each other than the plants of the same species. Contrary to expectations, it was observed that epigean insect species did not show distribution according to plant pattern and were not directly related to plants. It is thought that the epigean insect species sampled are affected by the altitude difference.

Key words: Shannon-Wiener, Simpson diversity, similarity, dominance, vertical distribution

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Burdur İli farklı anason (*Pimpinella anisum* L.) ve rezene (*Foeniculum vulgare* Mill.) agro- ekosistemlerinde epigean Hexapoda türlerinin biyolojik çeşitlilik parametrelerinin hesaplanması

Özet

Bu çalışma farklı coğrafik koşullarda bulunan üç farklı bölgede epigean böcek türlerinin biyolojik çeşitlilik parametrelerinin karşılaştırılması amacıyla 2022 yılında yapılmıştır. Çalışma alanı olarak 3 farklı rakımda yer alan Tefenni Ovası, Beyköy (Abdülmelik) Ovası and Çaylı Dağ Köyü seçilmiştir. Her bölgede anason ve rezenenin olduğu agro-ekosistemlere çukur tuzaklar yerleştirilmiş ve çukur tuzaklarla örneklenen epigean böcek türleri haftalık olarak kontrol edilmiştir. Çoğu Carabidae (Coleoptera) familyasından olmak üzere toplam 117 epigean böcek türene ait 2086 birey örneklenmiştir. En yüksek sayıda birey sırasıyla 841 ve 440 ile Tefenni Ovası'nda rezene ekili tarla (*Tf*) ve yine Tefenni Ovası'nda anason ekili tarla (*Ta*)'da örneklenmiştir. Shannon-Wiener çeşitliliğinin sonuçları 2,7893 ile en yüksek *Ta*'da, en düşük ise 2,1775 ile Çaylı Dağ Köyü'nde anason ekili tarla (*Ca*)'da bulunmuştur. Simpson çeşitlilik sonuçları da 0.9196 ile en yüksek *Ta*'da ve 0.7813 ile en düşük *Ca*'da hesaplanmıştır. Simpson'ın dominantlık sonuçları, *Ca*'nın 0.2187 ile en yüksek dominantlığa sahip agro-ekosistem olduğunu belirlemiştir. Hem Shannon'a hem de Simpson Evenness'e göre; Beyköy Ovası'nda rezene ekili tarla (*Bf*) ve yine Beyköy Ovası'nda anason ekili tarla (*Ba*)'da yaşayan epigean türlerinin popülasyon yoğunluklarının diğer tarımsal ekosistemlere göre daha dengeli olduğu görülmüştür. Yüzde benzerlik analizi farklı coğrafi koşullarda seçilen bölgelerin birbirlerine aynı tür bitkilerin birbirine benzemelerinden daha çok benzediklerini göstermektedir. Beklenenin aksine epigean böcek türlerinin bitki desenine göre dağılım göstermedikleri ve bitkilerle doğrudan ilişkili olmadıkları görülmüştür. Örneklenen epigean böcek türlerinin rakım farkından etkilendikleri düşünülmektedir.

Anahtar kelimeler: Shannon-Wiener, Simpson çeşitlilik, benzerlik, dominantlık, dikey dağılım

[*] *Corresponding author* / Haberleşmeden sorumlu yazar: Tel.: +905076725309; Fax.: +902462713036; E-mail: gokhanaydin@isparta.edu.tr
 Geliş tarihi: 02.11.2022; Yayın tarihi: 15.12.2022 BioDiCon. 1064-021122

1. Introduction

Biological diversity or briefly "biodiversity" refers to the variety of life on Earth at all its levels, from genes to ecosystems. Genetic Diversity is defined as genetic variability present within species while Species Diversity is defined as the number of different species present in an ecosystem and relative abundance of each of those species. Ecosystem diversity contains the entirety of interacting organisms as an ecological unit and their physical environment.

Increasing urbanization due to human population growth has brought along many problems such as global climate change, environmental pollution, habitat destruction, intensive use of pesticides and synthetic fertilizers in agricultural areas to obtain more products from unit area, infertility of agricultural lands, etc. Thus, human activities threaten the biodiversity on our planet and species richness is gradually decreasing [1-6]. As a result of transformation of the agro-ecosystems into urban areas, simulations until 2035 have showed a continuous decline of farmers in all scenarios [7]. Many scientific studies have been conducted on the negative effects of human activities on biodiversity [8-16].

Agricultural biodiversity supports the basic structure, functions, protection of the food chain, food production and food security of the agro-ecosystem [5, 17]. Organic farming practices in agricultural lands are of great importance for the protection and sustainability of the biological diversity in agro-ecosystems. Pesticides and synthetic fertilizers, which are used unnecessarily and intensively in conventional farming, in underdeveloped countries and even in some developing countries, have a negative impact on the environment, human and animal health [3, 6, 18-20]. Unfortunately, such countries cannot achieve the transition from conventional agriculture to organic agriculture (if they do not export organic agricultural products). This has two reasons: The first is that the public is unconscious of the healthy products obtained as a result of organic agriculture and/or good agricultural practices. The second and even more tragic reason is the lack of financial means for the most of the producers to grow organic products and for the most of the citizens to buy them.

Some epigean species of Carabidae, Scarabaeidae, Tenebrionididae families have been frequently used to measure biodiversity, as bio-indicator species for habitat description and habitat destruction for the improvement of an agro-ecosystem and/or for sustainability of protected areas [1, 2, 21, 22].

The study was carried out to evaluate the biodiversity parameters of epigean species living in organically grown Anise (*Pimpinella anisum* L.) and Fennel (*Foeniculum vulgare* Mill.) agro-ecosystems at three different altitudes in Burdur Province.

2. Material and Methods

2.1. Study areas

The study areas were selected in Tefenni Plain, Beyköy (Abdülmelik) Plain and Çaylı Mountain Village which were located at different altitudes in the Tefenni District of Burdur Province. One anise (*Pimpinella anisum* L.) and one fennel (*Foeniculum vulgare* Mill.) agro-ecosystems were selected in each region (six habitats in total) in order to measure the effects of vertical distribution on epigean insect biodiversity. Altitude of anise planted field in Tefenni Plain (*Ta*) (N37°32'89.82 E29°78'17.91) was 1150 m., fennel planted field in Tefenni Plain (*Tf*) (N37°19'41.58 E29°46'57.98) was 1147 m., anise planted field in Beyköy (Abdülmelik) Plain (*Ba*) (N37°14'9.21 E29°43'10.72) was 1216 m., fennel planted field in Beyköy (Abdülmelik) Plain (*Bf*) (N37°.23'79.05, 29°.72'01.80) was 1225 m., anise planted field in Çaylı Mountain Village (*Ca*) (N37°12'35.09 E29°48'19.56) was 1532 m., and fennel planted field in Çaylı Mountain Village (*Cf*) (N37°.21'03.79 E29°.81'23.21) was 1513 m. The main data of the study were obtained from the presence-absence status and population densities of epigean insect species which refers to an organism's activity above the soil surface. Field studies were carried out between June and September of 2022.

2.2. Sampling of epigean insect species

The epigean species were sampled by pitfall traps. Totally 60 pitfall traps (10 traps for each agro-ecosystems) were placed in Tefenni Plain, Beyköy (Abdülmelik) Plain and Çaylı Mountain Village which were different altitudes. In this method, 10 plastic containers with a diameter of 15 cm and a depth of 20 cm were placed at intervals of 5 meters each in habitats at different altitudes, keeping the open parts at the same level as the soil level [23]. Data obtained from pitfall traps were used to measurement of biological diversity parameters. Pitfall traps were checked weekly and the numbers of insects caught were recorded in the charts. Insects placed in plastic containers specially prepared for each agro-ecosystem were brought to the laboratory for pinning, labeling, counting and diagnosis. The sampled insects were separated at the morphospecies level by considering at their morphological features and each was given a number.

2.3. Statistical analysis: Measurement of biological diversity parameters

Biodiversity parameters of plots were calculated using the EvenDiv 1.1 program [24], the parameters used and their calculation methods are given below:

for species diversity;
- Shannon-Wiener diversity index (H')

……$H' = -\sum pi \ln(pi)$

pi: the importance value of a species as a proportion of all species
ln: the natural logarithm
- Simpson diversity index (S)

……$S = 1 - \sum \mathrm{ni}(\mathrm{ni}-1)/\mathrm{N}(\mathrm{N}-1)$

i: number of species
ni: the importance value of a species as a proportion of all species
N: s the sum of the number of individuals

for species dominancy;
- Simpson dominance index (Sd)

……$Sd = \sum \mathrm{ni}(\mathrm{ni}-1)/\mathrm{N}(\mathrm{N}-1)$

i: number of species
ni: the importance value of a species as a proportion of all species
N: the sum of the number of individuals

for species evenness;
- Shannon Evenness index (EH')

……$EH' = H'/\ln(\mathrm{N})$

H': Shannon-Wiener diversity
ln: the natural logarithm
N: the sum of the number of individuals
- Simpson Evenness index (ESm)

……$ESm = S/\mathrm{N}$

S: Simpson diversity
N: the sum of the number of individuals [25, 26].

MVSP (Multi Variate Statistical Package) 3.11c program was used to classify selected plots [27].

for similarity;
- Percentage similarity index (%S)

……$\%S = \sum \min(\mathrm{a}, \mathrm{b}, \ldots\ldots\ldots, \mathrm{x})$

∑min: the sum of the smallest values whose percentages are calculated in the habitat with the smallest values in the other habitat whose similarity is calculated [28].

3. Results

In the study, a total of 2086 individuals belonging to 117 epigean insect species, mostly from the carabid family, were sampled between June and September, 2022 (Table 1). Based on the data obtained from the pitfall traps; the highest species richness was found in *Tf* with 39 epigean insect species while the lowest species richness was found in *Cf* with 23 species. The highest number of individuals were sampled in *Tf* and *Ta* with 841 and 440, respectively (Table 1). The results of Shannon-Wiener diversity were found to be the highest in *Ta* with 2.7893 while the lowest was found in *Ca* with 2.1775. Similar to Shannon-Wiener diversity results, Simpson diversity results were calculated as highest in Ta with 0.9196 and lowest in Ca with 0.7813. Simpson's dominance results determined that *Ca* was the highest dominant agro-ecosystem with 0.2187. The second and third most dominant agro-ecosystems were found to be *Tf* and Cf with 0.1847, 0.1635, respectively. According to both Shannon and Simpson Evenness; the population densities of epigean species living in *Bf* and *Ba* were found to be more balanced than in other agro-ecosystems (Table 1).

Table 1. Biological diversity parameter results obtained from pitfall trap in the study areas.

	Tf*	***Ta***	***Bf***	***Ba***	***Cf***	***Ca***
Species richness	39	34	26	24	23	29
No of Individuals	841	440	106	175	197	324
Diversity indices						
Shannon-Wiener[H]	2.3257	**2.7893**	2.7575	2.4618	2.2393	**2.1775**
Simpson Index[D]	0.1847	**0.0804**	0.0872	0.1269	0.1635	**0.2187**
Simpson Diversity[1-D]	0.8153	**0.9196**	0.9128	0.8731	0.8365	**0.7813**
Evenness indices						
Shannon-Evenness[EH']	0.6348	**0.7910**	**0.8464**	0.7746	0.7142	0.6467
Simpson-Evenness [ESm]	0.1388	**0.3658**	**0.4411**	0.3283	0.2659	0.1577

* *Tf*: Fennel in Tefenni Plain; *Ta*: Anise in Tefenni Plain; *Bf*: Fennel in Beyköy (Abdülmelik) Plain; *Ba*: Anise in Beyköy (Abdülmelik) Plain; *Cf*: Fennel in Çaylı Mountain Village; *Ca*: Anise in Çaylı Mountain Village

Shannon-Wiener diversity result showed high and a balanced curve in Ta and Bf if compared to others (upper left of Figure 1). It is seen that this rate is shown with the lowest curve in *Cf* and *Ca* agro-ecosystems where altitudes were the highest. Similar to Shannon-Wiener, Simpson diversity results also showed that the curve was found to be highest and stable in the *Ta* and *Bf* ranges (upper right of Figure 1). The dominance, which is inversely proportional to the diversity, was shown by the lowest curve in the *Ta* and *Bf* agro-ecosystems in contrast to the diversity. According to Simpson dominance, the highest dominance curve was seen in *Ca* (lower left of Figure 1). Shannon-evenness, which determine whether the number of individuals belonging to the species in the habitats is evenly distributed, showed that the most stable curve was between *Ta* and *Bf* as in the diversity results. It was determined that the habitat with the lowest evenness value was the *Tf* (Lower right of Figure 1).

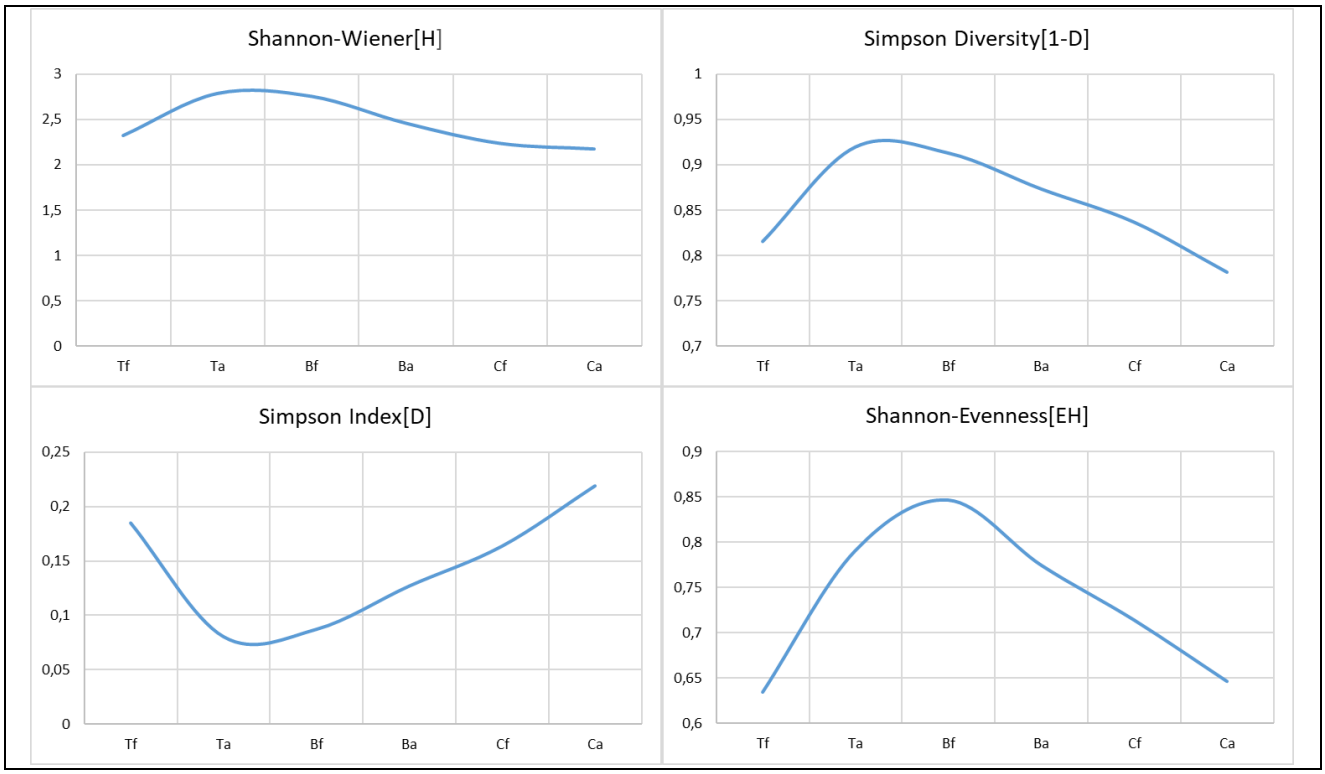

Figure 1. Results of biological diversity parameter Shannon-Wiener (upper left), Simpson diversity (upper right), Simpson dominancy (lower left), and Shannon-Evenness (lower right) with the data obtained from the pitfall traps in *Tf*, *Ta*, *Bf*, *Ba*, *Cf*, and *Ca*.

According to percent similarity the most similar agro-ecosytems were found to be *Tf-Ta* and *Ba-Bf* with 56.52% and 43.42%, respectively. *Ca* was found 29.44% similar to the group formed by *Tf* and *Ta*. Besides *Cf* was found 28.26% similar to the group formed by *Ca*, *Tf* and Ta. The node of *Ba-Bf* was found to be 21.09 % similar to the node of *Cf-Ca-Ta-Tf*. Despite having the same vegetation, fennel, *Tf* and *Bf* were calculated as the most dissimilar areas with 12.67%. *Ba* and *Tf* were found to be also one of the dissimilar agro-ecosystems with 14.37% (Figure 2).

4. Conclusions and Discussion

Species richness was highest at the lowest altitude (~1150 m) in *Tf* and *Ta*. The highest biodiversity values obtained in present study were 2.79 and 2.76 in *Ta* and *Bf*, respectively. The dominance value, which increased or decreased inversely with the diversity, was recorded as 0.22 in the highest *Ca*. Both species richness and biodiversity results measured in low altitude were found to be higher than those measured in high altitude. Our study showed that insect species and therefore diversity results were affected by altitude differences than plant canopy. The low altitude positively affected insect species richness and diversity of epigean species, while high altitude negatively affected these values. This result showed that the insect assemblages sampled during the study were composed of epigean species that were not indicator for habitat and/or plant.

There are many factors affecting species richness and biodiversity. The apple orchards with pesticide application have been found less similar than the apple orchards with organic farming [3]. The present study showed that the altitude differences of the regions were similarly grouped among themselves in terms of percent similarity index. Moreover in present study, the distribution of epigean insects was made according to altitude not plant pattern. Insect biodiversity has been lower at higher altitude than at lower altitude [29] and it changes according to plant pattern [30].

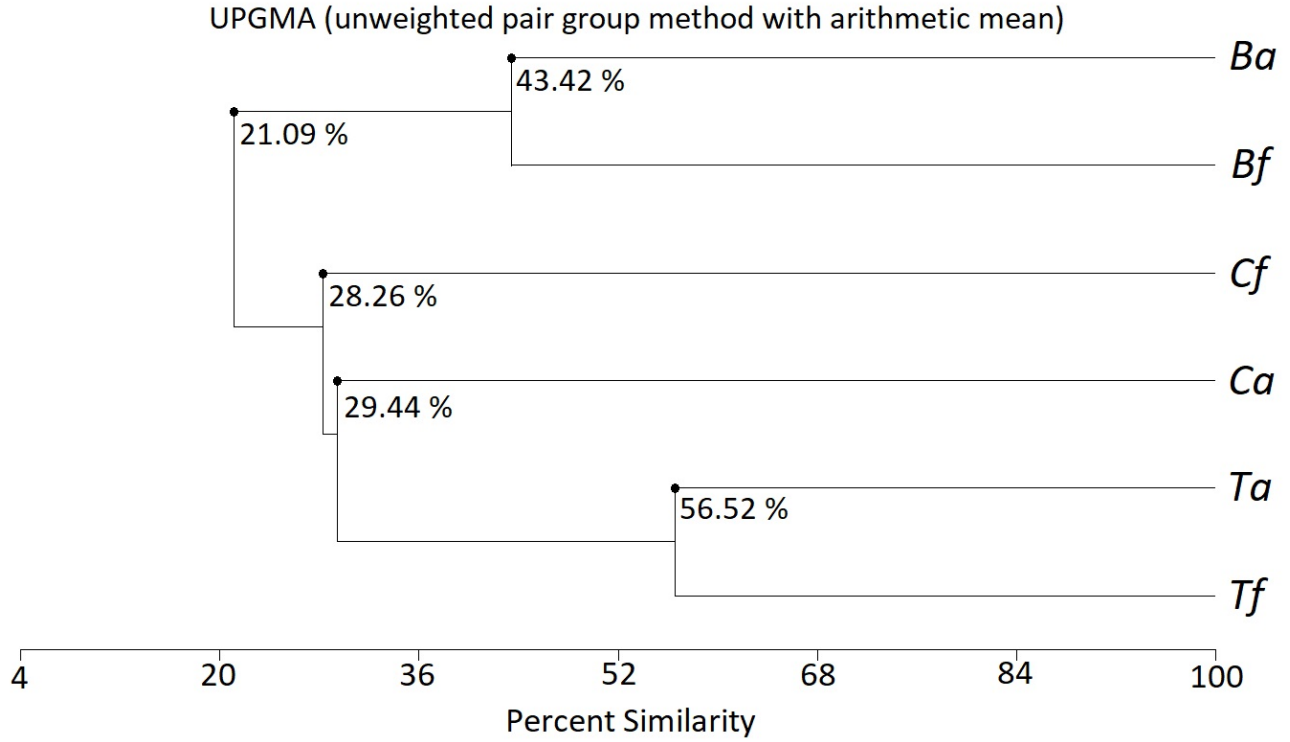

Figure 2. Percent Similarity analysis calculated considering the epigean species sampled in *Tf*, *Ta*, *Bf*, *Ba*, *Cf*, and *Ca*.

In one of the numerous studies on biodiversity has been reported that the species richness is higher in the undergrowth layer than in the forest canopy for common species [31]. Insect species richness, evenness, and diversity of the ecosystems can be affected by anthropogenic effect such as tourism, pesticide application, plant destruction, presence of roads, and many abiotic and biotic factors such as plant pattern, soil structure, climate, food, and different altitudes [1, 4, 6, 19, 21, 32, 33]. Many scientific studies show that the measured biodiversity values in natural areas are higher than in un-natural or destructed areas [2-6, 9, 11, 12, 14, 16, 20, 22]. However, there was no habitat destruction in all three regions with different geographical conditions, almost the only difference was the altitude difference.

Similarity analysis results showed that regions with different geographical conditions do not resemble each other even if they have the same plant pattern.

In the present study, it was determined that epigean insects were distributed according to different altitudes rather than plant pattern. The results from this study clearly show that the insect species sampled from different habitats are not directly related to the plant pattern. When the different regions where the plant pattern is the same are compared with each other in terms of similarity, it is seen that the similarity rates of the habitats with the same plant pattern are quite low. According to percent similarity results *Ca* was found dissimilar to *Ea* and *Ba* with 63.09% and 73.95%, respectively. Similarity analysis results obtain from the sampled epigean insect species, *Ba* was found to be 71.39% dissimilar to *Ea*. Similar results were seen in fields planted with fennel: Cf was found dissimilar to *Ef* and *Bf* with 77.84% and 72.28, respectively. It was seen that the most dissimilar habitats were Bf and Ef, which were also planted with fennel, and the result of dissimilarity was found 87.33%.

As mentioned above, many factors may affect insect diversity. In our study, it was observed that the vertical distribution of epigean insects was affected by altitude hence insect biological diversity decreased at high altitudes.

Acknowledgement

This work was supported by Research Fund of the Isparta University of Applied Sciences. Project Number: 2021 YL1-0147.

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