ISSN 1010-6960
E-ISSN 2536-491X

Türkiye Entomoloji Dergisi

Turkish Journal of Entomology

Cilt (Vol.): 45 Sayı (No.): 3 2021

Türkiye Entomoloji Dergisi
(Turkish Journal of Entomology)

Cilt (Vol.) **45** **Sayı** (No.) **3** **Eylül** (September) **2021**

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Turkish Journal of Entomology

The Turkish Journal of Entomology is a quarterly journal which has been published by the Entomological Society of Turkey. It accepts original research articles in the fields of entomology and agricultural zoology in Turkish or English.
Abstracted/Indexed in Biological Abstracts, BIOSIS Previews, CAB Abstracts, FAO AGRIS, Elsevier Scopus, Global Health, Information Reference Library, Review of Agricultural Entomology, SCI-E, TÜBİTAK/ULAKBİM, VINITI, Zoological Record.

Annual subscription price: € 75 Price of a single issue: € 20

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e-mail: dergi@entomoloji.org.tr
web : http://www.entomoloji.org.tr

Basım Yeri: META Basım 0.232 343 64 54 Bornova - İzmir

Türkiye Entomoloji Dergisi
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Cilt (Vol.) **45** **Sayı** (No.) **3** **Eylül** (September) **2021**

İçindekiler (Contents)

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Türk. entomol. derg., 2021, 45 (3): 295-304
DOI: http://dx.doi.org/10.16970/entoted.852947

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Wing shape analysis on some species of *Terellia serratulae* (L., 1758) group (Diptera: Tephritidae) based on geometric morphometric analysis

Bazı *Terellia serratulae* (L., 1758) grup (Diptera: Tephritidae) türlerinde geometrik morfometrik analiz temelli kanat şekil analizi

Mehmet YARAN [1*] **Ayça ÖZKAN KOCA[2]** **Murat KÜTÜK[3]**

Abstract

Tephritidae (fruit flies) is one of the most important Diptera families and includes more than 200 pest species. Some species in this family have a high level of similarity and are difficult to distinguish morphologically. In this study, landmark-based geometric morphometric analysis using wing images was performed on three members of the *Terellia* (*sensu stricto*) *serratulae* group in order to distinguish *Terellia fuscicornis* (Loew, 1844), *Terellia nigripalpis* Hendel, 1927, and *Terellia serratulae* (L., 1758). Specimens of the *T. fuscicornis*, *T. nigripalpis* and *T. serratulae* used in the study were collected from three provinces (İzmir, Kahramanmaraş and Adıyaman) of Turkey between 2016 and 2018. The geometric morphometric analysis of the wings, using fifteen landmarks, indicated significant differences in the wing shapes of each species, separating them successfully into distinct groups. CVA (canonical variate analysis) results based on the wing shapes strongly support the existence of taxonomically three different species. The reidentification accuracies were high, and wing shape discriminated three species of *Terellia* with over 87% accuracy. Finally, we concluded that landmark-based geometric morphometric analysis could be a powerful tool to identify *Terellia* spp.

Keywords: Geometric morphometric, Tephritidae, *Terellia*, Turkey

Öz

Tephritidae (meyve sinekleri) 200'den fazla zararlı türü içeren en önemli sinek familyalarından bir tanesidir. Bu familyadaki bazı türler yüksek seviyede benzerlik içerir ve morfolojik olarak ayrımları zordur. Bu çalışmada, *Terellia fuscicornis* (Loew, 1844), *Terellia nigripalpis* Hendel, 1927 ve *Terellia serratulae* (L., 1758) türlerini ayırt etmek için, kanat resimleri kullanılarak landmark tabanlı geometrik morfometrik analizi, *Terellia* (*sensu stricto*) *serratulae* grubunun üç üyesi üzerine uygulandı. Çalışmada kullanılan *T. fuscicornis*, *T. nigripalpis* ve *T. serratulae* bireyleri Türkiye'nin üç ilinden (İzmir, Kahramanmaraş ve Adıyaman) 2016 ve 2018 yılları arasında toplanmıştır. On beş landmark kullanılarak uygulanan geometrik morfometrik analiz, her bir türün kanat şekillerinde önemli farklılıklar olduğunu göstermiş ve türleri başarılı bir şekilde farklı gruplara ayırmıştır. Kanat şekillerine dayalı CVA (kanonikal varyete analizi) sonuçları, taksonomik olarak üç farklı türün varlığını güçlü bir şekilde desteklemektedir. Kanat şekli, *Terelllia*'nın üç türünü 87% üzerinde doğrulukla ayırt etmiş ve tekrar teşhislerin doğrulamaları yüksek bulunmuştur. Son olarak, landmark temelli geometrik morfometrik analizin *Terellia* türlerini tanımlamak için güçlü bir araç olabileceği sonucuna varılmıştır.

Anahtar sözcükler: Geometrik morfometrik, Tephritidae, *Terellia*, Türkiye

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Received (Alınış): 05.01.2021 Accepted (Kabul ediliş): 17.07.2021 Published Online (Çevrimiçi Yayın Tarihi): 27.07.2021

Introduction

The fruit fly family, Tephritidae, is one of the largest family of the Diptera and includes about 492 genera and 4,716 species (Pape et al., 2011). The genus *Terellia* Robineau-Desvoidy, 1830 includes approximately 60 species, which are widely dispersed throughout the Palearctic region (Korneyev & Merz, 1996; Norrbom et al., 1999; Korneyev, 2003, 2006; Kütük, 2009; Kütük et al., 2011; Korneyev et al., 2013; Zarghani et al., 2017; Yaran et al., 2018).

Tephritid flies are almost all phytophagous and include numerous pests of fruit and vegetable crops (Zamani & Khaghaninia, 2016). They include a number of important pest species groups that cannot be adequately identified by morphological or molecular characters (Schutze et al., 2012; Cann et al., 2015) Many species of fruit flies do not attack economically important crops and exploit the flower heads of Asteraceae plants; these are useful in the biocontrol of weeds (White & Elson-Harris, 1992; Headrick & Goeden, 1998; Zamani & Khaghaninia, 2016).

Korneyev (1985) reviewed and recognized the genus *Terellia* as having several species groups, based on similarity of structure of the male terminalia, particularly in respect to the glans of the phallus. The genus *Terellia* contains *serratulae* and *ruficauda* groups, also the Nearctic *Terellia occidentalis* (Snow, 1894) and *Terellia palposa* (Loew, 1862). All of these species have long, semi-tubular sclerites of the acrophallus and the paired flaps inside the glans sparsely covered with blunt spines as synapomorphic characters (Korneyev, 1999). According to Korneyev (1985), *serratulae* group includes seven species. These are: *Terellia serratulae* (L., 1758), *Terellia longicauda* (Meigen, 1838), *Terellia fuscicornis* (Loew, 1844), *Terellia syllibi* (Rondani, 1870), *Terellia nigripalpis* Hendel., 1927, *Terellia latigenalis* Hering, 1942, *Terellia sabroskyi* Freidberg, 1982. White (1989) revised *Terellia virens* (Loew, 1846) species group and synonymized *T. syllibi* as a junior synonym of *T. virens.* Except for *T. latigenalis,* the remaining five species of the serratulae group are widespread in Turkey (Kütük & Yaran, 2011).

The species *T. fuscicornis*, *T. nigripalpis,* and *T. serratulae* have a high level of morphological similarities, and are widespread in Turkey. However, the host plant preferences of these species are different and diverse. The artichoke fruit fly, *T. fuscicornis* is a non-frugivorous species that infest the flower heads of artichokes, *Cynara scolymus* L., 1753 and *C. syriaca* Boiss., 1846 (Asteraceae) (Freidberg & Kugler, 1989). It also infests the flower heads of milk thistle, *Silybum marianum* L., 1753 (Asteraceae) (Knio et al., 2002). In this work, we collected specimens of *T. fuscicornis* from *C. scolymus*. According to Hendel (1927), *T. nigripalpis* infests *Cirsium vulgare* (Savi) Ten, 1835 (Asteraceae), but in this study we obtained *T. nigripalpis* specimens from *Centaurea iberica* Trev. ex Sprengel, 1826 (Asteraceae) which is a new host plant for *T. nigripalpis*. Another species *T. serratulae* infests three genera of thistles: *Carduus* L., *Cirsium* Mill. and *Picnomon* Adans (Asteraceae) (Knio et al., 2002). In this study, we collected specimens of *T. serratulae* from *Picnomon acarna* L., 1753. Although *T. nigripalpis* and *T. serratulae* share *C. vulgare* as same host plant, however, the specimens collected from different host plants in this study.

Morphometry is an important method used to identify and determine speciation in insects, including fruit flies, due to its low cost and ease of applicability. In order to distinguish similar and related species, standard morphometric approaches have been used for many years and distinctive morphological characters facilitated studies of taxonomists. Over the last 15 years, geometric morphometric approaches dealing with strictly numerical multivariate analysis of morphological structures, especially the landmark method, have been actively applied to insect taxonomy, like species identification and determination of speciation levels (Wu et al., 2009). However, wings are often preferred in geometric morphometric studies on insects due to their two-dimensional distinctive venation structure, translucent and relatively solid structure.

In this study, we aimed to differentiate between three species (*T. fuscicornis*, *T. nigripalpis* and *T. serratulae*) in the *Terellia serratulae* group, which are distributed in Turkey, based on geometric morphometric analysis of the wings. Two species of the *serratulae* group, *T. longicauda* and *T. sabrosky,* were not included in the analysis because of insufficient available material. The main purpose of this study was to use geometric morphometric approach to measure wing size and shape for previously identified specimens of *T. fuscicornis*, *T. nigripalpis* and *T. serratulae,* and to determine: (1) whether wing size and shape are effective discriminators between species; (2) the extent of differences between these species based on wing analysis, and (3) if any of these species be suspected as conspecific based on morphometric shape data.

Materials and Methods

Sample collection and preparation

Three species of the *serratulae* group were chosen for analysis, *T. fuscicornis*, *T. nigripalpis* and *T. serratulae.* Samples of the species were collected from three locations in İzmir, Kahramanmaraş and Adıyaman Provinces, Turkey. Detailed information of sampling sites for all individuals are shown in Table 1.

A total of 120 females from the three species (40 of *T. fuscicornis,* 41 of *T. nigripalpis* and 39 of *T. serratulae*) were used in this study. The right wing was separated from each specimen and mounted on a slide using Entellan mounting medium. To obtain x and y coordinate scores from landmark, wing images were taken by a camera attached to Olympus SZX 12 microscope on 12.5x magnification for each specimen of wing, and saved as JPEG format.

Table 1. Collection sites in Turkey and host plants of three *Terellia* spp.

Species	N	Province	Coordinates, Altitude	Date	Host plant
T. fuscicornis	40 ♀♀	İzmir, Urla	38°18' N, 26°45' E, 95 m	28.06.2018	*Cynara scolymus*
T. nigripalpis	41 ♀♀	Kahramanmaraş, Çağlayancerit	37°44' N, 37°14' E, 1461 m	30.05.2016	*Centaurea iberica*
T. serratulae	39 ♀♀	Adıyaman, Besni	37°43' N, 37°49' E, 1022 m	07.05.2018	*Picnomon acarna*

*****N: number of individuals.

Statistical analysis

Fifteen homologous Type 1 landmarks (Figure 1) (Bookstein, 1991) were chosen for comparison following the method described by Schutze et al. (2012).

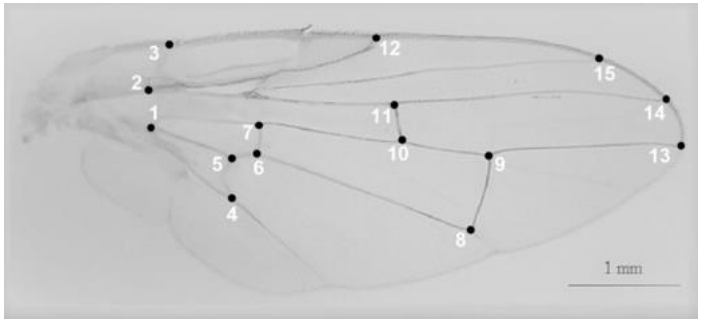

Figure 1**.** Right wing of *Terellia fuscicornis* showing each of the 15 landmarks adopted from Schutze et al. (2012).

All landmarks were digitized using the computer program tpsDig 2.12 (Rohlf, 2008) for which x, y coordinates were generated and saved as a text file (all specimens were scored by a single experimenter in order to reduce the measurement error). Thus, the geometry of shape was captured by a configuration of topographically corresponding landmarks (Marcus et al., 2000) digitized on each specimen.

Two-dimensional coordinates of the landmarks, obtained from tpsDig, were aligned using the generalized Procrustes superimposition analysis (GPA) (Rohlf & Slice, 1990; Dryden & Mardia, 1998; Rohlf, 1999). GPA removed all information of the configurations that were not related to shape, minimizing the distance between homologous landmarks by translating, rotating, and scaling all specimens. Then, shape differences in wing were tested using several statistical analyses. Size analysis was performed on the centroid size (CS) values (Bookstein, 1991), which was calculated as the square root of the summed squared distances of each landmark from the center of the landmark configuration.

Wing size differences between species were analyzed through Kruskal-Wallis test and box plots using Statistica 8.0 software (Statsoft, 2007). The landmark coordinates obtained from tpsDig were used as an input in Morpheus (Slice, 2002) and MorphoJ v.1.06 (Klingenberg, 2011) softwares. These softwares were first perform a GPA to extract shape information from the data and remove differences in orientation, position and isometric size. After GPA superimposition analysis, MANOVA (multivariate analysis of variance) and pairwise analysis was performed in Morpheus to see differences in wing shape of species. The relationship between CS and shape variation was examined by multivariate regression using MorphoJ. The statistical significance of this test was estimated by permutations using 10,000 runs (Klingenberg, 2011). The coordinates of the landmarks were also analyzed using tpsRelw 1.46 (Rohlf, 2007) to perform relative warp analysis (RWA-singular value decomposition analysis), and to calculate singular values for each principal warp and the relative contribution of each landmark. The relative similarities or dissimilarities of the *Terellia* spp. were analyzed by discriminant function analysis (DFA) and canonical variate analysis (CVA) followed by cross validation test (a leave-one-out) using MorphoJ. In order to find out the intensive deformations on the wing shape and comparison wing deformation of *Terellia* spp., the wing shape differences were illustrated on deformation grids using Morpheus software. To determine the significance of differences in the wing shapes, we performed permutation tests (10,000 runs) with Mahalanobis and Procrustes distances. The UPGMA (an unweighted pair group method with arithmetic mean; Rohlf, 2004) dendrogram was constructed by using Mahalanobis distances calculated from the DFA to show the relationships among the *Terellia* spp. based on wing shape.

Results and Discussion

Size analyses

Wing centroid size significantly differed between the three *Terellia* spp. ($F = 71.2$, $P < 0.05$). *Terellia fuscicornis* had larger wing size than *T. nigripalpis* and *T. serratulae*. *Terellia serratulae* had the smallest wing sizes (Figure 2). The Kruskal-Wallis test, based on the CS data for wing ($H = 90.0$, $P < 0.05$), also demonstrated that there are significant centroid size differences between the species. The relationship between CS and wing shape variables showed a significant, but low allometric residue: 6.9 % ($P < 0.0001$).

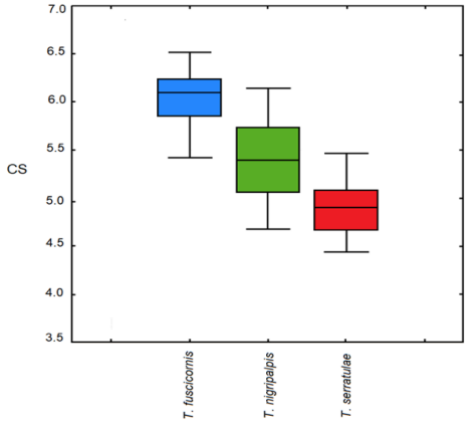

Figure 2. Size differences of three *Terellia* spp. in the wing based on geometric morphometric analysis. CS, average centroid size.

Shape analyses

Differences between the three *Terellia* spp. tested with pairwise analysis and MANOVA. For pairwise comparisons and MANOVA, individuals of these *Terellia* spp. were assigned into three species group. In the pairwise comparisons for wing shape, the differences between the species were found statistically significant ($P < 0.05$). In addition, all groups were found to be significantly different according to MANOVA (Wilks' $\lambda = 0.000$, $p < 0.05$). As a result, a significant shape differentiation was determined between the species.

In the Procrustes ANOVA test, the shape and the centroid were estimated from total variation. Procrustes ANOVA test showed that there were statistically significant differences between these *Terellia* spp. in terms of both size and shape ($P < 0.0001$). The relative warps were calculated with the data obtained from wings by using an orthogonal alignment projection method. According to the results of RWA of wings, singular values were explained by 26 relative warps. The landmarks 5, 6 and 7 were determined as having the highest relative contributions. The landmarks 8, 9 and 15 were associated with the highest variances for aligned specimens with values of $s^2 = 0.0000794$, 0.0000967 and 0.0000831, respectively, whereas landmark 5 was associated with the lowest variance ($s^2 = 0.0000170$). In RWA, individuals of *T. fuscicornis* and individuals of *T. serratulae* were in overlapping groups, while the individuals of *T. nigripalpis* formed a non-overlapping cluster with the other species (Figure 3). For wing shape, CVA resulted in separation of the three *Terellia* spp. Shape variation between the species was explained by two axes. The first and the second axes explained 68.3% and 31.7% of the total variation, respectively. On the CVA scatter plot, three groups are clearly visible: first group included individuals of *T. fuscicornis*, the second group included individuals of *T. nigripalpis*, and the third group included individuals of *T. serratulae* (Figure 4). All pairwise permutation tests performed with Mahalanobis distances revealed that a highly significant difference in the wing shape of species (Table 2; permutation test, 10,000 runs, $P < 0.0001$). With Procrustes distance estimators, we also obtained significant difference in wing shapes ($P < 0.0001$).

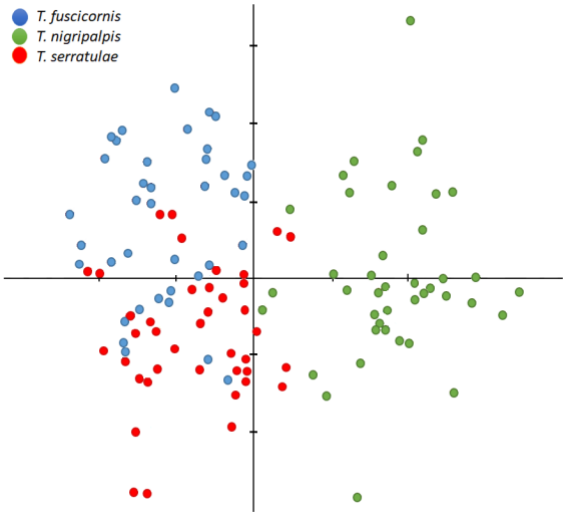

Figure 3. Two-dimensional scatter plot of relative warp analysis based on wing shape of three *Terellia* spp.

Table 2. Difference in the shape of wings of three *Terellia* spp.

Species	Mahalanobis distances			Procrustes distances		
	T. fuscicornis	*T. nigripalpis*	*T. serratulae*	*T. fuscicornis*	*T. nigripalpis*	*T. serratulae*
T. fuscicornis	-	<.0001	<.0001	-	<.0001	<.0001
T. nigripalpis	7.390	-	<.0001	0.031	-	<.0001
T. serratulae	5.760	5.764	-	0.021	0.028	-

* *P*-values above the diagonal; distances between populations below the diagonal, $P < 0.0001$ denote a significant difference.

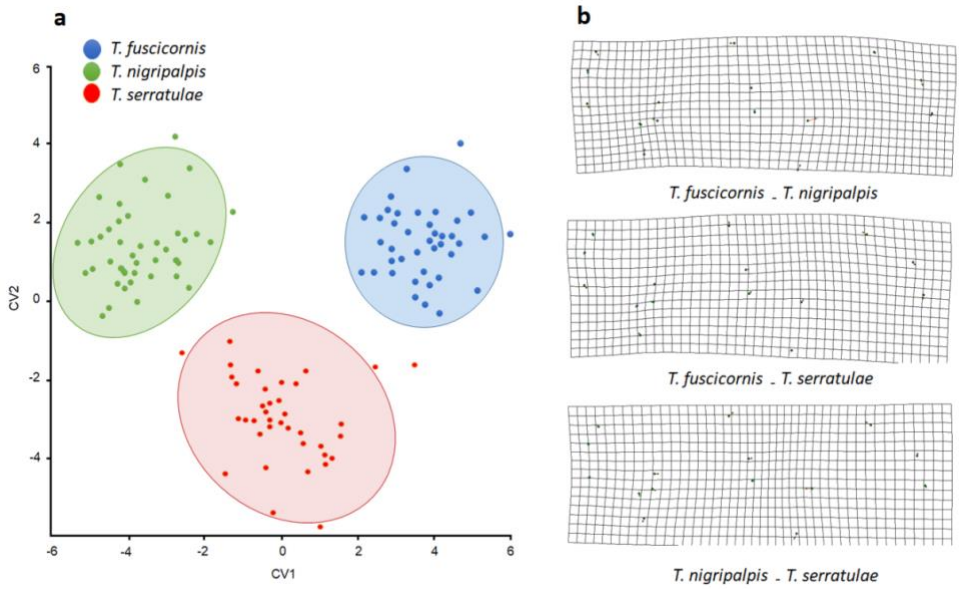

Figure 4. a) Two-dimensional scatter plot of CVA based on wing shape of three *Terellia* spp., species group are indicated by circles whose diameters represent the 95% confidence intervals around the group centroid; b) Comparison of the deformation grids for the three *Terellia* spp.

Figure 5 shows the phenetic relationships between the *Terellia* spp. based on Mahalanobis distances computed from the DFA. The phenogram resulted in two main branches. The first branch consisted of *T. fuscicornis* and *T. serratulae*; the second branch consisted of *T. nigripalpis*.

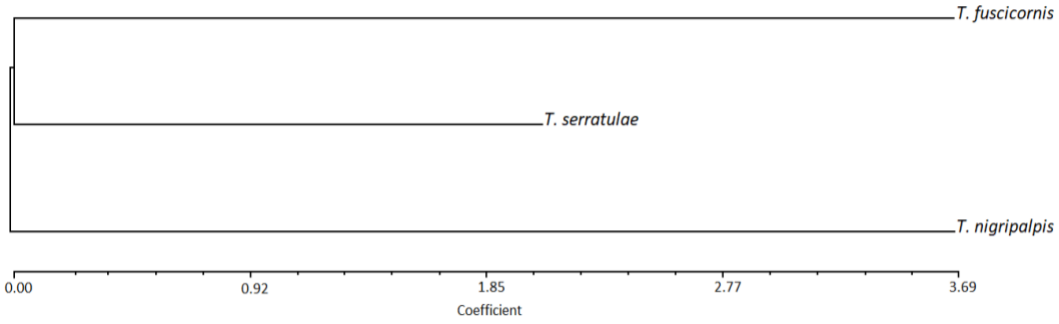

Figure 5. UPGMA phenogram showing the wing shape relationship among three *Terellia* spp. based on Mahalanobis distances.

Table 3 summarized the group assignments with respect to species, and the three *Terellia* spp. were correctly classified to their assigned groups (100%). Cross validation test based on two discriminant functions reassigned 95% of the colonies to their correct groups. The percentage of correct classifications was high for all leave-out-one cross-validated groups (*T. fuscicornis* 100%, *T. nigripalpis* 97.6% and *T. serratulae* 87.2%) (Table 4).

Table 3. Classification results of three *Terellia* spp. based on wing

Species	N	*T. fuscicornis*	*T. nigripalpis*	*T. serratulae*
T. fuscicornis	40	40 (100.0)	- (0.0)	- (0.0)
T. nigripalpis	41	- (0.0)	41 (100.0)	- (0.0)
T. serratulae	39	- (0.0)	- (0.0)	39 (100.0)

*N, number of specimens; percent classifications are in parentheses.

Table 4. Reclassification of three *Terellia* spp. based on wing

Species	N	*T. fuscicornis*	*T. nigripalpis*	*T. serratulae*
T. fuscicornis	40	40 (100.0)	- (3.4)	- (3.4)
T. nigripalpis	41	- (0.0)	40 (97.6)	1 (2.4)
T. serratulae	39	2 (5.1)	3 (7.7)	34 (87.2)

*N, number of specimens; percent classifications are in parentheses.

Multivariate identifications of the landmark-based geometric morphometric data (the shape variables) can be generated through a variety of methods (Rohlf, 1999). The thin plate spline (TPS; Bookstein, 1991) approach is another method that is a suitable way to visualize possible shape differences as smooth deformations. TPS allows mapping the deformation in shape of target region of a species group into another. When wing shape differences between the three species were illustrated by deformation grids, the deformation grids were carefully checked for wing shape, the highest deformations were seen in pairs *T. fuscicornis* and *T. nigripalpis.* The landmarks 8, 9 and 15 were associated with the three highest variances for aligned specimens on wings and these are also the points where high deformations were observed (Figure 4).

Discussion

One of the species of the *serratulae* group, *T. fuscicornis,* which occurs in many countries of the Mediterranean Basin, is closely associated with its host (Merz & Korneyev, 2004). Another species, *T. serratulae,* has wide distribution in the Palearctic region (Merz & Korneyev, 2004). However, *T. nigripalpis* only occurs in Turkey and Iran (Hendel, 1927; Görmez, 2011; Kütük & Yaran, 2011; Namin & Korneyev, 2018). These three species can be distinguished morphologically by the following characters: coloration of third segment of antenna, coloration of palpus, oviscape length and host plant (Freidberg & Kugler, 1989; Kütük & Yaran, 2011). These characters generally do not have a quantitative basis. Morphologically, the body length and wing length of male and female individuals in all three species are very similar to each other (Freidberg & Kugler, 1989; Görmez, 2011). In this study, the differences in size and wing shape of previously identified three *Terellia* spp. in Turkey were investigated by the landmark based-geometric morphometric approach. In previous studies, landmark based-geometric morphometric method was effectively applied to differentiate cryptic species [such as cryptic species of *Rhagoletis* (Yee et al., 2009), cryptic species of *Bactrocera* (Kitthawee & Rungsri, 2011; Schutze et al., 2012)], different species [such as *Bactrocera dorsalis* and *Ceratitis capitata* (Pieterse et al., 2017)] and species complex [such as *Anastrepha fraterculus* complex (Perre et al., 2014; Prezotto et al., 2019), *Ceratitis* FAR complex (Cann et al., 2015)] within the Tephritidae family. In our study, the geometric morphometric approach was applied for the first time to distinguish three species of the *serratulae* group in the genus *Terellia.* The findings show the importance of landmark based-geometric morphometric analysis in distinction of morphologically closely related species in the same taxonomic group.

Our results indicate significant wing shape and size differentiation between the three studied species of the serratulae group. The identification accuracies were complete and wing shape morphometry discriminated to three species with 100% accuracy. The higher reassignment classifications by geometric morphometric provided valuable results in clarifying morphologically closely related species. However, three *Terellia* spp. were completely separated based on the size and shape of wings. Although *T. fuscicornis,* and *T. serratulae* do not separate completely in RWA, CVA result based on the wing shape strongly support the existence of three taxonomically distinct species. All species showed intraspecific variation in RWA and CVA analyses. Individuals of all three species feed on more than one host (Freidberg & Kugler, 1989; Knio et al., 2002). Consequently, the heterogeneity in each species depends probably on host preference. Haddad et al. (2017) also investigated genetic and morphometric variations of *T. serratulae* in Lebanese populations, and emphasized that the difference in phenology between host of *T. serratulae* suggests intraspecific variation.

Insect wings are good indicators of population responses to changes that occur in their environment (Johansson et al., 2009). Thus, variation in host and population density are key factors associated with fly wing polyphenisms. Our findings clearly show that we can distinguish between *Terellia* spp. based on wing size and shape. This research is the first to study members of *Terellia* in Turkey in this way. Although the geometric morphometric approach applied in this research is a useful method, we cannot conclude that it is a sufficient method to distinguish *Terellia* spp. However, molecular tools should also be used along with size-independent characters in order to evaluate the species differentiation within the genus *Terellia.* In order to see the preference of host as environmental impact, on fly wing polyphenisms of different species new researches should be applied by using both molecular tools and size-independent characters.

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Türk. entomol. derg., 2021, 45 (3): 305-322
DOI: http://dx.doi.org/10.16970/entoted.929607

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

A faunistic study on the family Sphecidae (Hymenoptera) in the Upper Kelkit Valley with two new records and a checklist for Turkey[1]

Yukarı Kelkit Vadisi'nde Sphecidae (Hymenoptera) familyası üzerine faunistik bir çalışma, Türkiye için iki yeni kayıt ve tür kontrol listesi

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Abstract

This paper reports a study of Sphecidae (Insecta: Hymenoptera) fauna of the Upper Kelkit Valley, one of the important natural areas of Turkey. In total, 316 adult sphecid specimens were collected by insect net from various habitats in Erzincan, Giresun, Gümüşhane and Sivas Provinces between 2015-2018. The specimens were stored in Tokat Gaziosmanpaşa University Entomology Research Laboratory, Tokat, Turkey. Thirty-two taxa were identified. Of these, 12 species and subspecies are new records for the fauna of the study area, and *Ammophila gussakovskii* (Dollfuss, 2013) and *Podalonia nigrohirta* (Kohl, 1888) are recorded for the first time from Turkey. Currently, 34 species of five genera of Ammophilinae, 13 species and one subspecies of two genera of Sceliphrinae and 29 species and two subspecies of five genera of Sphecinae of Sphecidae, giving 76 species and three subspecies belonging to 12 genera, are known from Turkey. A distributional checklist of the Turkish Sphecidae is included.

Keywords: Fauna, Hymenoptera, new record, Sphecidae, Turkey

Öz

Bu makale, Türkiye'nin önemli doğal alanlarından biri olan Yukarı Kelkit Vadisi'nin Sphecidae (Insecta: Hymenoptera) faunası üzerine bir çalışmayı bildirmektedir. 2015-2018 yılları arasında Erzincan, Giresun, Gümüşhane ve Sivas illerinde çeşitli habitatlardan toplam 316 ergin sphecid örneği atrap ile toplanmıştır. Örnekler Tokat Gaziosmanpaşa Üniversitesi Entomoloji Araştırma Laboratuvarı'nda saklanmaktadır. 32 takson teşhis edilmiştir. Bunlardan 12 tür ve alttür araştırma bölgesinin faunası için yeni kayıt olup *Ammophila gussakovskii* (Dollfuss, 2013) ve *Podalonia nigrohirta* (Kohl, 1888) Türkiye'den ilk kez kaydedilmiştir. Şu anda, Türkiye'den Ammophilinae altfamilyasından beş cinse ait 34 tür, Sceliphrinae altfamilyasından 2 cinse ait 13 tür ve bir alttür ve Sphecinae altfamilyasından 5 cinse ait 29 tür ve iki alttür, toplamda ise 12 cinse ait 76 tür ve üç alttür bilinmektedir. Türkiye Sphecidae familyasına ait dağılışsal bir kontrol listesi dahil edilmiştir.

Anahtar sözcükler: Fauna, Hymenoptera, yeni kayıt, Sphecidae, Türkiye

[1] This study was a part of the PhD thesis of the first author, accepted at 07.10.2020 in Tokat Gaziosmanpaşa University and supported by Tokat Gaziosmanpasa University, Scientific Research Unit, Grant Project No: 2017/44
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Received (Alınış): 29.04.2021 Accepted (Kabul ediliş): 29.07.2021 Published Online (Çevrimiçi Yayın Tarihi): 30.07.2021

Introduction

Sphecidae includes medium to large-bodied solitary wasps belonging to the superfamily Apoidea (Hymenoptera) with 791 species identified worldwide (Pulawski, 2021). The members of this family are found in all zoogeographical regions except glaciers and they are particularly common and diverse in temperate regions. Most of the species belonging to this family are important to ecosystems in at least two ways. Firstly, they control insect and spider populations by hunting them in order to gather food for their larvae and secondly, they contribute to the pollination of flowering plants as they feed on nectar (Bohart & Menke, 1976).

Many studies have been conducted on the Turkish Sphecidae, starting from a study by Lepeletier de Saint Fargeau (1845) and other studies followed (Kohl, 1890; Fahringer & Friese, 1921; Bytinski-Salz, 1957; de Beaumont, 1967, 1969; Guichard & Harvey, 1967). The family has been extensively studied mostly faunistically by both local and international researchers over the past two decades (Gayubo & Özbek, 2005; Yıldırım & Ljubomirov, 2005, 2007; Ljubomirov & Yıldırım, 2008; Yıldırım, 2012; Bayındır et al., 2013; Dollfuss, 2013b; Gülmez & Can, 2015; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Can & Gülmez, 2019). Recently, a checklist was prepared by Yıldırım (2014), in which 67 species and subspecies were given. Following this study, new taxa have been added to the fauna and the status of some taxa have changed (Bayındır et al., 2013; Dollfuss, 2013a,b, 2015, 2016; Gülmez & Can, 2015; Can & Gülmez, 2019; Danilov & Byvaltsev, 2020). Therefore, it will be useful to present the current status of the fauna in the light of previous and recent studies.

Having a range of elevations and a variety of insect habitats, Kelkit Valley is one of the most important natural areas in Turkey (Kurt, 2006). Despite the rapid expansion of urbanization and intensive agricultural activities in the region, there are still natural areas that have not been destroyed. The upper part of the valley includes many districts of four provinces, Erzincan, Giresun, Gümüşhane, and Sivas. Since the valley is located at the intersection of three geographical regions, namely the Black Sea, Central Anatolia, and Eastern Anatolia, it has both humid and arid climatic characteristics. The valley contains Euro-Siberian vegetative elements close to the Black Sea coast, while it has Iranian-Turanian elements in the interior. Karaer & Kılınç (2001) recorded 1316 plant taxa in Kelkit Valley and reported that 132 of them were endemic species and subspecies. The diversity of climate and vegetation means that the region is also rich in insect diversity. Many species are known as endemics in the studied area (e.g. Assing, 2009; Anlaş, 2019, 2020, 2021). Also, *Prionyx radoszkowskyi* Kohl, 1888 (Sphecidae), *Lestiphorus egregius* (Handlirsch, 1893), *Crossocerus heydeni* Kohl, 1880, *Lestica eurypus* (Kohl, 1898), *Parapiagetia tridentata* Tsuneki, 1972, and *Diodontus major* Kohl, 1901 (Crabronidae) were recorded only from upper part of Kelkit Valley (Erzincan and Sivas provinces) in Turkey (Can & Gülmez, 2019; Kaplan & Yıldırım, 2021).

Despite the rich fauna of the Kelkit Valley and the presence of intensive studies in other parts of Turkey, the family Sphecidae had not been studied sufficiently in that region. Most of the previous studies are based on a limited number of specimens collected locally during short visits by scientists (de Beaumont, 1967; Gayubo & Özbek, 2005; Yıldırım & Ljubomirov, 2005, 2007; Yıldırım, 2012; Yıldırım et al., 2016; Gülmez et al., 2015; Gülmez, 2016, 2019; Can & Gülmez, 2019), so they cannot adequately represent the fauna.

The aim of the study was to determine the species of the Sphecidae family in Kelkit Valley and therefore to update the fauna of the region. This paper also presents an updated list of species in Turkey.

Materials and Methods

Field studies were conducted at locations within the boundaries of Suşehri, Akıncılar, Gölova, Zara, İmranlı, Şebinkarahisar, Çamoluk, Alucra, Şiran, Kelkit, Refahiye which constitute the Upper Kelkit Valley of Erzincan, Giresun, Gümüşhane and Sivas Provinces (Figure 1, Table 1). Adult insect specimens were

collected from their natural habitats with an insect net between 2015 and 2018. All specimens were deposited in the Entomology Research Laboratory of the Biology Department in Tokat Gaziosmanpaşa University. Specimens were identified according to Bitsch et al. (1997), Schmid-Egger (2005), Dollfuss, (2010a; 2013a). Geographical distribution of species is given according to Pulawski (2021). A list of the species is given below along with the collection date, locations, specimen numbers of each sex and global distribution. Photographs of the samples were taken with a Canon 650D camera using Sigma 105 mm F2.8 Ex Dg macro lens.

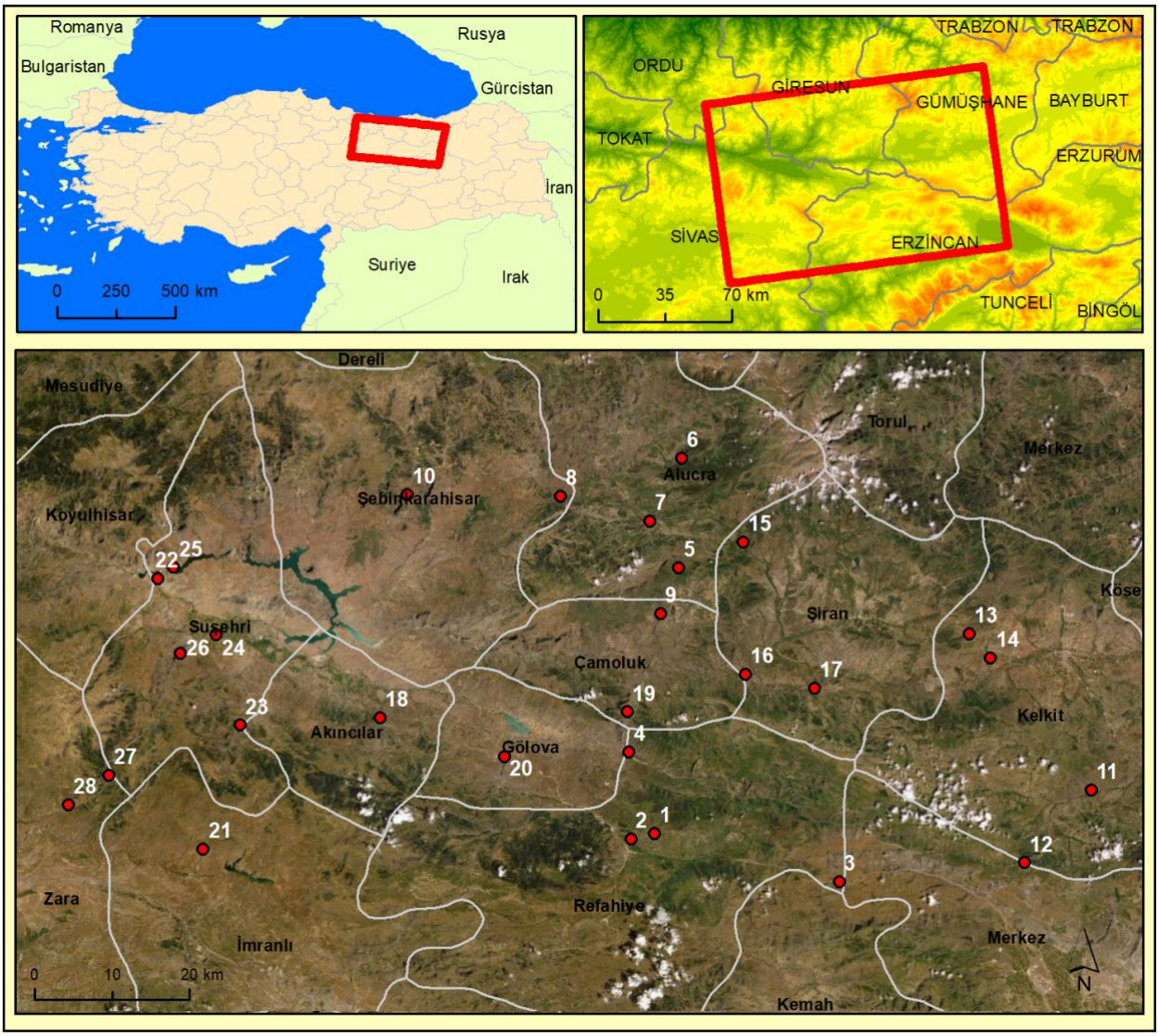

Figure 1. Map of the study area.

Table 1. Coordinates, altitude and habitat types of the collection localities in the Upper Kelkit Valley

Loc. No	Localities	Coordinates	Altitude (m)	Habitat Type
1	Erzincan, Refahiye, Akçiğdem	39°55'33" N, 38°48'46" E	1700	steppe
2	Erzincan, Refahiye, Sağlık	39°55'12" N, 38°46'37" E	1660	steppe
3	Erzincan, Refahiye, Sakaltutan	39°52'12" N, 39°05'31" E	1970	steppe
4	Erzincan, Refahiye, Çat	40°01'15" N, 38°46'26" E	1250	steppe, scrub
5	Giresun, Alucra, Arda	40°14'09" N, 38°50'56" E	1600	settlement
6	Giresun, Alucra, Gökçebel	40°21'50" N, 38°51'10" E	1610	coniferous forest
7	Giresun, Alucra, Gürbulak	40°17'24" N, 38°48'18" E	1560	steppe, scrub
8	Giresun, Alucra, Mesudiye	40°19'08" N, 38°40'08" E	1440	gallery forest
9	Giresun, Çamoluk, Hacıören	40°10'58" N, 38°49'15" E	1410	steppe, scrub
10	Giresun, Şebinkarahisar	40°19'12" N, 38°26'06" E	1250	scrub
11	Gümüşhane, Kelkit, Ağıl	39°58'33" N, 39°28'26" E	1660	steppe
12	Gümüşhane, Kelkit, Ahmediye	39°53'31" N, 39°22'19" E	2100	steppe
13	Gümüşhane, Kelkit, Çilhoroz	40°09'32" N, 39°17'24" E	1550	steppe, scrub
14	Gümüşhane, Kelkit, Kılıçtaşı	40°07'51" N, 39°19'19" E	1390	steppe
15	Gümüşhane, Şiran, Fındıkbeli	40°15'57" N, 38°56'45" E	1675	steppe
16	Gümüşhane, Şiran, Güreşköy	40°06'43" N, 38°57'00" E	1190	scrub
17	Gümüşhane, Şiran, Seydibaba	40°05'45" N, 39°03'18" E	1450	gallery forest
18	Sivas, Akıncılar, Şenbağlar	40°03'36" N, 38°23'45" E	1110	steppe
19	Sivas, Gölova, Arslanca	40°04'04" N, 38°46'15" E	1190	scrub
20	Sivas, Gölova, Çobanlı	40°00'54" N, 38°35'06" E	1290	steppe, scrub
21	Sivas, İmranlı, Aşağıçulha	39°54'18" N, 38°07'48" E	1830	steppe
22	Sivas, Suşehri, Akçaağıl	40°13'12" N, 38°03'25" E	770	steppe
23	Sivas, Suşehri, Akşar	40°02'60" N, 38°11'02" E	1110	steppe
24	Sivas, Suşehri, Aşağısarıca	40°09'18" N, 38°08'49" E	930	steppe
25	Sivas, Suşehri, Çamlıgöze	40°13'60" N, 38°04'52" E	830	steppe, scrub
26	Sivas, Suşehri, Çokrak	40°07'59" N, 38°05'35" E	1040	steppe
27	Sivas, Suşehri, Geminbeli	39°59'24" N, 37°59'10" E	2010	gallery forest
28	Sivas, Zara, Kumoğlu	39°57'18" N, 37°55'30" E	1660	steppe

Results

Subfamily Ammophilinae André, 1886

Ammophila campestris Latreille, 1809 (Figure 2a, b)

Material examined. Erzincan: Refahiye, Sağlık, 1660 m, 12.VII.2018, ♂; Refahiye, Sakaltutan, 2010 m, 27.VII.2018, ♂; Giresun: Alucra, Gürbulak, 1600 m, 13.VII.2016, ♂; Gümüşhane: Kelkit, Ağıl, 1700 m, 13.VII.2016, ♀, 8 ♂♂; Şiran, Fındıkbeli, 1875 m, 24.VII.2016, ♂; 08.VI.2017, ♂; 02.VII.2018, ♀; Sivas: Zara, Kumoğlu, 1660 m, 13.VI.2017, ♂.

Global distribution. Central and East Asia, Europe, North Africa, Siberia, Turkey (Pulawski, 2021).

Ammophila gussakovskii Dollfuss, 2013 (Figure 2c, d)

Material examined. Erzincan: Refahiye, Sakaltutan, 1970 m, 29.VI.2017, 2 ♂♂; 11.VII.2018, ♀.

Global distribution. Central Asia and Caucasus (Pulawski, 2021).

Remark: New record for Turkish fauna.

Ammophila haladai Dollfuss, 2013 (Figure 2e)

Material examined. Giresun: Çamoluk, Hacıören, 1410 m, 24.VII.2016, ♀; Sivas: Suşehri, Geminbeli, 2010 m, 29.VI.2018, ♀.

Global distribution. Russia, Turkey (Pulawski, 2021).

***Ammophila heydeni* Dahlbom, 1845 (Figure 2f, g)**

Material examined. Erzincan: Refahiye, Çat, 1250 m, 11.VIII.2016, 2 ♂♂; 01.VIII.2017, ♂; Refahiye, Sakaltutan, 1970 m, 11.VII.2018, 4 ♂♂; 27.VII.2018, ♂; Giresun: Alucra, Arda, 1600 m, 24.VII.2016, 2 ♂♂; Alucra, Gürbulak, 1600 m, 13.VII.2016, ♀, 14 ♂♂; 24.VII.2016, 10 ♂♂; 28.VI.2017, ♂; 07.VIII.2017, 3 ♂♂; 11.VI.2018, ♂; 02.VII.2018, ♂; Alucra, Mesudiye, 1470 m, 03.IX.2015, ♀; 11.VIII.2016, ♂; Çamoluk, Hacıören, 1420 m, 11.VIII.2016, ♀; Şebinkarahisar, 1300 m, 03.IX.2015, ♂; 13.VII.2016, 3 ♂♂; 24.VII.2016, ♂; 28.VI.2017, ♂; 07.VIII.2017, ♀, ♂; Gümüşhane: Kelkit, Ağıl, 1700 m, 13.VII.2016, 7 ♂♂; Kelkit, Ahmediye, 2100 m, 13.VII.2016, 2 ♂♂; Kelkit, Çilhoroz, 1550 m, 26.VII.2017, ♂; 02.VII.2018, ♂; Kelkit, Kılıçtaşı, 1390 m, 29.VI.2017, ♂; Şiran, Fındıkbeli, 1875 m, 13.VII.2016, 5 ♂♂; 24.VII.2016, ♀, 7 ♂♂; 28.VI.2017, 4 ♂♂; 11.VII.2017, ♀; Şiran, Güreşköy, 1190 m, 11.VIII.2016, ♂; 26.VII.2017, ♀, 3 ♂♂; Sivas: Akıncılar, Şenbağlar, 1110 m, 02.VII.2017, ♂; 12.VIII.2017, ♂; Gölova, Çobanlı, 1290 m, 01.VIII.2017, 3 ♀♀, 3 ♂♂; 12.VIII.2017, ♀; İmranlı, Aşağıçulha, 1830 m, 29.VI.2018, ♂; Suşehri, Akşar, 1110 m, 02.VII.2017, ♂; Suşehri, Aşağısarıca, 930 m, 17.V.2018, ♂; Suşehri, Çamlıgöze, 830 m, 06.VIII.2015, ♂; 13.V.2017, ♂; 05.VI.2017, ♀; 08.VI.2017, ♂; 07.VIII.2017, ♂; 02.VI.2018, ♀; Suşehri, Geminbeli, 2010 m, 18.VII.2017, ♂; 24.VII.2017, ♂; 01.VIII.2017, ♂; 17.VII.2018, 6 ♂♂.

Global distribution. Asia, Europe, North Africa and Turkey (Pulawski, 2021).

***Ammophila mongolensis* Tsuneki, 1971 (Figure 2h)**

Material examined. Giresun: Şebinkarahisar, 1300 m, 03.IX.2015, ♀.

Global distribution. Central and Eastern Asia, Turkey (Pulawski, 2021).

***Ammophila sabulosa* (L., 1758) (Figure 2i, j)**

Material examined. Erzincan: Refahiye, Sakaltutan, 1970 m, 11.VII.2018, ♂; Giresun: Alucra, Gökçebel, 1600 m, 03.IX.2015, ♂; Alucra, Gürbulak, 1560 m, 13.VII.2016, 2 ♂♂; 11.VI.2018, 2 ♂♂; Çamoluk, Hacıören, 1410 m, 24.VII.2016, ♂; Şebinkarahisar, 1300 m, 13.VII.2016, ♂; 24.VII.2016, ♀; 07.VIII.2017, 3 ♂♂; 24.VII.2018, ♀; Gümüşhane: Şiran, Fındıkbeli, 1875 m, 08.VI.2017, ♂; Sivas: Akıncılar, Şenbağlar, 1110 m, 05.VI.2017, 2 ♂♂; Gölova, Çobanlı, 1290 m, 12.VIII.2017, 3 ♂♂; Suşehri, Akçaağıl, 770 m, 12.VIII.2017, ♂; Suşehri, Akşar, 1110 m, 08.VI.2017, ♂; Suşehri, Aşağısarıca, 930 m, 17.V.2018, ♂; Suşehri, Çamlıgöze, 830 m, 06.VIII.2015, 2 ♀♀; Suşehri, Geminbeli, 2010 m, 18.VII.2017, ♀, ♂; 24.VII.2017, ♀; 01.VIII.2017, 3 ♂♂; 29.VI.2018, 2 ♂♂; 17.VII.2018, 6 ♂♂.

Global distribution. Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Ammophila striata* Mocsáry, 1879 (Figure 2k)**

Material examined. Gümüşhane: Kelkit, Ağıl, 1700 m, 13.VII.2016, ♂.

Global distribution. Central Asia, Southern Europe, Russia, and Turkey (Pulawski, 2021).

***Ammophila terminata* F. Smith, 1856 (Figure 2l)**

Material examined. Gümüşhane: Kelkit, Ağıl, 1700 m, 13.VII.2016, ♀.

Global distribution. Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Hoplammophila armata* (Illiger, 1807) (Figure 2m)**

Material examined. Sivas: Suşehri, Çamlıgöze, 830 m, 06.VIII.2015, ♂; 03.VIII.2016, ♂.

Global distribution. Europe, Iran, Russia, Turkey (Pulawski, 2021).

***Hoplammophila clypeata* (Mocsáry, 1883) (Figure 2n)**

Material examined. Giresun: Alucra, Gürbulak, 1560 m, 11.VI.2018, ♂.

Global distribution. Europe, North Africa and Turkey (Pulawski, 2021).

***Podalonia alpina* (Kohl, 1888) (Figure 2o)**

Material examined. Sivas: Gölova, Çobanlı, 1290 m, 12.VIII.2017, ♂.

Global distribution. Central and East Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Podalonia fera* (Lepeletier de Saint Fargeau, 1845) (Figure 2p, q)**

Material examined. Erzincan: Refahiye, Çat, 1250 m, 01.VIII.2017, 5 ♂♂; Giresun: Alucra, Mesudiye, 1440 m, 03.IX.2015, ♂; Şebinkarahisar, 1300 m, 03.IX.2015, 2 ♀♀; Sivas: Akıncılar, Şenbağlar, 1140 m, 12.VIII.2017, 2 ♂♂; Suşehri, Çokrak, 1040 m, 24.VII.2017, ♀.

Global distribution. Central Asia, Europe, Russia and Turkey (Pulawski, 2021).

***Podalonia hirsuta* (Scopoli, 1763) (Figure 2r,s)**

Material examined. Erzincan: Refahiye, Sakaltutan, 2010 m, 14.VI.2016, 2 ♂♂; 27.VII.2018, ♀; Gümüşhane: Şiran, Fındıkbeli, 1875 m, 28.VI.2017, ♀; 11.VII.2017, ♂; Sivas: Akıncılar, Şenbağlar, 1110 m, 16.IV.2017, 4 ♀♀; Gölova, Çobanlı, 1290 m, 12.VIII.2017, ♂; Suşehri, Aşağısarıca, 930 m, 16.IV.2017, ♀; Suşehri, Çamlıgöze, 830 m, 25.IV.2018, ♀; 29.IV.2018, ♀; 02.VI.2018, 4 ♂♂; Suşehri, Geminbeli, 2010 m, 17.VII.2018, 5 ♂♂.

Global distribution. Central and East Asia, Europe, Russia and Turkey (Pulawski, 2021).

***Podalonia nigrohirta* (Kohl, 1888) (Figure 2t)**

Material examined. Erzincan: Refahiye, Sakaltutan, 1900 m, 29.VI.2017, ♂.

Global distribution. Central Asia (Pulawski, 2021).

Remark: New record for Turkish fauna.

***Podalonia tydei* (Le Guillou, 1841) (Figure 2u, v)**

Material examined. Sivas: Gölova, Çobanlı, 1290 m, 17.IX.2015, ♀, ♂; Zara, Kumoğlu, 1660 m, 09.VIII.2016, ♀.

Global distribution. Africa, Arabian Peninsula, Asia, Cyprus, Madagascar, Russia and Turkey (Pulawski, 2021).

Subfamily Sceliphrinae Ashmead, 1899

***Chalybion femoratum* (Fabricius, 1781) (Figure 2w)**

Material examined. Sivas: Suşehri, Akşar, 1110 m, 24.VII.2017, 2 ♀♀.

Global distribution. Central and East Asia, Europe, North Africa and Turkey (Pulawski, 2021).

***Chalybion flebile* (Lepeletier de Saint Fargeau, 1845) (Figure 2x)**

Material examined. Sivas: Suşehri, Çokrak, 1040 m, 17.VII.2018, ♂.

Global distribution. Arabian Peninsula, Central Asia, Cyprus, North Africa, South Europe and Turkey (Pulawski, 2021).

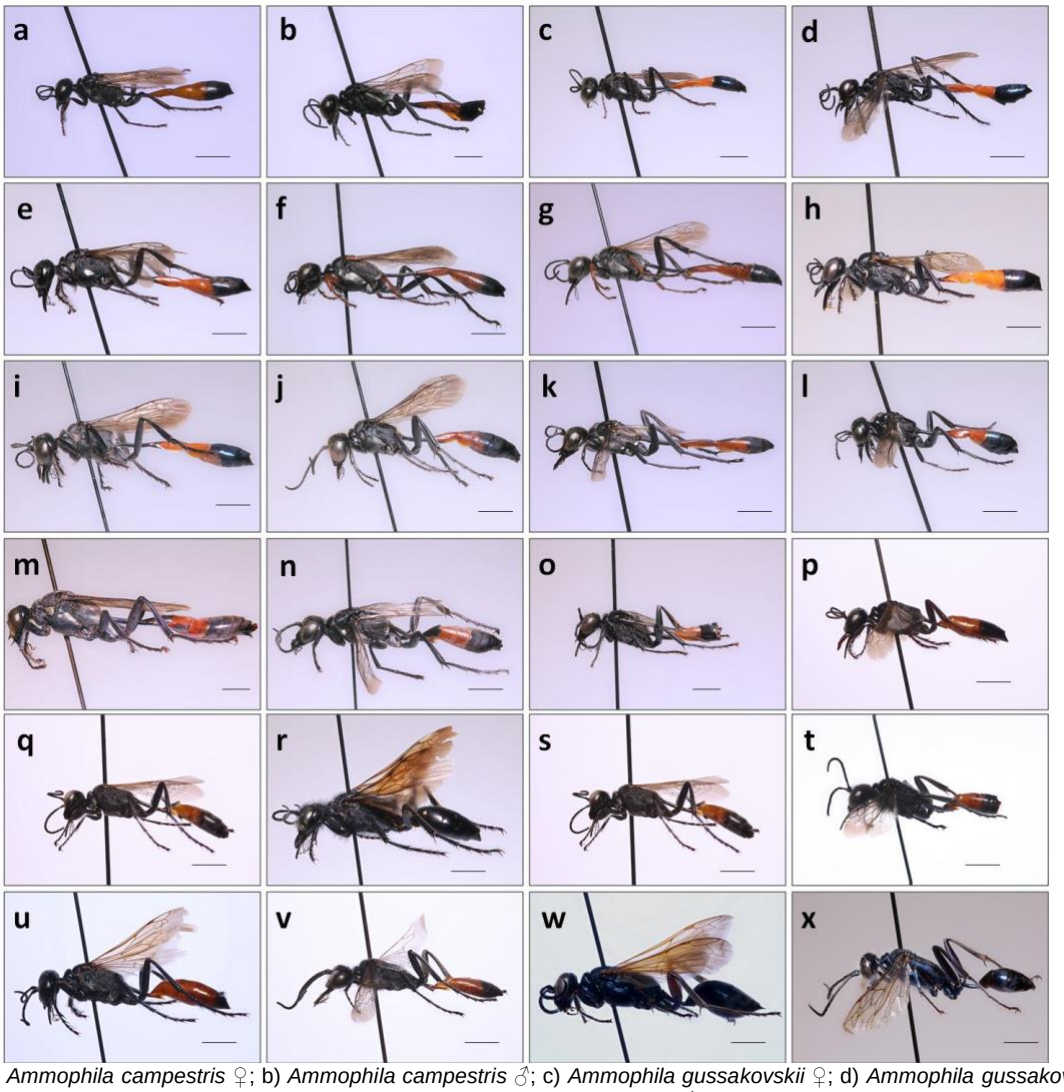

Figure 2. a) *Ammophila campestris* ♀; b) *Ammophila campestris* ♂; c) *Ammophila gussakovskii* ♀; d) *Ammophila gussakovskii* ♂; e) *Ammophila haladai* ♀; f) *Ammophila heydeni* ♀; g) *Ammophila heydeni* ♂; h) *Ammophila mongolensis* ♀; i) *Ammophila sabulosa* ♀; j) *Ammophila sabulosa* ♂; k) *Ammophila striata* ♂; l) *Ammophila terminata* ♀; m) *Hoplammophila armata* ♂; n) *Hoplammophila clypeata* ♂; o) *Podalonia alpina* ♂; p) *Podalonia fera* ♀; q) *Podalonia fera* ♂; r) *Podalonia hirsuta* ♀; s) *Podalonia hirsuta* ♂; t) Podalonia nigrohirta ♂; u) *Podalonia tydei* ♀; v) *Podalonia tydei* ♂; w) *Chalybion femoratum* ♀; and x) *Chalybion flebile* ♂ (scale bars: 2 mm).

***Sceliphron arabs* (Lepeletier de Saint Fargeau, 1845) (Figure 3a)**

Material examined. Sivas: Suşehri, Çamlıgöze, 830 m, 06.VIII.2015, ♀.

Global distribution. Georgia, Iraq, Iran, Turkey (Pulawski, 2021).

***Sceliphron curvatum* (F. Smith, 1870) (Figure 3b)**

Material examined. Giresun: Şebinkarahisar, 1250 m, 20.VII.2017, ♀.

Global distribution. Central and East Asia, Europe, South America, Russia and Turkey (Pulawski, 2021).

***Sceliphron destillatorium* (Illiger, 1807) (Figure 3c, d)**

Material examined. Erzincan: Refahiye, Akçiğdem, 1700 m, 13.VII.2017, ♀; Refahiye, Sakaltutan, 1975 m, 12.VII.2018, 2 ♀♀, ♂; 27.VII.2018, 2 ♂♂; Giresun: Çamoluk, Arslanca, 1180 m, 28.VI.2017, ♀; Çamoluk, Hacıören, 1410 m, 20.VII.2017, ♀; 28.VI.2017, ♀; Gümüşhane: Şiran, Seydibaba, 1450 m, 03.VII.2018, ♂; Sivas: Akıncılar, Şenbağlar, 1140 m, 11.VII.2018, ♀; İmranlı, Aşağıçulha, 1830 m, 18.VII.2017, ♀; Suşehri, Akşar, 1110 m, 24.VII.2017, 2 ♀♀; Suşehri, Aşağısarıca, 930 m, 02.VI.2018, ♀; 05.VII.2018, ♂; Suşehri, Çokrak, 1140 m, 05.VII.2018, 2 ♂♂.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, North Africa and Turkey (Pulawski, 2021).

***Sceliphron funestum* Kohl, 1918 (Figure 3e)**

Material examined. Sivas: Suşehri, Çokrak, 1040 m, 05.VII.2018, ♀.

Global distribution. Greece, Iran, Turkey (Pulawski, 2021).

***Sceliphron madraspatanum tubifex* (Latreille, 1809) (Figure 3f)**

Material examined. Sivas: Akıncılar, Şenbağlar, 1140 m, 01.VIII.2017, ♀.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, Russia and Turkey (Pulawski, 2021).

Subfamily Sphecinae

***Palmodes occitanicus* (Lepeletier de Saint Fargeau & Serville, 1828) (Figure 3g)**

Material examined. Giresun: Alucra, Mesudiye, 1440 m, 02.VII.2018, ♂; Sivas: Suşehri, Boyalıca, 980 m, 18.VII.2017, ♂.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Palmodes strigulosus* (A. Costa, 1861) (Figure 3h)**

Material examined. Erzincan: Refahiye, Çat, 1250 m, 26.VII.2017, ♀; Giresun: Şebinkarahisar, 1210 m, 13.VII.2016, ♀.

Global distribution. Arabian Peninsula, Central Asia, Europe, Russia and Turkey (Pulawski, 2021).

***Prionyx kirbii* (Vander Linden, 1827) (Figure 3i, j)**

Material examined. Giresun: Alucra, Gürbulak, 1560 m, 07.VIII.2017, ♀, ♂; Çamoluk, Hacıören, 1410 m, 24.VII.2016, 2 ♀♀; 11.VIII.2016, 3 ♂♂; Şebinkarahisar, 1200 m, 07.VIII.2017, ♀, 5 ♂♂; Gümüşhane: Kelkit, Çilhoroz, 1550 m, 02.VII.2018, ♂; Kelkit, Kılıçtaşı, 1380 m, 29.VI.2017, ♂; Sivas: Gölova, Çobanlı, 1290 m, 12.VIII.2017, ♂; Suşehri, Aşağısarıca, 830 m, 13.VI.2017, ♂; Suşehri, Çamlıgöze, 830 m, 11.VII.2017, ♀; 07.VIII.2017, 6 ♀♀, 3 ♂♂; Suşehri, Çokrak, 1040 m, 17.VII.2018, ♂.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, North and South Africa, Russia and Turkey (Pulawski, 2021).

***Prionyx lividocinctus* (A. Costa, 1861) (Figure 3k)**

Material examined. Gümüşhane: Şiran, Güreşköy, 1190 m, 11.VIII.2016, ♀.

Global distribution. Arabian Peninsula, Central Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Prionyx nudatus* (Kohl, 1885) (Figure 3l, m)**

Material examined. Erzincan: Refahiye, Çat, 1250 m, 01.VIII.2017, ♀; 26.VII.2017, 2 ♀♀; Refahiye, Sakaltutan, 1970 m, 11.VII.2018, 2 ♂♂; Giresun: Alucra, Gökçebel, 1600 m, 03.IX.2015, ♀; Şebinkarahisar, 1300 m, 03.IX.2015, ♀, ♂; Sivas: Akıncılar, Şenbağlar, 1140 m, 02.VI.2018, ♂; Gölova, Çobanlı, 1290 m, 12.VIII.2017, ♀; Suşehri, Boyalıca, 930 m, 22.VIII.2015, ♂.

Global distribution. Central and East Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Sphex flavipennis* Fabricius, 1793 (Figure 3n, o)**

Material examined. Erzincan: Refahiye, Çat, 1250 m, 01.VIII.2017, ♂; Giresun: Şebinkarahisar, 1200 m, 24.VII.2016, ♀; 20.VII.2017, 2 ♂; 24.VII.2018, ♀; Gümüşhane: Kelkit, Çilhoroz, 1550 m, 02.VII.2018, ♂; Şiran, Güreşköy, 1190 m, 11.VIII.2016, ♂; Sivas: Akıncılar, Şenbağlar, 1140 m, 30.VIII.2016, ♂; 01.VIII.2017, ♀, 2 ♂♂; 12.VIII.2017, 3 ♀♀; 11.VII.2018, 2 ♂♂; Suşehri, Boyalıca, 980 m, 18.VII.2017, ♀, 2 ♂♂; Suşehri, Çamlıgöze, 830 m, 11.VII.2017, ♂; Suşehri, Çokrak, 1040 m, 05.VII.2018, ♂.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Sphex fumicatus* Christ, 1791 (Figure 3p)**

Material examined. Sivas: Suşehri, Çokrak, 1040 m, 19.VI.2016, 2 ♀♀.

Global distribution. Africa, Arabian Peninsula, Central and East Asia, Europe, Sourh America, Russia and Turkey (Pulawski, 2021).

***Sphex funerarius* Gussakovskij, 1934 (Figure 3q, r)**

Material examined. Giresun: Alucra, Mesudiye, 1530 m, 03.IX.2015, ♂; Şebinkarahisar, 1200 m, 07.VIII.2017, ♀; Gümüşhane: Şiran, Güreşköy, 1190 m, 11.VIII.2016, 2 ♀♀; Sivas: Akıncılar, Şenbağlar, 1140 m, 01.VIII.2017, ♀; 12.VIII.2017, 3 ♀♀.

Global distribution. Arabian Peninsula, Central and East Asia, Europe, North Africa, Russia and Turkey (Pulawski, 2021).

***Sphex melanocnemis* Kohl, 1885 (Figure 3s)**

Material examined. Sivas: Akıncılar, Şenbağlar, 1140 m, 01.VIII.2017, 2 ♀♀; Gölova, Çobanlı, 1290 m, 11.VIII.2018, ♀; Suşehri, Çokrak, 1040 m, 05.VII.2018, ♀.

Global distribution. China, Israel, Jordan, Syria, Turkey (Pulawski, 2021).

***Sphex pruinosus* Germar, 1817 (Figure 3t)**

Material examined. Sivas: Akıncılar, Şenbağlar, 1140 m, 30.VIII.2016, ♂; 12.VIII.2017, ♂; Suşehri, Boyalıca, 980 m, 18.VII.2017, ♂.

Global distribution. Africa, Arabian Peninsula, Central and East Asia, Cyprus, Europe and Turkey (Pulawski, 2021).

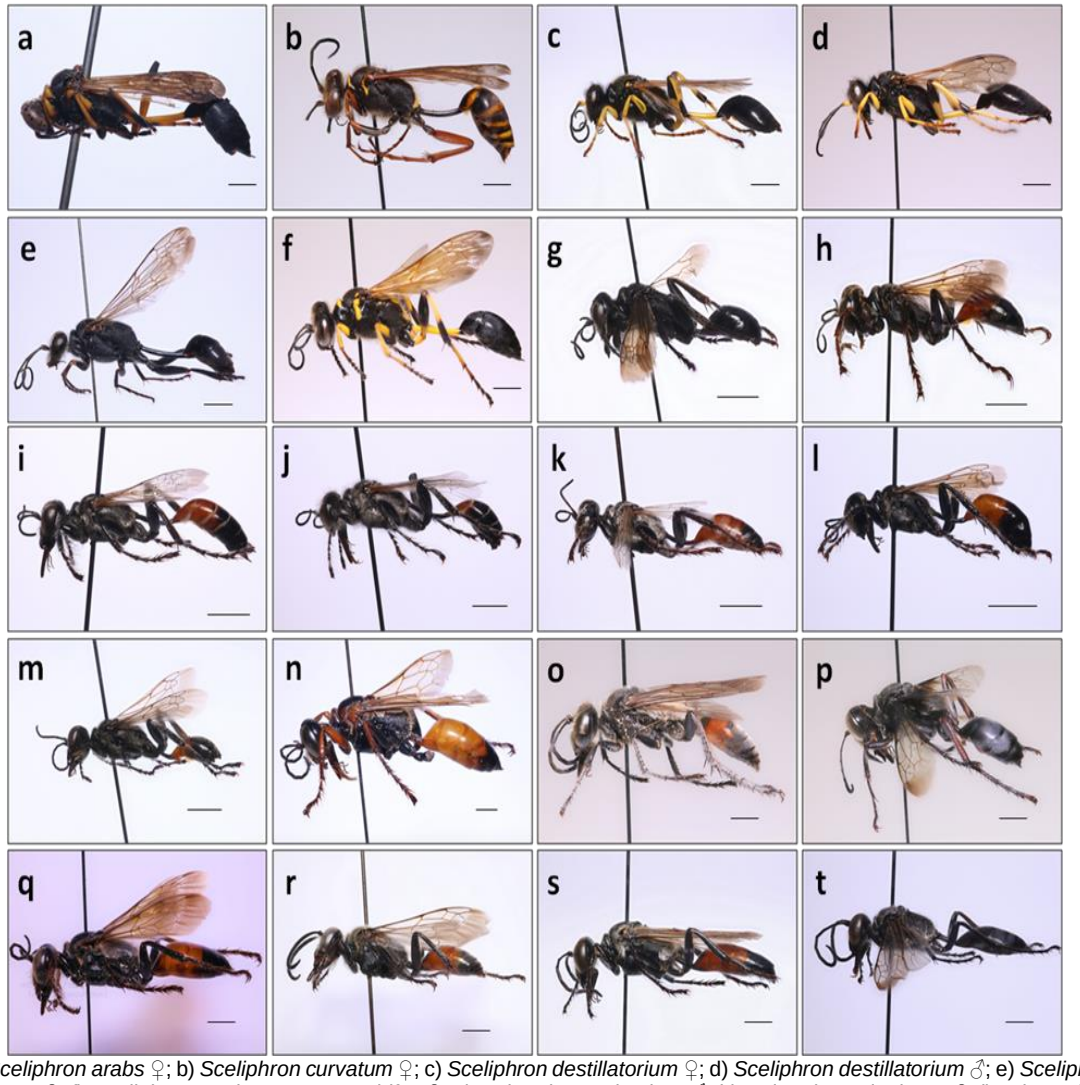

Figure 3. a) *Sceliphron arabs* ♀; b) *Sceliphron curvatum* ♀; c) *Sceliphron destillatorium* ♀; d) *Sceliphron destillatorium* ♂; e) *Sceliphron funestum* ♀; f) *Sceliphron madraspatanum tubifex* ♀; g) *Palmodes occitanicus* ♂; h) *Palmodes strigulosus* ♀; i) *Prionyx kirbii* ♀; j) *Prionyx kirbii* ♂; k) *Prionyx lividocinctus* ♀; l) *Prionyx nudatus* ♀; m) *Prionyx nudatus* ♂; n) *Sphex flavipennis* ♀; o) *Sphex flavipennis* ♂; p) *Sphex fumicatus* ♀; q) *Sphex funerarius* ♀; r) *Sphex funerarius* ♂; s) *Sphex melanocnemis* ♀; and t) *Sphex pruinosus* ♂ (scale bars: 2 mm).

Discussion

Thirty-two species and subspecies in eight genera of Sphecidae were determined from Upper Kelkit Valley. Of these, 12 are new records for the provinces in the region. *A. gussakovskii* and *P. nigrohirta* were also recorded for the first time for Turkish fauna, so the number of taxa belonging to the family was raised to 79. Prior to this study, Sphecidae family had been represented by 33 species in the provinces sampled. New species records were added to the fauna of these provinces; therefore, distribution areas of some previously known species in Turkey have been expanded (Figure 4). The most widespread species in the studied area were *A. heydeni*, *A. sabulosa, P. hirsuta* and *P. kirbii*.

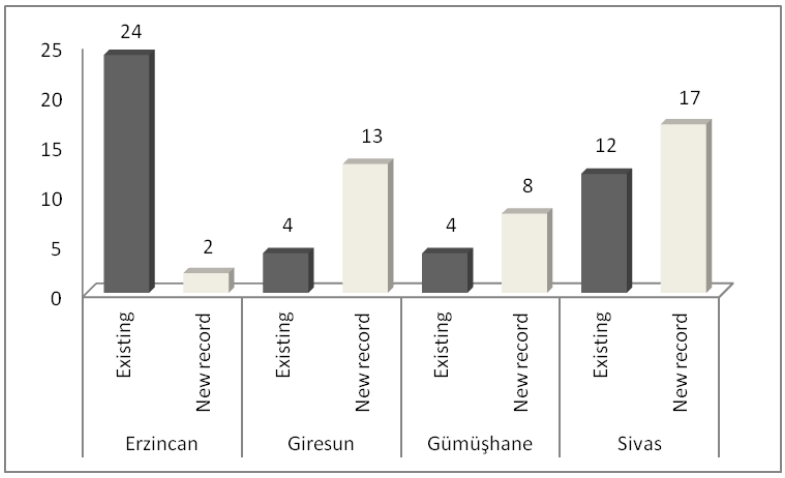

Figure 4. Number of existing and newly recorded species from the Sphecidae family in the study area.

Kelkit Valley forms a narrow corridor through which Central Asian and Caucasian fauna elements cross to Central Anatolia (Demirsoy, 2002). The two species, *A. gussakovskii* and *P. nigrohirta*, which are new records for Turkey, originally spread in Central Asia and the Caucasus (Pulawski, 2021). Since they are firstly determined in the Kelkit Valley in Turkey, they most likely reached the country recently during their westward spread. For now, Erzincan province is the westernmost distribution point of the species in the Palearctic region.

Vertical distribution of the species in the research area ranged from 800 to 2100 m. The largest number of samples were collected between 1000 and 1200 m. Most likely, elevations in these ranges have favorable habitats and suitable climatic conditions for most of the species. The cosmopolitan species, including *A. heydeni, A. sabulosa, P. hirsuta, S. destillatorium* and *P. nudatus*, were found at almost all altitudes in the region, while *A. gussakovskii* and *P. nigrohirta* were only found in locations above 1900 m (Figure 5).

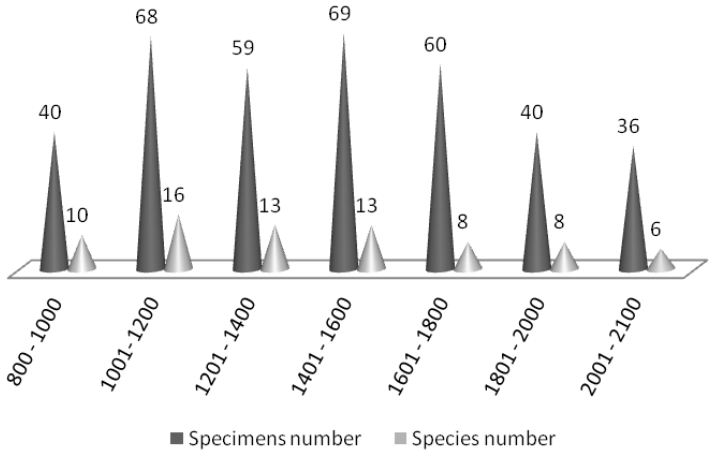

Figure 5. Vertical distribution of the detected species in the research area.

In the present study, Turkey Sphecidae species list has been updated. The taxa added to the Turkish Sphecidae fauna following the recent list prepared by Yıldırım (2014) and the modifications in the names of species/subspecies are included in our study. With the two newly recorded species in this study, the number of species and subspecies belonging to the Specidae is reached to 79 in 12 genera (Table 2) in Turkey.

Table 2. Current species list of Sphecidae in Turkey

Taxon	Distribution in Turkey	References
Subfamily Ammophilinae		
Genus *Ammophila* W. Kirby, 1798		
Ammophila assimilis Kohl, 1901	Adana, Antalya, Mersin	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Dollfuss, 2015
Ammophila barbara (Lepeletier de Saint Fargeau, 1845)	Ağrı, Ankara, Bayburt, Bitlis, Erzincan, Isparta, Konya, Muş, Nevşehir, Osmaniye	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Dollfuss, 2013b, 2015; Yıldırım et al., 2016
Ammophila campestris Latreille, 1809	Ankara, Bolu, Bursa, Erzurum, Gümüşhane, Kahramanmaraş, Kars, Kayseri, Mersin, Sivas, Trabzon	Ljubomirov & Yıldırım, 2008; Dollfuss, 2013b; Yıldırım, 2014; Yıldırım et al., 2016
Ammophila elongata Fischer de Waldheim, 1843	Van	Dollfuss, 2013a, 2013b
Ammophila gracillima Taschenberg, 1869	Iğdır	Yıldırım et al., 2016
Ammophila gussakovskii Dollfuss, 2013	Erzincan	Present data
Ammophila haladai Dollfuss, 2013	Bolu, Erzincan, Isparta, Kars, Konya, Mersin, Nevşehir, Van	Dollfuss, 2013a, 2013b
Ammophila heydeni Dahlbom, 1845	Adana, Afyonkarahisar, Amasya, Ankara, Antalya, Artvin, Aydın, Bayburt, Bilecik, Bingöl, Bitlis, Bursa, Çankırı, Çorum, Edirne, Erzincan, Erzurum, Gümüşhane, Hatay, Iğdır, İstanbul, İzmir, Kahramanmaraş, Karaman, Kars, Kastamonu, Kayseri, Kırşehir, Konya, Kütahya, Malatya, Mersin, Muş, Nevşehir, Niğde, Sakarya, Sivas, Sinop, Şanlıurfa, Tekirdağ	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2012; Bayındır et al., 2013; Dollfuss, 2013b, 2015; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Gülmez, 2019
Ammophila hungarica Mocsáry, 1883	Adana, Amasya, Ankara, Aydın, Bursa, Erzincan, Erzurum, Gaziantep, İstanbul, İzmir, Konya, Mersin, Muğla, Osmaniye, Sivas	Ljubomirov & Yıldırım, 2008; Dollfuss, 2013b; Gülmez, 2019
Ammophila mongolensis Tsuneki, 1979	Sivas	Dollfuss, 2013b
Ammophila pubescens Curtis, 1836	Ağrı, Erzurum, Kars, Nevşehir, Niğde	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Dollfuss, 2013b
Ammophila sabulosa (L., 1758)	Adana, Aksaraya, Amasya, Ankara, Antalya, Artvin, Aydın, Balıkesir, Bayburt, Bilecik, Bolu, Bursa, Çankırı, Erzincan, Erzurum, Eskişehir, Iğdır, Isparta, İstanbul, İzmir, Kahramanmaraş, Kars, Kocaeli, Konya, Kütahya, Mersin, Manisa, Muş, Rize, Tokat, Trabzon, Tunceli, Van, Zonguldak	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012; Bayındır et al., 2013; Dollfuss, 2013b; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Gülmez, 2019; Örgel et al., 2020
Ammophila sareptana Kohl, 1884	Ankara, Çankırı, Erzurum, Kırşehir, Kütahya, Mersin, Sivas, Tekirdağ	Ljubomirov & Yıldırım, 2008; Dollfuss, 2013b; Yıldırım et al., 2016
Ammophila sinensis Sickmann, 1894	Erzincan, Erzurum	Ljubomirov & Yıldırım, 2008; Yıldırım, 2012
Ammophila striata Mocsáry, 1878	Kahramanmaraş, Konya, Kütahya, Sivas, Van	Ljubomirov & Yıldırım, 2008; Gülmez, 2019
Ammophila terminata F. Smith, 1856	Ankara, Antalya, Bayburt, Bursa, Erzurum, İstanbul, Kars, Mersin, Niğde, Nevşehir, Van	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2012; Dollfuss, 2013b; Yıldırım et al., 2016; Gülmez, 2019
Ammophila theryi (Gribodo, 1894)	Konya	Ljubomirov & Yıldırım, 2008
Ammophila vagabunda F. Smith, 1856	Niğde	Dollfuss, 2013b
Genus *Eremochares* Gribodo, 1883		
Eremochares dives (Brullé, 1833)	Ankara, Denizli, Konya, Mersin, Niğde	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b
Genus *Hoplammophila* de Beaumont 1960		
Hoplammophila aemulans (Kohl, 1901)	Muğla	Dollfuss, 2015
Hoplammophila anatolica de Beaumont, 1960	Antalya, Mersin	Ljubomirov & Yıldırım, 2008
Hoplammophila armata (Illiger, 1807)	Artvin, Hakkari, Konya, Mersin, Samsun, Sivas, Tokat	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b; Gülmez & Dizer, 2016; Gülmez, 2019
Hoplammophila clypeata (Mocsáry, 1883)	Mersin, Tekirdağ, Tokat, Tunceli	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b; Gülmez & Dizer, 2016; Yıldırım et al., 2016

Table 2. (Continued)

Taxon	Distribution in Turkey	References
Genus *Parapsammophila* Taschenberg, 1869		Dollfuss, 2013a, 2013b
Parapsammophila caspica (Gussakovskij, 1930)	Mersin	Dollfuss, 2010b
Genus *Podalonia* Fernald, 1927		
Podalonia affinis (Kirby, 1798)	Amasya, Ankara, Antalya, Ardahan, Artvin, Bayburt, Bursa, Erzurum, Iğdır, Kars, Kayseri, Mersin, Nevşehir, Sivas, Tokat, Trabzon	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b, 2013b; Tüzün & Yüksel, 2010; Gülmez & Dizer, 2016; Yıldırım et al., 2016
Podalonia alpina (Kohl, 1888)	Erzurum, Gümüşhane, Kars, Kayseri, Mersin	Ljubomirov & Yıldırım, 2008; Dollfuss, 2013b
Podalonia ebenina (Spinola, 1839)	Ankara, Bingöl, Bolu, Erzurum, Kayseri, Kırşehir, Konya, Niğde, Sivas	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b; Tüzün & Yüksel, 2010
Podalonia fera (Lepeletier de Saint-Fargeau, 1845)	Amasya, Ankara, Artvin, Bursa, Bingöl, Denizli, Erzincan, Erzurum, Eskişehir, Hakkari, İzmir, Kahramanmaraş, Kars, Kayseri, Konya, Kütahya, Manisa, Mersin, Muş, Niğde, Rize, Tokat, Tunceli	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b, 2013b; Tüzün & Yüksel, 2010; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012; Bayındır et al., 2013; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Gülmez, 2019
Podalonia flavida (Kohl, 1901)	Isparta, Kayseri, Konya, Manisa	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b
Podalonia harveyi (de Beaumont, 1967)	Ankara	Ljubomirov & Yıldırım, 2008
Podalonia hirsuta (Scopoli, 1763)	Adana, Amasya, Ankara, Ardahan, Artvin, Aydın, Bayburt, Bingöl, Bilecik, Bitlis, Bolu, Bursa, Çorum, Denizli, Diyarbakır, Elazığ, Erzincan, Erzurum, Giresun, Gümüşhane, Hakkari, Hatay, İstanbul, İzmir, Kahramanmaraş, Kars, Kastamonu, Kayseri, Konya, Kütahya, Manisa, Mersin, Muğla, Niğde, Rize, Samsun, Sivas, Tokat, Trabzon, Uşak	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b, 2013b, 2015; Tüzün & Yüksel, 2010; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012; Bayındır et al., 2013; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Örgel et al., 2020
Podalonia luffii (Saunders, 1903)	Erzurum, Nevşehir	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b
Podalonia nigrohirta (Kohl, 1888)	Erzincan	Present data
Podalonia tydei tydei (Le Guillou, 1841)	Adana, Ankara, Antalya, Artvin, Aydın, Balıkesir, Bursa, Elazığ, Erzincan, Erzurum, Iğdır, İstanbul, Kars, Kayseri, Konya, Malatya, Manisa, Mersin, Samsun, Şırnak, Tokat, Tunceli	Ljubomirov & Yıldırım, 2008; Dollfuss, 2010b, 2013b; Tüzün & Yüksel, 2010; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Örgel et al., 2020
Subfamily Sceliphrinae		
Genus *Chalybion* Dahlbom, 1843		
Chalybion femoratum (Fabricius, 1781)	Ankara, Burdur, Bursa, Denizli, Erzincan, Erzurum, Hakkâri, Iğdır, Karabük, Kars, Konya, Malatya, Manisa, Mersin, Nevşehir, Şırnak	Ljubomirov & Yıldırım, 2008; Yıldırım, 2012, 2014; Dollfuss, 2016; Gülmez, 2019
Chalybion flebile (Lepeletier de Saint-Fargeau, 1845)	Antalya, Aydın, Burdur, Diyarbakır, Elazığ, Erzurum, Gaziantep, Hakkari, Hatay, Kars, Malatya, Manisa, Mersin, Niğde, Tokat, Tunceli, Şanlıurfa	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Bayındır et al., 2013; Yıldırım, 2014; Dollfuss, 2016; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Gülmez, 2019
Chalybion klapperichi (Balthasar, 1957)	Denizli	Dollfuss, 2016
Chalybion minos (de Beaumont, 1965)	Antalya, Balıkesir, Denizli, Elazığ, Malatya, Mersin	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Dollfuss, 2016
Chalybion omissum (Kohl, 1889)	Adana, Ankara, Antalya, Burdur, Çanakkale, Denizli, Hakkari, Isparta, İzmir, Konya, Manisa, Mersin, Muğla, Şırnak, Van	Ljubomirov & Yıldırım, 2008; Bayındır et al., 2013; Yıldırım, 2014; Dollfuss, 2016; Yıldırım et al., 2016;
Chalybion turanicum (Gussakovskij, 1935)	Adıyaman, Antalya, İzmir, Kayseri, Mardin, Mersin	Dollfuss, 2016
Chalybion walteri (Kohl, 1889)	Adıyaman, Burdur, Denizli, Eskişehir, Gaziantep, Hatay, Iğdır, Kahramanmaraş, Kayseri, Malatya	Ljubomirov & Yıldırım, 2008; Yıldırım, 2012, 2014; Dollfuss, 2016; Yıldırım et al., 2016

Table 2. (Continued)

Taxon	Distribution in Turkey	References
Genus *Sceliphron* Klug, 1801		
Sceliphron arabs (Lepeletier de Saint Fargeau, 1845)	Adana, Antalya, Batman, Iğdır, Malatya, Mersin, Muş, Şanlıurfa, Tokat, Tunceli	Yıldırım, 2014; Dollfuss, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Gülmez, 2019
Sceliphron curvatum (Smith, 1870)	Amasya, Erzurum, Kocaeli, Ordu, Samsun, Tokat	Gülmez & Can, 2015a; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Ertürk et al., 2019; Ertürk & Taş, 2021
Sceliphron destillatorium (Illiger, 1807)	Adana, Adıyaman, Afyonkarahisar, Amasya, Ankara, Antalya, Artvin, Aydın, Burdur, Bursa, Çanakkale, Elazığ, Erzincan, Erzurum, Eskişehir, Giresun, Hatay, Isparta, İstanbul, İzmir, Kahramanmaraş, Karaman, Kars, Kastamonu, Konya, Malatya, Manisa, Mardin, Mersin, Muğla, Niğde, Ordu, Osmaniye, Sakarya, Şanlıurfa, Şırnak, Tokat, Trabzon	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2012, 2014; Gülmez & Can, 2015b; Dollfuss, 2016; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018
Sceliphron funestum Kohl, 1918	Adana, Adıyaman, Antalya, Aydın, İzmir, Mersin, Muğla, Siirt	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Dollfuss, 2016; Yıldırım et al., 2016
Sceliphron madraspatanum madraspatanum (Fabricius, 1781)	Ankara, İstanbul, Mersin, Muğla	de Beaumont, 1967; Gülmez & Tüzün, 2005; Dollfuss, 2016; Gülmez, 2019
Sceliphron madraspatanum tubifex (Latreille, 1809)	Amasya, Ankara, Antalya, Bursa, Çorum, Denizli, Kahramanmaraş, Konya, Mersin, Muğla, Tokat	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Gülmez & Dizer, 2016; Yıldırım & Tezcan, 2018
Sceliphron spirifex (L., 1758)	Adana, Adıyaman, Antalya, Aydın, Balıkesir, Bursa, Denizli, Hatay, Isparta, İstanbul, İzmir, Kahramanmaraş, Manisa, Mersin, Muğla, Niğde, Tokat, Trabzon	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012, 2014; Dollfuss, 2016; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018
Subfamily Sphecinae Latreille, 1802		
Genus *Chilosphex* Menke, 1976		
Chilosphex argyrius (Brullé, 1833)	Bursa, Denizli, Erzurum, Hatay, Isparta, Kars, Tunceli	Ljubomirov & Yıldırım, 2008; Bayındır et al., 2013; Yıldırım, 2014; Yıldırım et al., 2016
Chilosphex pseudargyrius (Roth, 1967)	Konya, Mardin, Mersin	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Genus *Isodontia* Patton, 1880		
Isodontia paludosa (Rossi, 1790)	Adıyaman, Ankara, Antalya, Artvin, Bursa, Erzincan, Erzurum, Isparta, Kars, Konya, Niğde, Tokat, Van	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012, 2014; Bayındır et al., 2013; Gülmez & Dizer, 2016
Isodontia splendidula (Costa, 1858)	Ankara, Hatay, Manisa, Mersin, Sakarya, Tokat, Tunceli	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Gülmez & Dizer, 2016; Yıldırım et al., 2016
Genus *Palmodes* Kohl, 1890		
Palmodes melanarius (Mocsáry, 1883)	Aksaray, Ankara, Denizli, İzmir	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Yıldırım et al., 2016; Danilov & Byvaltsev, 2020
Palmodes minor (Morawitz, 1890)	Amasya, Ankara, Konya	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Danilov & Byvaltsev, 2020
Palmodes occitanicus (Le Peletier & Serville, 1828)	Antalya, Balikesir, Bursa, Denizli, Erzincan, Erzurum, Iğdır, İstanbul, Kars, Manisa, Mersin, Muğla, Nevşehir, Şanlıurfa, Tokat, Tunceli	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Danilov & Byvaltsev, 2020
Palmodes orientalis (Mocsáry, 1883)	Burdur, Isparta, Kars	Bayındır et al., 2013; Yıldırım et al., 2016
Palmodes strigulosus (Costa, 1861)	Adıyaman, Amasya, Ankara, Antalya, Bilecik, Bingöl, Burdur, Bursa, Denizli, Elazığ, Erzincan, Erzurum, Isparta, Kars, Kayseri, Kırklareli, Konya, Manisa, Mardin, Mersin, Tokat	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2012, 2014; Gülmez & Dizer, 2016; Yıldırım et al. 2016; Danilov & Byaltsev, 2020; Örgel et al., 2020

Table 2. (Continued)

Taxon	Distribution in Turkey	References
Genus *Prionyx* Vander Linden, 1827		
Prionyx crudelis (Smith, 1856)	Kahramanmaraş, Manisa, Mersin	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Örgel et al., 2020
Prionyx guichardi (de Beaumont, 1967)	Kayseri, Kırşehir	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx haberhaueri (Radoszkowski, 1871)	Çankırı	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx kirbii (Vander Linden, 1829)	Adana, Afyonkarahisar, Amasya, Ankara, Antalya, Bursa, Çankırı, Erzurum, Isparta, İzmir, Kars, Kayseri, Kütahya, Manisa, Mersin, Samsun, Tokat	Ljubomirov & Yıldırım, 2008; Japoshvili & Ljubomirov, 2012; Bayındır et al., 2013; Yıldırım, 2012, 2014; Gülmez & Dizer, 2016; Gülmez, 2019; Örgel et al., 2020
Prionyx lividocinctus (Costa, 1861)	Ankara, Antalya, Bursa, Çanakkale, Denizli, Elazığ, Erzincan, Kayseri, Kırklareli, Manisa, Mardin, Mersin, Şanlıurfa	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx niveatus (Dufour, 1854)	Ankara, Kars	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx nudatus (Kohl, 1885)	Amasya, Ankara, Antalya, Artvin, Bitlis, Burdur, Bursa, Çankırı, Erzincan, Erzurum, Iğdır, İstanbul, Kars, Konya, Sivas, Tokat	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2012, 2014; Gülmez & Dizer, 2016; Yıldırım et al., 2016
Prionyx radoszkowskyi Kohl, 1888	Erzincan	Can & Gülmez, 2019
Prionyx songaricus (Eversmann, 1849)	Adıyaman, Antalya, Batman, Denizli, Konya, Malatya, Manisa, Mardin, Mersin, Şanlıurfa	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014; Yıldırım et al., 2016
Prionyx subfuscatus (Dahlbom, 1845)	Ankara, Antalya, Bursa, Erzurum, İstanbul, Kars, Kayseri, Mersin, Sivas	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx viduatus mocsaryi (Kohl, 1883)	Erzincan, Erzurum, Isparta	Ljubomirov & Yıldırım, 2008; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012, 2014
Prionyx viduatus pollens (Kohl, 1885)	Eskişehir	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Prionyx viduatus viduatus (Christ, 1791)	Amasya, Ankara, Antalya, Çankırı, Denizli, Kars, Mersin, Niğde, Sivas, Tokat	Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2014; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Gülmez, 2019
Genus *Sphex* L., 1758		
Sphex afer Lepeletier de Saint Fargeau, 1845	Konya	de Beaumont, 1967
Sphex atropilosus Kohl, 1885	Erzurum, Kars	Dollfuss, 2008, Ljubomirov & Yıldırım, 2008; Yıldırım, 2012, 2014
Sphex funerarius Gussakovskij, 1934	Adana, Ankara, Antalya, Artvin, Aydın, Balıkesir, Bursa, Çankırı, Denizli, Erzincan, Erzurum, Eskişehir, Giresun, Gümüşhane, Hatay, İstanbul, İzmir, Kars, Kayseri, Konya, Kütahya, Manisa, Mersin, Muğla, Rize, Tokat, Tunceli	Dollfuss, 2008, Ljubomirov & Yıldırım, 2008; Japoshvili & Ljubomirov, 2012; Yıldırım, 2012, 2014; Bayındır et al., 2013; Gülmez & Dizer, 2016; Yıldırım et al., 2016;
Sphex leuconotus Bullé, 1833	Ankara, Artvin, Erzurum, Eskişehir, Hatay, Iğdır, Kars, Konya, Muş, Şanlıurfa, Van	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2012, 2014; Yıldırım et al., 2016;
Sphex melanocnemis Kohl, 1885	Ankara, Bursa, Çankırı, Çanakkale, Denizli, Elazığ, Mersin, Konya, Şanlıurfa	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Sphex oxianus Gussakovsky, 1928	Ankara, Artvin, Şanlıurfa	Ljubomirov & Yıldırım, 2008; Yıldırım, 2014
Sphex pruinosus Germar, 1817	Adana, Ankara, Antalya, Artvin, Balıkesir, Denizli, Erzincan, Erzurum, Iğdır, Isparta, İzmir, Kahramanmaraş, Kırıkkale, Konya, Malatya, Mersin, Muğla, Muş, Tokat, Trabzon, Tunceli	Dollfuss, 2008; Ljubomirov & Yıldırım, 2008; Tüzün & Yüksel, 2010; Yıldırım, 2012, 2014; Bayındır et al. 2013; Gülmez & Dizer, 2016; Yıldırım et al., 2016; Yıldırım & Tezcan, 2018; Gülmez, 2019

Acknowledgments

We are grateful to Tokat Gaziosmanpaşa University Scientific Research Projects Coordination Unit (Project number: 2017/44) for financial support.

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Türk. entomol. derg., 2021, 45 (3): 323-330
DOI: http://dx.doi.org/10.16970/entoted.938523

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

A new species of *Trionymus* (Berg, 1899) (Hemiptera: Pseudococcidae) genus in Turkey[1]

Türkiye'de *Trionymus* (Berg, 1899) (Hemiptera: Pseudococcidae) cinsine ait yeni bir tür

Hüseyin YERLİKAYA[2*] **Hüseyin BAŞPINAR[3]** **M. Bora KAYDAN[4]**

Abstract

The genus *Trionymus* (Berg, 1899) (Hemiptera: Coccomorpha: Pseudococcidae) was investigated based on samples collected on plants from Poaceae, Cyperaceae and Juncaceae in Aydın Province, Turkey, between 2019 and 2020. The specimens of the new species were collected on *Juncus acutus* L. (Poales: Juncaceae) and were slide-mounted. In total, 10 specimens were examined under a microscope and illustrations were prepared. As a result of the study, *Trionymus oncueri* sp. n. Kaydan & Yerlikaya is described and illustrated. In addition, an identification key for the currently known *Trionymus* species found on Poaceae, Cyperaceae and Juncaceae (Poales) in the Palearctic Region is provided and discussed.

Keywords: Identification key, new species, taxonomy, *Trionymus,* Turkey

Öz

Aydın İli'ndeki Poaceae, Cyperaceae ve Juncaceae familyasına bağlı bitkilerinden 2019-2020 yıllarında toplanan *Trionymus* (Berg**,** 1899) (Hemiptera: Coccomorpha: Pseudococcidae) cinsine ait örnekler incelenmiştir. Yeni türe ait örnekler *Juncus acutus* L. (Poales: Juncaceae) üzerinden toplanmış ve preparatları yapılmıştır. Toplam olarak 10 adet örnek laboratuvarda mikroskop altında incelenmiş ve yeni bir *Trionymus* türü olarak, *Trionymus oncueri* sp. n. Kaydan & Yerlikaya tanımlanmıştır. Çalışmada ayrıca, Palearktik Bölge'de Poaceae, Cyperaceae ve Juncaceae (Poales) üzerinde bulunan ve halihazırda bilinen *Trionymus* türleri için bir teşhis anahtarı oluşturulmuş ve tartışılmıştır.

Anahtar sözcükler: Teşhis anahtarı, yeni tür, taksonomi, *Trionymus,* Türkiye

[1] This study was supported by Aydın Adnan Menderes University Research Fund, Aydın, Turkey, Grant Project No: ZRF-19018.
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Received (Alınış): 23.05.2021 Accepted (Kabul ediliş): 29.07.2021 Published Online (Çevrimiçi Yayın Tarihi): 04.08.2021

Introduction

Turkey is a country with 783,562 km^2 area connecting Asia, Africa and Europe, and has many different habitats with unique ecological peculiarities in different latitudes and altitudes. There are different biogeographical regions, namely, Europe-Siberia (Kars-Erzurum plate), Iranian-Turan (from eastern Turkey to Middle Anatolia), and south and the west coasts of the country are under Mediterranean climatic conditions. As a result of this diversity of ecology, many regions show different form of ecosystems and their transitions among the zones. Although most of the ecosystems in the country are steppes, many other lands include distinct ecosystems such as forests, mountains, wetlands, coastal and marine, and different combinations of these systems. So, tremendous number of fauna and flora species and their populations are enabling to occur in such diverse of ecological characteristics.

The presence of waxy and powdery secretions on their body is the main characteristic of mealybugs. In general, mealybugs in life are often dorsoventrally compressed, and vary from oval-elongated to rounded in shape, and pinkish to grayish in color, and covered by white powdery wax in life (Cox & Ben-Dove, 1986; Kaydan et al., 2015). Mealybugs being nourished on a variety of woody and herbaceous plants, and they are usually localized to a specific part of the host (Williams, 2004).

The mealybugs in the Coccomorpha represent the second largest family group with 2,256 species in 291 genera in three families, Pseudococcidae, Rhizoecidae and Putoidae (Garcia Morales et al., 2020). About 700 species in 106 genera are known in the Palearctic Region (Garcia Morales et al., 2020). *Pseudococcus* Westwood, 1840, *Dysmicoccus* Ferris, 1950, and *Phenacoccus* Cockerell, 1893 are the most species-rich among the 46 genera of the family Pseudococcidae in Palearctic region (Garcia Morales et al., 2020). There are 77 species of mealybugs recorded in Turkey, and the most abundant genera are *Phenacoccus*, *Peliococcus* Borchsenius, 1948, *Pelionella* Kaydan, 2015, and *Trionymus* (Berg, 1899) (Hemiptera: Pseudococcidae) (Kaydan et al., 2013, 2015).

Some species of *Trionymus* resemble some species of *Dysmicoccus* and the distinction appears to be arbitrary. Recently, *Trionymus multivorus* (Kiritchenko, 1936) was synonymized with *Trionymus angustifrons* Hall, 1926, and its transfer to *Dysmicoccus* as *Dysmicoccus angustifrons* (Hall, 1926) suggested (Matile-Ferrero et al., 2015). Three species of the genus, *Trionymus aberrans* Goux, 1938, *Trionymus cressae* (Hall, 1927), and *Trionymus perrisii* (Signoret, 1875) were listed for the scale insect fauna of Turkey (Kaydan et al., 2013), and all of them were collected from monocotyledonous plants.

In this study, a new *Trionymus* species collected from leaf sheets of *Juncus acutus* L. (Poales: Juncaceae) is described and illustrated based on adult female morphology. In addition, an identification key for the currently known *Trionymus* species found on Poaceae, Cyperaceae and Juncaceae (Poales) in the Palearctic Region is provided.

Materials and Methods

Collecting of the specimens

The mealybug specimens were collected on roots of the weed *J. acutus* in a wetland area during a survey conducted in 2019-2020 in Aydın Province, Turkey. In total, ten specimens were examined and evaluated in the laboratory.

Identification of the specimens

Slide-mounted adult female mealybug specimens were prepared at the Plant Protection Department of Çukurova University, Adana, Turkey, according to Kosztarab & Kozár (1988) with a slight modification (the specimens were rinsed with ionized water using a fine brush to rinsed off the KOH). Identification studies were performed using the keys constructed by Danzig & Gavrilov-Zimin (2015), and Kosztarab & Kozar (1988). The slides are stored in the Çukurova University Coccoidea collection, Adana, Turkey (KPTC).

Morphometric methods

Trionymus specimens were examined under a phase-contrast compound microscope (Leica DM2500), and the main taxonomic characters were measured for the species description. The morphological terms followed Williams (2004) and Williams & Granara de Willink (1992). Measurements were performed recording the maximum dimensions (e.g., body width was recorded at the widest part) and are expressed as a range. In the measurements, the claw is excluded in the tarsal length, yet the setal base is included in setal lengths. Cerarii are numbered after Williams & Granara de Willink (1992), with cerarius one being on the head, anterior to the antenna, and cerarius 17 being on segment VIII.

A generalized individual was represented in a drawing based on several specimens used for the description. The left half of dorsum and the right half of venter were represented in each illustration which is divided longitudinally. Structural details are shown as enlargements around the central drawing, and are drawn to different scales. Although translucent pores on the hind legs are located mostly on the dorsal surface, they are illustrated ventrally on the main drawing for convenience.

Results

Genus: *Trionymus* (Berg, 1899) (Hemiptera: Pseudococcidae)

Type species: *Trionymus perrisii* (Signoret, 1875) (Hemiptera: Pseudococcidae)

Synonym: *Westwoodia* Signoret, 1875; *Signoretia* Kraatz, 1988; *Bergrothia* Kraatz, 1988; *Bergrothiella* Reitter, 1898; *Pergandiella* Cockerell, 1899.

Diagnosis: Adapted from Williams (2004).

Adult female

Body of adult female elongate normally broadly oval, with 5 or fewer pairs of cerarii; 1-4 pairs usually situated on last abdominal segments, occasionally 1 or 2 pairs present on head margin. Anal lobe cerarii each containing paired setae, either conical or setose, with or without trilocular pores next to collars, all situated on a membranous or sclerotized area. Antennae each 6-8 segmented. Legs well developed; claw without a denticle. Sometimes anterior proximal edge of hind coxa indistinct, with translucent pores extending onto surrounding derm. Circuli present or absent. Spiracles normal, not surrounded by sclerotized areas. Both ostioles pairs present. Ventral surface of each anal lobe usually membranous. Anal ring usually situated at apex of abdomen, bearing 6 hair-like setae. Oral collar tubular ducts of different sizes present or absent on dorsum, always present on venter; sometimes abundant. Multilocular disc pores present at least on venter.

The genus has a worldwide distribution with 124 species of which 61 species have a Palearctic distribution. Most species feed on grass leaves; usually under leaf sheaths, stems or roots. Four species have been recorded in Turkey, namely *T. aberrans*, *T. cressa* and *T. perrisii* (Kaydan et al., 2013). Recently Williams et al. (2015) considered *T. multivorus* as *D. angustifrons*. However, Kaydan et al. (2015) recorded *Trionymus artemisiarum* (Borchsenius, 1949) but did not mention that it was a new species record for Turkey. However, Kaydan et al. (2015) indicated that *T. artemisiarum* was not a typical member of the genus *Trionymus* and placed in the Trabutini clade in their phylogenetic tree. For this reason, *T. artemisiarum* was not included in the following key to species of *Trionymus*.

Key to adult females of *Trionymus* (Berg, 1899) of the Palearctic region modified from Danzig and Gavrilov-Zimin (2015), and Kosztarab & Kozar (1988)

1. Trilocular pores numerous and more or less evenly distributed on body sides 2

- Trilocular pores only on venter few and unevenly scattered ..... *T. borchsenii* (Danzig, 1983)

2. Anal ring horseshoe-shaped ..... *T. aberrans* Goux, 1938

- Anal ring more or less rounded 3

3. Anal ring complicated with 2 or more outer rows of spinule 4

- Anal ring complete or with reduced number of pores and spinule 5

4. Anal ring with 2 rows of spinule; multilocular pores present on abdominal sternites only ..... *T. pietranerae* Goux, 1941

- Anal ring with 3-4 rows of spinule; multilocular pores scattered on all body surfaces ..... *T. polyporus* Hall, 1924

5. Tubular ducts with pores attached to duct opening ..... *T. williamsi* Ezzat, 1959

-Tubular ducts without attached pores 6

6. Multilocular pores scattered on all dorsum and on all or on p-most part of venter 7

- Multilocular pores present mainly in transverse rows on abdominal segments and more rarely occasionally present on venter surface of cephalothorax 10

7. Cerarii numbering 1 pair 8

- Cerarii numbering 2-3 pairs ..... *T. internodii* (Hall, 1923)

8. Anal ring simplified; circuli absent ..... *T. masrensis* Hall, 1925

- Anal ring complete; circulus present 9

9. All oral collar tubular ducts of about one size ..... *T. diminutus* (Leonardi, 1918)

- Oral collar tubular ducts of two sizes ..... *T. phragmitis* (Hall, 1923)

10. Anal lobe cerarii do not lie on sclerotized plate or slight sclerotization present only just near the bases of cerarian setae 11

- Anal lobe cerarii lies on large sclerotization plate 18

11. Oral collar tubular ducts of simple type only ..... *T. copiosus* (Borchsenius, 1949)

- Tubular ducts with collars of different shape and size 12

12. Anal ring reduced number of pores and spinule ..... *T. caucasicus* (Danzig, 1985)

- Anal ring complete 13

13. Oral collar tubular ducts of 3 sizes ..... *T. santilongi* (Mazzeo, 1995)

- Oral collar tubular ducts of 1 or 2 sizes 14

14. Oral collar tubular ducts of about 1 size ..... *T. danzigae* (Kozár & Kosztarab, 1976)

- Oral collar tubular ducts of 2 sizes 15

15. Oral collar tubular ducts with deep collar, occupying almost half of duct length 16

- Oral collar tubular ducts with small collar poorly visible; occupying almost less than one third of duct length 17

16. Dorsal oral collar tubular ducts of one size ..... *T. radicum* (Danzig, 1986)

- Dorsal oral collar tubular ducts of two sizes ..... *T. dagestanicus* Danzig, 1998

17. Dorsal oral collar tubular ducts of two sizes, dorsal multilocular pores present .....

..... *T. hamberdi* (Borchsenius, 1949)

- Dorsal oral collar tubular ducts of one size, dorsal multilocular pores absent..*T. thulensis* Green, 1931

18. Tubular ducts with very wide and deep collar occupying about half of duct length .....

.....*T. kirgisicus* (Borchsenius, 1949)

- Tubular duct with small narrow collar or simple 19

19. Sclerotized plate of anal lobe similar in size or only slightly larger than anal ring with 25-45 trilocular pores 20

- Sclerotized plate of anal lobe significantly larger than anal ring with 70-75 trilocular pores.....

.....*T. phalaridis* (Green, 1925)

20. Multilocular disc pores present on cephalothorax on dorsum and venter ..... *T. perrisii* (Signoret, 1875)

- Multilocular disc pores absent on cephalothorax on dorsum and venter .....

.....*T. oncueri* **sp. n.** Kaydan & Yerlikaya

***Trionymus oncueri* sp. n. Kaydan & Yerlikaya (Figure 1)**

Material examined. Holotype: Aydın: Çine, Doğanyurt, 37°35'51"N, 27°59'32"E, 61 m, 15.V.2019, *Juncus acutus*, H. Yerlikaya, M. Bora Kaydan, 1 adult female (marked with red circle); Paratypes: Aydın: Nazilli, 37°53'38"N, 28°19'38"E, 66 m, 05.VIII.2019, *Juncus acutus*, H. Yerlikaya, 4 adult females; as same label as holotype are on the same slide.

Description of the slide-mounted adult female

Adult female. Body elongate-oval, 2.74-4.72 mm long, 0.56-1.04 mm wide. Eyes marginal, about 35.0-37.5 µm wide. Antenna 8 segmented, 380-420 µm long; apical segment 87.5-95 µm long, 30.0-32.5 µm wide, with 4 fleshy setae, each setae 40.0-42.5 µm long and apical setae each 40-45 µm long. Clypeolabral shield 190-195 µm long, 170-175 µm wide. Labium 3 segmented, 110-115 µm long, 110-115 µm wide. Anterior spiracles each 50-55 µm long, 22.5-25.0 µm wide across atrium; posterior spiracles each 60-65 µm long, 30-35 µm wide across atrium. Legs well developed, length data for posterior legs: coxa 150-155 µm with 8-10 translucent pores present, trochanter plus femur 260-270 µm, tibia plus tarsus 310-315, claw 25-30 µm. Ratio of lengths of tibia plus tarsus to trochanter plus femur 1.06-1.09:1; ratio of lengths of tibia to tarsus 0.89-1.0:1; ratio of length of hind trochanter plus femur to greatest width of femur 2.75-3.2:1. Tarsal digitules capitate, each 47.5-50.0 µm long. Claw digitules capitate, 27.5-30.0 µm long. Both pairs of ostioles present; anterior ostioles each with a total for both lips of 6–9 trilocular pores and no setae; posterior ostioles each with a total for both lips of 17-22 trilocular pores and 1–3 esetae. Anal ring 85-90 µm wide, bearing 6 setae with each setae 110-130 µm long.

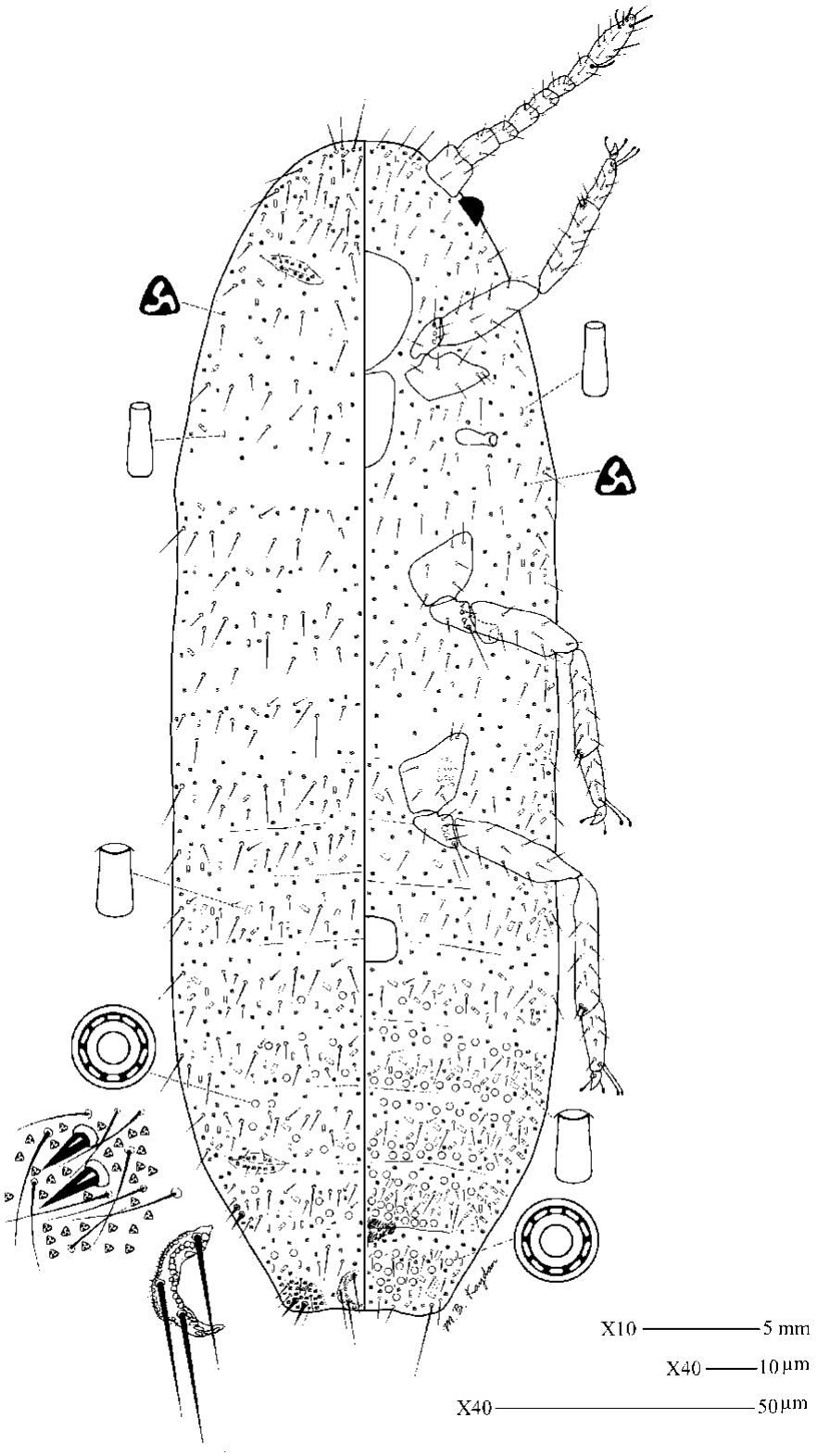

Figure 1. *Trionymus oncueri* Kaydan & Yerlikaya, sp.n. (General illustration x10 is used; for the details surrounding the main illustration x40 is used).

Dorsum. Derm membranous, anal lobe cerarii present, each with 2 conical cerarian setae, each 20-25 µm long, 30-35 trilocular pores and 7 or 8 axillary setae on sclerotized area. Body setae flagellate, each 15-50 µm long, scattered on head, thorax and abdominal segments. Trilocular pores each 2.5-3.0 µm in diameter, scattered over entire body. Multilocular disc pores each 7.5-8.0 µm in diameter present on abdominal segments; as follows: segment IV, 5-7; V, 15-17; VI, 19-21; VII, 8-10; VIII plus IX, 5-7. Oral collar tubular ducts of two sizes; larger one, each 7.0-8.0 µm long and 3.0-3.5 µm wide, present over entire body and as single rows across on abdominal segments, smaller one, each 5 µm long and 2.0-2.5 µm wide present on submarginal area on abdominal segments, thorax and head.

Venter. Setae flagellate, each 15-90 µm long, longest setae situated medially on head. Apical setae of anal 145-155 µm long. Multilocular disc pores each 7.5-8.0 µm in diameter present on abdominal segments as follows: segment IV, 7-9; V, 22-24; VI, 60-64; VII, 70-76; VIII plus IX, 40-42. Trilocular pores, each 3-4 µm in diameter, scattered. Oral collar tubular ducts in two sizes; larger one, each 7-10 µm long, 5 µm wide, present over most of body and as single rows across the abdominal segments, as follows: segment I-III, 27-31; IV, 49-51; V, 72-76; VI, 74-78; VII, 45-49; VIII plus IX, 30-34; smaller one each 5 µm long and 2.0-2.5 µm wide, in single rows across the abdominal segments and submarginal area on thorax and head.

Comments

Trionymus oncueri Kaydan & Yerlikaya **sp. n.** is characterized by the following combination of features: (1) one pair of cerarii, (2) multilocular disc pores present on dorsum on abdominal segments, (3) oral collar tubular ducts in two sizes present in transverse rows on abdominal segments, scattered on thorax and head (4) translucent pores present on coxa and (5) eight segmented antennae. *Trionymus oncueri* Kaydan & Yerlikaya is closest to *Trionymus perrisii* (Signoret) in having (1) anal lobe cerarii lies on large sclerotization plate, one pair of cerari, (2) multilocular disc pores present on dorsum on abdominal segments, (3) oral collar tubular ducts in two sizes present in tranverse rows on abdominal segments, scattered on thorax and head, but differs from *T. perrisii* lacking multilocular disc pores on head and thorax on dorsum.

Etymology

This species is named after very famous Entomologist, Prof. Dr. Cezmi Öncüer, who made great and valuable entomological studies in Ege University and Adnan Menderes University, Agricultural Faculty, Plant Protection Department (İzmir and Aydın, respectively) in Turkey.

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Türk. entomol. derg., 2021, 45 (3): 331-341
DOI: http://dx.doi.org/10.16970/entoted.963283

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Functional response and egg production of a native *Typhlodromus recki* Wainstein, 1958 (Acari: Phytoseiidae) population to *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae)[1]

Typhlodromus recki Wainstein, 1958 (Acari: Phytoseiidae)'nin yerli popülasyonunun *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) üzerinde işlevsel tepkisi ve yumurta verimi

Firdevs ERSİN[2*]

Abstract

In this study, which was conducted to determine predation potential of *Typhlodromus recki* Wainstein, 1958 (Acari: Phytoseiidae) at Ege University, Faculty of Agriculture, Department of Plant Protection in 2018-2019. Functional response and egg production of the predatory mite, *T. recki* fed on different biological stages (egg, larva, protonymph, deutonymph and adult male) of the two-spotted spider mite (green form), *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) were studied under laboratory conditions (25±1°C, 60±10% RH and 16:8 h L:D photoperiod). In the experiments, seven prey densities (2, 4, 8, 16, 32, 64 and 128) for each biological stage of the prey were offered daily to the predatory mite. The results of logistic regression analysis indicated that *T. recki* had a Type II functional response on each developmental stage of its prey according to Holling's models. The attack rate (α) and the handling time (T_h) varied based on the biological stages of the prey. The highest α and the lowest T_h values were determined as 1.035 and 0.001 when the predator fed on larvae and eggs of its prey, respectively. The highest average daily mean number of the eggs consumed by *T. recki* was 111 at 128 prey densities. The highest average daily mean number of eggs deposited by the predator were found to be 1.05 when it fed on the eight-prey density of *T. urticae* protonymphs. In addition, the lowest average daily mean number of eggs deposited by the predator was 0.15 when fed on the two-prey density with *T. urticae* adult males. The study indicates that *T. recki* could be effective and promising biological control agent for *T. urticae.*

Keywords: Biological control, fecundity, Phytoseiidae, predatory mite, *Tetranychus urticae*

Öz

Bu çalışma 2018-2019 yıllarında Ege Üniversitesi Ziraat Fakültesi, Bitki Koruma Bölümü'nde avcı akar, *Typhlodromus recki* Wainstein, 1958 (Acari: Phytoseiidae)'nin besin tüketim potansiyelini belirlemek için gerçekleştirilmiştir. Avcı akar, *T. recki*'nin iki noktalı kırmızıörümcek (yeşil formu), *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae)'nin farklı biyolojik dönemleri (yumurta, larva, protonimf, deutonimf ve ergin erkek) üzerinde işlevsel tepkisi ve yumurta verimi laboratuvar koşulları altında (25±1°C, %60±10 RH and 16:8 L:D) çalışılmıştır. Denemelerde, avcı akara avın her bir biyolojik dönemi için günlük yedi farklı (2, 4, 8, 16, 32, 64 ve 128) besin yoğunluğu verilmiştir. Regresyan analizi sonuçlarına göre, *T. recki* avının bütün gelişme dönemlerinde Holling modeline göre Tip II işlevsel tepki gösterdiği belirlenmiştir. Avcı akarın arama (α) ve avlanma kapasiteleri (T_h) av biyolojik dönemlerine bağlı olarak değişkenlik göstermiştir. Avcı akara ait en yüksek α değeri ve en düşük T_h değeri, avının larva ve yumurtası ile beslendiğinde sırası ile 1.035 ve 0.001 olarak belirlenmiştir. Avcı akar tarafından tüketilen günlük en yüksek yumurta dönemi 128 av yoğunluğunda 111 olmuştur. Avcı akar tarafından bırakılan günlük en yüksek yumurta sayısı ise, *T. urticae*'nin 8 protonimf yoğunluğunda 1.05 bulunmuştur. Ayrıca, *T. recki*'nin günlük bıraktığı en düşük yumurta sayısı ise 2 av yoğunluğunda 0.15 olarak *T. urticae*'nin ergin erkekleri ile beslendiğinde saptanmıştır. Bu çalışma *T. recki*'nin, *T. urticae*'nin mücadelesinde kullanılmak üzere etkili ve ümit var bir biyolojik savaş etmeni olabileceğini göstermiştir.

Anahtar sözcükler: Biyolojik savaş, üreme, Phytoseiidae, Predatör akar, *Tetranychus urticae*

[1] This study was supported by TUBITAK, project number: 118O666.
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Received (Alınış): 06.07.2021 Accepted (Kabul ediliş): 29.07.2021 Published Online (Çevrimiçi Yayın Tarihi): 04.08.2021

Introduction

Two-spotted spider mite, *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae), is a generalist herbivore known to feed on more than 1200 plant species in 140 different plant families that damages both field and greenhouse crops worldwide (Zhang, 2003; Migeon & Dorkeld, 2021). *Tetranychus urticae* is a notorious pest due to its ability to develop resistance due to extensive use of insecticides/acaricides combined with its short life cycle and high fecundity (Stumpf et al., 2001; Yorulmaz & Ay, 2009; Migeon et al., 2010). Also, insecticides/acaricides usage has affected not only the pest species but also environment, human health and non-target organisms, such predators and parasitoids (Sánchez-Bayo, 2011). Nowadays, augmentative release of biological control agents such as predatory mites has become important for managing spider mite outbreaks. Phytoseiid mites are mostly effective and eco-friendly biological control agents to be used in biological control programs as some of them are easily mass-reared and available commercially all over the world. Although, there are some commercially produced predatory mites, the potential of many species is virtually unknown.

Typhlodromus recki Wainstein, 1958 (Acari: Phytoseiidae), for instance, is one of the most commonly found predatory mites in some areas of Europe and the Middle East (Tixier et al., 2020), where it was found on a wide range of plants, especially non-cultivated species but occasionally it is also found on crops such as aubergine, citrus, grapevines, potato, olive, orchard trees, strawberry and tomato (Swirski & Amitai, 1982; Şekeroğlu, 1984; Papaioannou-Souliotis et al., 1994; Tixier et al., 2003; Kumral, 2005; Rahmani et al., 2010; İnak & Çobanoğlu, 2018; Kreiter et al., 2020; Ersin et al., 2021). Therefore, it is expected that it may have great potential for biological control of mites. *Typhlodromus recki* is considered to be a generalist predator that is likely to feed on a wide range of pestiferous mites and arthropods. It can also reproduce on pollen, fungi and plant exudates in the absence of its main prey (McMurtry & Croft, 1997; McMurtry et al., 2013).

Before starting biological control studies, it is necessary to understand foraging behavior and predation capacity of natural enemies. Functional and numerical responses are among the most important characteristics and foraging behavior to understand the capacity and potential of predators on their prey (Fathipour & Maleknia, 2016). Predator and prey interactions are analyzed using functional response which determined consumption rates as function of prey densities. Holling's (1959) models include three types of functional responses: Type I, predator consumption rate increases linearly as density of prey increases, Type II response that a hyperbolic relationship in the predator consumption rate with increasing prey density, and Type III responses are sigmoidal, where the maximum consumption rate is reached at intermediate prey densities, before decreasing at higher densities (Soria-Díaz et al., 2018). Type II functional response, however, are the most common among phytoseiid mites. The functional responses of predators are usually influenced by temperature, relative humidity, host plant, prey stage, age and pesticide application (Escudero & Ferragut, 2005; Döker et al., 2016; Sousa Neto et al., 2020; Dalir et al., 2021). However, there have been no published studies on the functional response of *T. recki* to *T. urticae*.

Therefore, this study aimed to determine the functional response and fecundity of *T. recki* on different biological stages of *T. urticae*. The results obtained from the study will help to obtain detailed knowledge with regard to predation potential of *T. recki* on *T. urticae.*

Materials and Methods

Plant production, prey and predator culture

Barbunia plants (*Phaseolus vurgaris* cv. Barbunia supplied by Bursa Seeds, Bursa, Turkey) were grown in plastic pots in a climate room (25±1°C, 60±10% RH and 16:8 h L:D photoperiod). *Tetranychus urticae* (green form) collected from tomato plants in a greenhouse in Izmir was used for experimental studies and feeding *T. recki* colonies. They were reared on barbunia plants in the laboratory for more than 6 years and kept at 25±1°C, 60±10% RH and 16:8 h L:D photoperiod in the climate room. *Typhlodromus*

recki was collected from vegetable garden in Denizli, Turkey (Ersin et al., 2021), and it was reared on black plastic arenas (80 x 150 mm) on top of wet sponge in a plastic tray filled with tap water. The edges of arenas were sealed with tissue paper immersed in the water to provide moisture and prevent the mites from escaping (Overmeer, 1985). Mixed stages of *T. urticae* and Cattail pollen were offered as a food source for the predatory mite every 2 days at 25±1°C, 60±10% RH and 16:8 h L:D photoperiod in a controlled-climate room. Cattail pollen collected from *Typha latifiola* L. in Denizli, Turkey was dried in air for 24 h in the laboratory under low humidity conditions, then sieved and stored in the refrigerator at -20°C.

Functional response and egg production of *Typhlodromus recki*

Functional response and egg production of *T. recki* adult females to different stages of *T. urticae* were studied by modified Munger cells at 25±1°C, 60±10% RH and 16:8 h L:D photoperiod in an incubator (Sanyo, MLR 351H). A modified Munger cell (60 x 45 mm) that consisted of a stack containing three plates: base acrylic plate (2 mm thick), moistened filter paper, clean bean leaf; middle acrylic plate (5 mm thick and a central 23-mm diameter hole) and top covered with transparent acetate sheet (0.1 mm thick), respectively. Clean bean leaves obtained from the culture was placed abaxial side up on the filter paper. About 100 holes were punched into the transparent acetate sheet with an insect pin for ventilation. All layers were held together with two large binder clips (32 mm) (Kustutan & Cakmak, 2009; Kamburgil & Cakmak, 2014). To obtain prey stages of the same age (eggs, larvae, protonymphs, deutonymphs and adult males) for *T. recki*, adult females of *T. urticae* (about 40-50) from the stock culture were transferred onto clean leaf disc with a fine brush and allowed to deposit eggs for 24 h. Then, *T. urticae* females were removed from the leaf disc. Coeval eggs, larvae, protonymphs, deutonymphs and adult males of *T. urticae* transferred to experimental units with a fine brush. Seven different prey densities (2, 4, 8, 16, 32, 64 and 128) for each biological stage (eggs, larvae, protonymphs, deutonymphs and adult males) were offered to *T. recki* females per experimental unit. Prior to the experiments, gravid adult females of the predator obtained from culture were separately starved for 16 h in Eppendorf tubes. Then, the predatory mite was released individually onto the leaf discs and it was removed from the leaf disc after 24 h. The number of prey consumed and the eggs deposited by *T. recki* were recorded. Each prey density was repeated 20 times with different predatory mite individuals.

Statistical analysis

The functional responses of the predatory mite *T. recki* were determined after two-step data analysis (Juliano, 2001). The data of functional response were initially determined by a logistic regression the number of prey consumed (N_a/N_0) as a function of initial number of prey (N_a/N_0) (Juliano, 2001).

Equation 1 is used to determine the type of the functional response curve of the predatory mite, and P_0, (intercept), P_1 (linear), P_2 (quadratic) and P_3 (cubic coefficient) the respective coefficients.

When determining the functional response type; if the linear P_1 parameter is significantly negative, it shows that the predator has a Type II functional response (Juliano, 2001).

$$\frac{Na}{No} = \frac{exp\left(P_0+P_1N_0+P_2N_0^2+P_3N_0^3\right)}{1+exp\ (P_0+P_1N_0+P_2N_0^2+P_3N_0^3} \quad (1)$$

Given that Type II functional response were determined for all biological stages of the prey, the handling time and the attack rate were determined using the Holling's disc equation (Equation 2) (Holling, 1959). where, N is the initial number of prey offered, P is the number of predators, N_a is the number of prey consumed, a is the attack rate, T_h is the handling time (h), T is the experimental time.

$$\frac{N_a}{p} = \frac{aTN}{(1+aT_hN)} \quad (2)$$

The difference between the food consumption and the number of eggs deposited by the predatory mite fed on different biological stages of *T. urticae* was determined by one-way ANOVA, and means were subsequently separated by Student-Newman-Keuls test ($P < 0.05$). Before the analysis, the homogeneity of variances was checked using the Levene test, and when the test was significant, logarithmic transformation was applied to the data. In order to compare α and T_h values at different stages of food, pseudo-values (*rj*) for 20 replicates were produced using jackknife resampling method and Equation 3 was applied to the data (Efron, 1982).

$$rj = (20 * r) - [\,(20 - 1) * re] \quad (3)$$

The differences between α and T_h values were also determined using one-way ANOVA, followed by Student-Newman-Keuls test ($P < 0.05$). All analyses were conducted in SPSS version 25.0.

Results

All linear coefficients (P_1) are significantly negative for all of prey stages (Table 1). The proportion of the prey consumed decreased with increasing prey densities for all prey stages (Figure 1). The significantly negative P_1 values and the functional response curves clearly indicated that adult female *T. recki* had a Type II functional response to all biological stages of *T. urticae*. The attack rate and the handling time of *T. recki* on different biological stages of *T. urticae* were estimated by using Holling's disc equation. The highest numerically attack rate was found on larvae (1.04±0.147), followed by eggs (0.98±0.048), adult male (0.72±0.072), protonymph (0.64±0.078) and deutonymph (0.53±0.062) (Table 2). However, the attack rate is not significantly different between larvae and eggs. The shortest handling time was found on eggs (0.001±0.000) followed by protonymphs (0.012±0.002), larvae (0.018±0.001), adult males (0.022±0.001) and deutonymphs (0.062±0.004). There was a statistically significant difference between eggs, larvae, protonymphs, deutonymphs and adult males. However, no significant differences were observed between larvae, protonymphs and adult males. The daily mean number of the prey consumed by *T. recki* increased with increasing prey densities (Table 3). The highest number of eggs, larvae, protonymphs, deutonymphs and adult males consumed by *T. recki* was 111, 40.6, 42.0, 15.0 and 31.4 at 128 prey densities, respectively. In contrast, the lowest number of the prey consumed by the predator was 1.85 eggs, 1.90 larvae, 2.00 protonymphs, 1.75 deutonymphs and 1.95 adult males at two prey densities. The number of deutonymphs consumed by *T. recki* was the lowest at all prey densities except for two prey densities (Table 3; $P < 0.001$). The average number of eggs deposited by *T. recki* per day also increased with increasing prey densities (Table 4). The highest mean number of eggs (1.05 females/day) deposited by *T. recki* was determined at eight protonymphs prey densities. This value was not significantly different between all protonymphs prey densities. In contrast, the lowest oviposition rate (0.15 females/day) was found at the two adult males prey density.

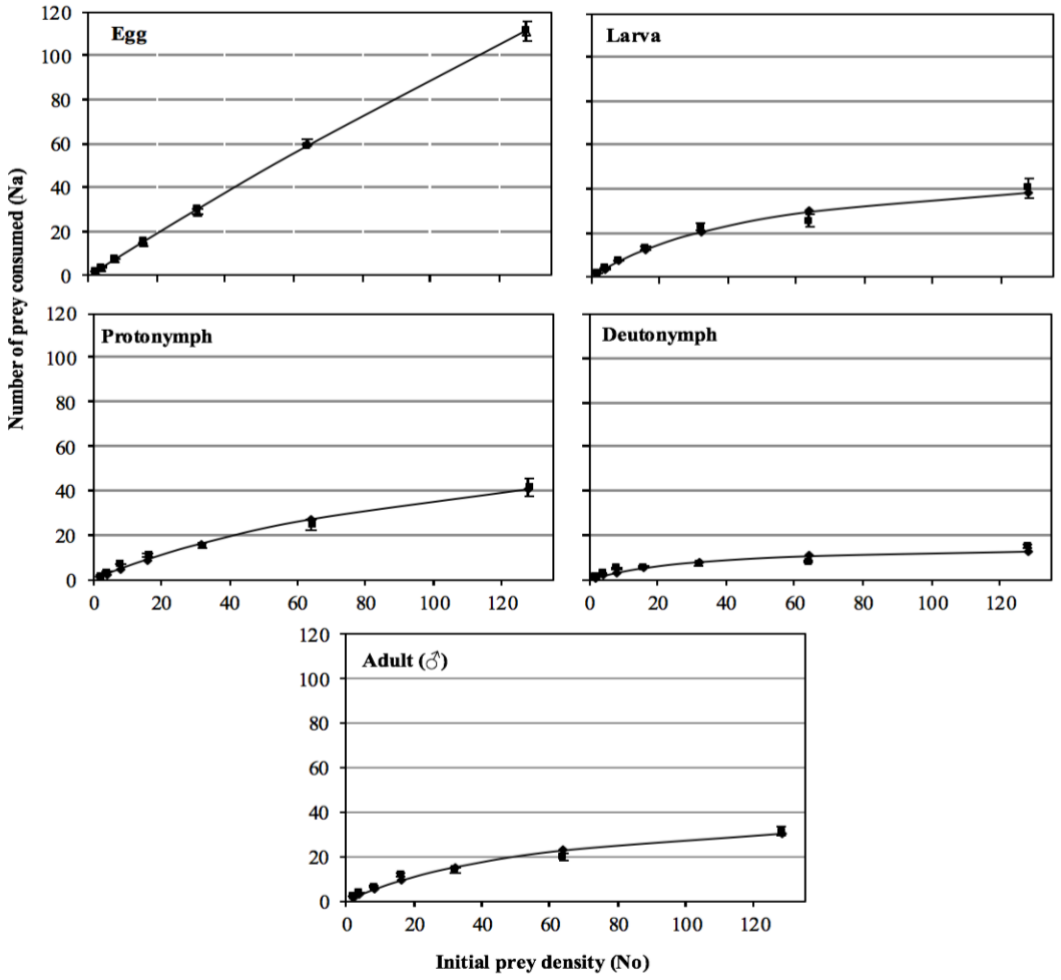

Figure 1. Functional response curves of *Typhlodromus recki* on fedd on egg, larva, protonymph, deutonymph and adult male at seven densities of *Tetranychus urticae*.

Table 1. Estimated coefficients from logistic regression of the different stages of *Tetranychus urticae* consumed by *Typhlodromus recki* as a function of initial prey density in 24 h

Prey stage	Parameters*	Estimate (±SE)	X^2	*P*
Egg	P_0	3.8667 (±0.2906)	177.023	<0.0001
	P_1	-0.1142 (±0.0203)	31.5494	<0.0001
	P_2	0.0023 (±0.0003)	39.2415	<0.0001
Larva	P_0	3.0618 (±0.1567)	381.4086	<0.0001
	P_1	-0.0786 (±0.0046)	291.5870	<0.0001
	P_2	0.0003 (±0.0000)	189.4967	<0.0001
Protonymph	P_0	3.5635 (±0.2757)	167.0422	<0.0001
	P_1	-0.1953 (±0.0187)	109.0868	<0.0001
	P_2	0.0028 (±0.0003)	74.3136	<0.0001
Deutonymph	P_0	1.4965 (±0.1856)	65.0054	<0.0001
	P_1	-0.1398 (±0.0152)	83.8422	<0.0001
	P_2	0.0018 (±0.0003)	37.3923	<0.0001
Adult (male)	P_0	2.8602 (±0.2393)	142.8469	<0.0001
	P_1	-0.1548 (±0.0168)	84.3527	<0.0001
	P_2	0.0020 (±0.0003)	45.4799	<0.0001

*P_0, P_1 and P_2 are intercept, linear and quadric, respectively.

Table 2. Attack rate (*a*) and handling time (T_h) of the Holling's disc equation for *Typhlodromus recki* preying on *Tetranychus urticae* different prey stages (mean ± SE)

Prey Stage	*a* ± SE		T_h ± SE		R^2
Egg	0.983±0.048	ab*	0.001±0.000	c	0.872
Larva	1.035±0.147	a	0.018±0.001	b	0.958
Protonymph	0.639±0.078	b	0.012±0.002	b	0.931
Deutonymph	0.531±0.062	b	0.062±0.004	a	0.665
Adult (male)	0.723±0.072	b	0.022±0.001	b	0.899

* Means within columns following by the same letter are not significantly different according to Student-Newman-Keuls Test *(F* = 4.03 *P* < 0.005 for *a*; *F* = 35.5 *P* < 0.001 for *Th*).

Table 3. Average daily number of different stages of *Tetranychus urticae* consumed by *Typhlodromus recki (*mean ± SE)

Prey density	Egg		Larva		Protonymph		Deutonymph		Adult (Male)		F	*P*
2	1.85±0.07	a*	1.90±0.10	a	2.00±0.00	a	1.75±0.09	a	1.95±0.05	a	2.083	>0.05
4	3.92±0.04	a	3.95±0.05	a	3.90±0.06	a	2.85±0.22	b	3.70±0.12	a	17.584	<0.001
8	7.62±0.21	a	7.80±0.15	a	7.30±0.23	a	5.15±0.31	c	6.35±0.32	b	16.922	<0.001
16	14.65±0.50	a	12.95±0.77	ab	11.35±0.80	b	5.80±0.35	c	11.75±0.63	b	28.736	<0.001
32	28.97±1.02	a	30.15±0.55	a	15.35±1.22	b	7.20±0.54	c	13.85±0.95	b	99.335	<0.001
64	60.85±1.00	a	25.75±2.88	b	25.0±2.39	b	8.25±0.59	d	19.75±1.37	c	181.336	<0.001
128	111.32±4.68	a	40.55±4.33	b	41.95±3.95	b	14.95±0.82	c	31.40±2.22	b	102.340	<0.001

* Means within same row with different letters are not significantly different according to *****Student-Newman-Keuls test or **†**Kruskal Wallis test.

Table 4. Average daily number of eggs deposited by *Typhlodromus recki* when fed with different stages densities of *Tetranychus urticae (*mean ± SE)

Prey density	Egg		Larva		Protonymph		Deutonymph		Adult (Male)		F	*P*
2	0.40±0.07	ab*	0.30±0.10	b	0.75±0.12	a	0.50±0.11	ab	0.15±0.08	b	4.314	<0.05
4	0.37±0.08	b	0.45±0.11	ab	0.75±0.14	a	0.20±0.09	b	0.20±0.09	b	3.884	<0.05
8	0.32±0.07	b	0.45±0.11	b	1.05±0.11	a	0.40±0.11	b	0.25±0.09	b	9.126	<0.001
16	0.25±0.06	b	0.55±0.13	ab	0.75±0.12	a	0.50±0.11	ab	0.30±0.10	b	4.267	<0.05
32	0.40±0.08	b	0.65±0.13	ab	0.90±0.14	a	0.45±0.11	b	0.40±0.11	b	3.356	<0.05
64	0.52±0.08	a	0.70±0.14	a	0.95±0.13	a	0.70±0.10	a	0.60±0.11	a	2.023	>0.05
128	0.74±0.10	a	0.70±0.12	a	0.95±0.11	a	0.45±0.11	a	0.70±0.10	a	2.061	>0.05

* Means within a row followed by the same letter are not significantly different according to *****Student-Newman-Keuls test or **†**Kruskal Wallis test.

Discussion

The results of this study demonstrated the predation potential of *T. recki* on different stages of *T. urticae*. This appears to be the first study to evaluate the predation potential of *T. recki* when offered *T. urticae* as prey. The functional response of *T. recki* was Type II (convex) indicating that the number of prey consumed increased with prey availability and then began to decrease when a maximum point was reached. Many predators with the Type II functional response model have been successfully used as biological control agents (Hughes et al., 1992; Fernandez-Arhex & Corley, 2003; Xiao & Fadamiro, 2010). The Type II functional response is also common among phytoseiid species such as *Neoseiulus cucumeris (*Oudemans, 1930) (Zheng et al., 2017), *Neoseiulus womersleyi* (Schicha, 1975) (Ali et al., 2011), *Galendromus occidentalis* (Nesbitt, 1951) (Xiao & Fadamiro, 2010), *Neoseiulus californicus (*McGregor, 1954) (Castagnoli & Simoni, 1999; Gotoh et al., 2004; Kustutan & Cakmak, 2009; Xiao & Fadamiro, 2010), *Euseius finlandicus (*Oudemans, 1915) (Shirdel, 2003), *Euseius hibisci (*Chant, 1959) (Badii et al., 2004),

*Iphiseius degenerans (*Berlese, 1889) (Fantinou et al., 2012), *Typhlodromus bagdasarjani* Wainstein & Arutunjan, 1967 (Farazmand et al., 2012) and *Kampimodromus aberrans (*Oudemans, 1930) (Kasap & Atlihan, 2011).

The attack rate refers to the time spend by a predator to searching for prey (Fatipour & Maleknia, 2016). In addition, the handling time describes the duration between first predator-prey encounter and end of feeding (Veeravel & Baskaran, 1997). These two parameters are used to determine the magnitude of functional response of the predators (Pervez & Omkar, 2005). The predators exhibited higher attack rate and shorter handling time are considered to have better potential as biological control agent. In this study, the highest numerical attack rate was found on larvae (1.035) while the shortest handling time was determined on eggs (0.001). Similarly, Song et al. (2016) reported that the highest attack rate of *N. californicus* was found on larvae (0.25) of *T. urticae*. The attack rate obtained on the larvae in the current study is close to that determined by Ali et al. (2011) for *N. womersleyi* (1.133) fed on larvae of *Tetranychus macfarlanei* Baker & Pritchard, 1960. These results clearly showed that the larvae may be the most preferred stage of the prey by phytoseiid mites. This can be explained by its smaller size and less mobile when compared to other mobile stages such as nymphs and adults. In addition, predators may also need to attack more prey due to their nutrition needs as already explained by Li & Zhang (2020).

The handling time also varied depending on the biological stage of the prey. The shortest handling time with eggs clearly indicated that *T. recki* spent less time to fed on eggs than the other biological stages, most probably due to its smaller size and inactivity. The handling time of *T. recki* in this study is shorter than those of *Amblyseius swirskii* Athias-Henriot, 1962 (0.518), *N. californicus* (1.732) and *N. womersleyi* (0.056) fed on *T. urticae* eggs (Xiao et al*.,* 2013; Sugawara et al., 2018). Döker et al. (2016) studied functional response of *N. californicus* with *T. urticae* eggs under different humidity conditions and they found that the handling time at 50-70% RH was 0.037 and 0.031, respectively. Fathipour et al. (2020) reported that the estimated minimum handling time of *A. swirskii* was 0.706 with *T. urticae* eggs close to that estimated by Xiao et al. (2013). The shortest handling time (0.153) of *Metaseiulus flumenis* (Chant, 1957) (Acari: Phytoseiidae) was found with *Oligonychus pratensis* (Banks, 1912) (Acari: Tetranychidae) eggs (Ganjisaffar & Perring, 2015). Different factors are likely to affect the handling time of predatory species such as prey movement, subduing, speed of predator (Hassell, 1978). In contrast, current results also show that the longest handling time for *T. recki* were found with deutonymph stage. This result is in agreement with findings of Li & Zhang (2020) who detected that the longest handling time for *N. cucumeris* was with deutonymphs of *T. urticae* compared to those obtained with other biological stages. The reason for a longer handling time with the deutonymph stage may also be related by the size of prey as discussed by Hassell (1978).

The result of this study showed that *T. recki* consumed more eggs of *T. urticae* than the other biological stages. McMurtry & Croft (1997) reported that life styles and feeding habits of phytoseiid mites, generalist predator species showed no prey preference or preferred larvae. However, *T. recki* did not fit into this classification because of more consumed or damaged eggs in this study. Kasap & Atlihan (2011) reported that generalist *K. aberrans* consumed more larvae than eggs. Prey preference of phytoseiid mites can vary according to the prey species. Similarly, Ganjisaffar & Perring (2015) reported that *M. flumenis* prefers *O. pratensis* eggs to other stages of its prey. Higher consumption of eggs in this study can be explained by the following reasons: (1) *T. recki* may prefer to feed on small prey; (2) high nutritional value of eggs (Burnett, 1971); (3) stages of eggs are immobile and easier to catch them; and (4) it can be penetrated to egg chorion instead of cuticle of other stages (Sabelis, 1985).

In this study, the numerically highest egg deposited by *T. recki* was determined when fed on protonymph. However, the predatory mite consumed more eggs than the other biological stages, and if the predator consumes more prey, it is expected to deposit more eggs. The possible reason is that the

predatory mite may try to consume or puncture the eggs with their mouthparts and damaged the eggs. If they are unsuccessful, they stop feeding. However, when feeding on protonymph, the predator may take high nutritional value. Blackwood et al. (2001) reported that generalist species may have mouthparts that are not as effective in piercing the egg chorion of *T. urticae* as mouthparts of more specialized species. For generalist predator species, there is some evidence that suggests *T. urticae* larvae may be more favorable than eggs with respect to both nutritional benefits. Zaher & Shehata (1971) found that *Typhlodromus pyri* Scheuten, 1857 feeding on mobile stages of *Tetranychus cinnabarinus* (Boisduval, 1867) were more fecundity than on eggs of the same species.

In order to find an effective predator in biological control programs, it is necessary to perform experiments on the characteristics of the predator including predation and oviposition activities. Although, many new phytoseiid mite species have been identified by researchers, information about their potential as biological control agents is limited (Helle & Sabelis, 1985; Kuştutan & Cakmak, 2009; Kamburgil & Cakmak, 2014). In addition, the potential of some species described many years ago, that are common in a diverse range of habitats (cultivated and uncultivated plants), also remains unknown. Among them, *T. recki* is known as one of the most common species in many European and West Asian countries as it was determined on a series of cultivated and uncultivated plants (Swirski & Amitai, 1982; Şekeroğlu, 1984; Papaioannou-Souliotis et al., 1994; Tixier et al., 2003; Kumral, 2005; Rahmani et al., 2010; İnak & Çobanoğlu, 2018; Tixier et al., 2020). However, information on the biological control potential of *T. recki* is limited with only a few recent studies (Tixier et al., 2020; Ersin et al., 2021). Tixier et al. (2020) reported that *T. recki* is a generalist predator and its biological characteristics are close to some other generalist predators such as *K. aberrans*, *T. pyri* and *N. californicus*. Tixier et al. (2020) tested this species for the first time against to *Tetranychus evansi* Baker & Pritchard, 1960 and *T. urticae* and concluded that *T. recki* preferred *T. urticae* over *T. evansi.* Ersin et al. (2021) also showed the feeding and reproduction ability of *T. recki* on *T. urticae* at five temperatures under laboratory conditions.

In conclusion, the results presented here demonstrate for the first time the ability of *T. recki* to control populations of *T. urticae*. The native population of *T. recki* has the potential to be a biological control agent of *T. urticae* due to its ability to feed and reproduce at all biological stages of its prey. Field and greenhouse experiments are needed to determine if the biocontrol potential of *T. recki* on *T. urticae* can be realized on different host plants under production conditions. As predator-prey release ratio is also important for the success of biological control, the most effective ratio should also be determined for *T. recki* to provide effective control for *T. urticae* (Cakmak et al., 2009; Kazak et al., 2015; Kasap, 2019).

Acknowledgements

This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK-Project Number: 118O666). I am grateful to Dr. Ibrahim Cakmak (Aydın Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, Aydın, Turkey) and Dr. İsmail Döker (Çukurova University, Faculty of Agriculture, Department of Plant Protection, Adana, Turkey) for data analyses and editing the manuscript.

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Türk. entomol. derg., 2021, 45 (3): 343-350
DOI: http://dx.doi.org/10.16970/entoted.918696

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Determination of the host status of some plant species with four different garlic populations of *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936 (Tylenchida: Anguinidae)[1]

Bazı bitki türlerinin *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936 (Tylenchida: Anguinidae)'nin dört farklı sarımsak popülasyonuna karşı konukçuluk durumlarının belirlenmesi

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Abstract

Stem and bulb nematode, *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936 (Tylenchida: Anguinidae) is widely distributed in areas where garlic is grown commercially in Turkey. One of the suitable methods for control of *D. dipsaci* under field conditions is rotation with non-host plant species. Thus, it is necessary to determine the host status of the plant species that can be used in rotation with the garlic plant. For this purpose, the host status of eight different plant species for four *D. dipsaci* populations obtained from important garlic growing areas was investigated in 2017 and 2018. The experiments were conducted with four replicates of treatments with nematode and without nematodes in a control environment room. Each plant was inoculated with 200 nematodes of the respective population. Six weeks after inoculation, the final nematode population in the plants and reproduction factors were determined. For all nematode populations, daffodil was an excellent host with reproduction factor (R_f) of 5.0-6.2. Onion and garlic plants were good hosts with R_f of 3.2-3.8 and 2.1-2.5, respectively. Lucerne, chickpea, leeks, lettuce and wheat were determined to be non-host species with R_f 0.6-0.7, 0.5-0.8, 0, 0 and 0.3-0.5, respectively. It was concluded that these non-host plant species can be used as rotational crops in the garlic production areas infested with *D. dipsaci*.

Keywords: Host, plant parasitic nematode, race, rotation, stem and bulb nematode

Öz

Soğan sak nematodu, *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936 (Tylenchida: Anguinidae) Türkiye'de ekonomik olarak sarımsak yetiştiriciliği yapılan üretim alanlarında yaygın olarak bulunmaktadır. *Ditylenchus dipsaci*'nin tarla koşullarında mücadelesi için uygun yöntemlerden birisi de konukçu olmayan bitki türleri ile rotasyon uygulamalarıdır. Bu nedenle sarımsak bitkisi ile rotasyona girebilecek bitki türlerinin nematoda konukçuluk durumlarının belirlenmesi önem arz etmektedir. Bu amaçla çalışmada sekiz farklı bitki türünün önemli sarımsak yetiştirme alanlarından elde edilen dört farklı *D. dipsaci* popülasyonuna karşı konukçuluk durumları 2017-2018 yıllarında araştırılmıştır. Denemeler iklim odası şartlarında nematodlu ve nematodsuz bitkiler için dört tekerrürlü olarak yürütülmüştür. Nematodlu bitkilere bitki başına 200 nematod inokule edilmiştir. İnokulasyondan altı hafta sonra bitkilerdeki sonuç nematod popülasyonu belirlenerek üreme faktörleri belirlenmiştir. Çalışmada bütün nematod popülasyonları için, nergis bitkisi 5.0-6.2 arasında üreme faktörü (R_f) ile mükemmel konukçu olarak belirlenmiştir. Soğan ve sarımsak bitkileri sırasıyla 3.2-3.8 ve 2.1-2.5 R_f ile iyi konukçu olarak tespit edilmiştir. Yonca, nohut, pırasa, marul ve buğday bitki türleri sırasıyla 0.6-0.7, 0.5-0.8, 0, 0 ve 0.3-0.5, R_f değerleri ile konukçu olmayan bitki türleri olarak belirlenmiştir. Gerçekleştirilen bu çalışma ile konukçu olmayan bitki türlerinin soğan sak nematodunun bulaşık olan üretim alanlarında rotasyon bitkisi olarak kullanılabileceği sonucuna varılmıştır.

Anahtar sözcükler: Bitki paraziti nematod, ırk, konukçu, münavebe, soğan-sak nematodu

[1] This study was supported by the General Directorate of Agricultural Research and Policies, Turkey, Grant Project No: TAGEM/BSAD/A/18/A2/P1/380. This study was undertaken as a part of PhD Thesis in Çukurova University, Institute of Science, Department of Plant Protection, Adana, Turkey.
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Received (Alınış): 20.04.2021 Accepted (Kabul ediliş): 11.08.2021 Published Online (Çevrimiçi Yayın Tarihi): 12.08.2021

Introduction

Garlic is an economically important commodities in Turkey and worldwide. The main nematode constraint for garlic production is stem and bulb nematode, *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936 (Tylenchida: Anguinidae). Infected garlic plants show stunting, yellowing of leaves and shoots, deformation and abnormal cell growth in leaves and stems, lesions range from yellow to dark brown in the bulbs. The nematode reduces product quality and causes economically significant yield loses. In onion and bulbous ornamental plants, 5-100% damage can occur due to *D. dipsaci* (Duncan & Moens, 2006). *Ditylenchus dipsaci* is widely distributed in areas with temperate climates (Abd-Elgawad & Askary, 2015) and is reported from most of the onion and garlic production areas of Turkey (Mennan, 2001; Yavuzaslanoglu et al., 2019; Ocal, 2021).

Ditylenchus dipsaci has the greatest intraspecific difference in the host range of plant parasitic nematodes and therefore has the greatest number of synonyms with thirteen nominal species (Subbotin et al., 2005). The classification of this nematode is made at the race level according to the host status of the plants. There are more than 30 races that can multiply on economically important plant species (Sturhan & Brzeski, 1991). Seinhorst (1957) identified 11 different races of *D. dipsaci* using nine different plant species. Accordingly, he reported that onion [*Allium cepa* L. (Asparagales: Amaryllidaceae)], garlic [*Allium sativum* L. (Asparagales: Amaryllidaceae)] and pea [*Pisum sativum* L. (Fabales: Fabaceae)] were among the hosts of the onion race. Thorne (1961) reported that the hosts of the onion race of *D. dipsaci* were rice [*Oryza sativa* L. (Poales: Poaceae)], hyacinth [*Hyacinthus orientalis* L. (Asparagales: Asparagaceae)], daffodil [*Narcissus* spp. L. (Asparagales: Amaryllidaceae)], thistle (*Silybum marianum* (L.) Gaertn. (Asterales: Asteraceae)] and parsley [*Spinacia oleracea* L. (Caryophyllales: Amaranthaceae)]. Eight races of *D. dipsaci* were defined by Janssen (1994) according to the plant from which they were obtained. The races determined by Janssen (1994) were lucerne [*Medicago sativa*, L. (Fabales: Fabaceae), red clover [*Trifolium pratense* L. (Fabales: Fabaceae)], oat [*Avena sativa* L. (Poales, Poaceae)], rye [*Secale cereale* L. (Poales, Poaceae)], sugar beet [*Beta vulgaris* L. (Caryophyllales: Amaranthaceae)], daffodil, tulip [*Tulipa* spp. L. (Liliales: Liliaceae)] and onion. Shubina (1992) reported that the onion race of *D. dipsaci* did not feed on maize [*Zea mays* L. (Poales: Poaceae)] but fed and reproduced on rice and pea. The host status of *D. dipsaci* obtained from onion in Amasya Suluova District in Turkey was investigated by Mennan (2001). Yavuzaslanoglu & Aksay (2021) reported susceptibility of plant species to onion and garlic populations of *D. dipsaci* from the Central Anatolia Region in Turkey. Viglierchio (1971) reported that the host status of local populations may be different. Therefore, the hosts of nematode populations that are distributed in different locations should be determined. However, the host status of different plant species to *D. dipsaci* populations obtained from different garlic production areas where most of the garlic production is undertaken has not been investigated widely in Turkey.

Therefore, the aim of this study was to investigate the host status of eight plant species using four *D. dipsaci* populations from garlic grown in production areas of Turkey.

Materials and Methods

Nematode populations

Ditylenchus dipsaci populations were collected in 2017 and 2018 from Adıyaman, Gaziantep, Kahramanmaraş and Kastamonu Provinces, Turkey, in areas with intensive garlic production. Nematode populations were identified as *D. dipsaci* (Ates Sonmezoglu et al., 2020). Location information about *D. dipsaci* populations is given in Table 1.

Mass production of pure cultures of *Ditylenchus dipsaci* populations

Stem and bulb nematodes obtained from the samples did not contain sufficient numbers to be used directly and were not pure populations. Therefore, pure cultures of *D. dipsaci* populations were propagated by the carrot culture method using nematodes obtained from plant samples. Sterile carrot discs were prepared in 2017-2019 in Atatürk Horticultural Central Research Institute, Yalova, Turkey (Chitambar, 2003; Kühnhold et al., 2006). Firstly, the carrots that were washed in tap water, drained and peeled then placed 97% ethanol for 10-15 min. Then carrots were peeled again with a sterile knife, sliced into ~1 cm thick disc and placed individually in Petri dishes. One female and one male *Ditylenchus dipsaci* were transferred to each sterile carrot disc. Cultures were incubated at 19-20ºC in the dark. Discs were cut into small pieces and placed on fresh sterile carrot discs for 2-4 months to maintain the cultures for use as inoculum (after extraction) for host status determination.

Table 1. Geographic locations of *Ditylenchus dipsaci* populations

Populations	Region	Province	District	Village	Latitude	Longitude
ADY1	South East Anatolia	Adıyaman	Tut	Yeşilyurt	37º44'55.55"N	38º01'08.55"E
GAZ4	South East Anatolia	Gaziantep	Oğuzeli	Koçaklar	36º52'57.73"N	37º31'57.40"E
KAH2	Mediterranean	Kahramanmaraş	Pazarcık	Narlı/Karaçay	37º22'13.96"N	37º07'54.63"E
KAS9	Black Sea	Kastamonu	Taşköprü	Vakıfbelören	41º30'07.37"N	34º15'01.19"E

Host status experiment

The plant species included in the experiment were wheat, lettuce, daffodil, chickpea, leek, garlic, onion and lucerne (Table 2).

Table 2. The cultivars and sources of the plant species used for host status determination

Plant species	Cultivar name	Source
Chickpea (*Cicer arietinum* L.)	Azkan	Altat Agriculture, Çorum, Turkey
Daffodil (*Narcissus tazetta* L.)	Karaburun	Ege University, Department of Horticulture, İzmir, Turkey
Garlic (*Allium sativum* L.)	Taşköprü 56	Atatürk Horticultural Central Research Institute, Yalova, Turkey
Leek (*Allium porrum* L.)	İnegöl 92	Atatürk Horticultural Central Research Institute, Yalova, Turkey
Lettuce (*Lactuca sativa* L.)	Grise maraichere	Atatürk Horticultural Central Research Institute, Yalova, Turkey
Lucerne (*Medicago sativa* L.)	Bilensoy	Intfa Agriculture, Konya, Turkey
Onion (*Allium cepa* L.)	Kantartopu 3	Atatürk Horticultural Central Research Institute, Yalova, Turkey
Wheat (*Triticum aestivum* L.)	Flamura 85	Altınbaşak Seed, Edirne, Turkey

Experiment was conducted in a controlled environment room at the Atatürk Horticultural Central Research Institute, Yalova, Turkey in 2019. In the experiment, sand, field soil and farm manure were sterilized, mixed in a ratio of 70:29:1 and added to 12.5 x 12.5 x 20 cm pots (2.5 L). One seed of each plant species was planted per pot. Four weeks after planting, when the plants were at the three- to four-leaf stage, 10 µl of 1% carboxymethyl cellulose solution containing 200 nematodes was dropped at the leaf base of each plant (Kühnhold et al., 2006). Non-inoculated plants of each cultivar were used as controls. The pots were arranged in a completely randomized design with four replicates and plants were grown at 20-25ºC and 70-80% RH in a 16:8 h L:D photoperiod. Six weeks after inoculation, plants were harvested and the plant growth parameters (plant height, stem diameter, number of leaves, root length, and combined shoot and root fresh weight) were measured. To extract nematodes, inoculated plants were cut into 1 cm pieces and placed in 15-cm Petri dishes according to a modified Baermann funnel technique for 48 h (Hooper et al., 2005). The extracted nematodes were counted under a stereomicroscope. The reproduction

factor (R_f), calculated as the number of nematodes obtained per plant at harvest divided by the 200 nematodes initially inoculated to the plant, was used to determine the host status of the test plants. Plant species were categorized as non-host with $R_f < 1$, poor host with $1 \leq R_f < 2$, good host with $2 \leq R_f \leq 4$ and excellent host with $R_f > 4$ (Hajihassani et al., 2016).

Statistical analysis

One-way analysis of variance was applied to the values of *D. dipsaci* ADY1, GAZ4, KAH2 and KAS9 populations in wheat, chickpea, daffodil, garlic, onion and lucerne. Differences between the treatments were evaluated using Tukey test at $P \leq 0.05$. Comparison biplot analysis was conducted to determine the relationship between *D. dipsaci* populations and hosts in terms of reproduction factors of nematode populations on host plants. Differences in plant parameters between nematode inoculated and uninoculated treatments for each plant species with each nematode population were compared by t-test. Statistical analyses were performed using JMP (13th ed.) and GenStat (14th ed.) software.

Results

No nematodes were extracted from any inoculated lettuce and leek plants at harvest. However, nematodes were obtained from chickpea, daffodil, garlic, lucerne, onion and wheat plants. R_f values of all *D. dipsaci* populations ranged between 0.5-0.8 with chickpea, 5.0-6.2 with daffodil, 2.1-2.5 with garlic, 0.6-0.7 with lucerne, 3.2-3.8 with onion and 0.3-0.5 with wheat (Table 3).

Population-host interaction was statistically significant ($F = 1.9$, $sd = 7.21$, $P < 0.05$). Daffodil plants ($R_f = 5.3$) were rated as excellent hosts ($R_f > 4$) whereas onion ($R_f = 3.4$) and garlic ($R_f = 2.3$) were rated as good hosts for all nematode populations ($2 \leq Rf \leq 4$). Chickpea, leek, lettuce, lucerne and wheat plants were non-hosts for all nematode populations ($R_f < 1$). The average R_f of the populations was between 0.3 and 0.8 for chickpea, lucerne and wheat, while no nematode was extracted from lettuce and leek (Table 3).

Table 3. Reproduction factor for *Ditylenchus dipsaci* in different plant species in a pot experiment conducted in a growth room

Ditylenchus dipsaci populations	Plant species							
	Chickpea	Daffodil	Garlic	Leek	Lettuce	Lucerne	Onion	Wheat
ADY1	0.7±0.1Ad[1]	5.0±0.9Ba	2.2±0.3Ac	0.0±0.0 Ad	0.0±0.0Ad	0.6±0.2Ad	3.3±0.3Ab	0.5±0.1Ad
GAZ4	0.5±0.2Ad	5.2±0.4Ba	2.3±0.7Ac	0.0±0.0 Ad	0.0±0.0Ad	0.6±0.1Ad	3.2±0.4Ab	0.4±0.1Ad
KAH2	0.8±0.1Ad	5.0±0.5Ba	2.5±0.5Ac	0.0±0.0 Ae	0.0±0.0Ae	0.7±0.2Ad	3.4±0.4Ab	0.3±0.1Ade
KAS9	0.6±0.2Ad	6.2±0.4Aa	2.1±0.9Ac	0.0±0.0 Ad	0.0±0.0Ad	0.7±0.2Ad	3.8±0.5Ab	0.5±0.1Ad

[1] Data are means of four replicates ± standard deviation. Means followed by the same lowercase letter within rows (plant species) or the same uppercase letters within columns (nematode populations) are not significantly different ($P < 0.05$, Tukey test).

No statistically significant differences between R_f values for nematode populations were found except for daffodil. In the daffodil, R_f of the KAS9 population was higher than other populations ($P < 0.05$).

The relationship between nematode populations and plant species was explained by comparison biplot analysis with a rate of almost 100% (Figure 1). The features close to the middle horizontal axis (PC1) were stable, while the stability of the features moving away from the axis was low. Also, the further a feature is located from the vertical axis (PC2) towards the right side (in the direction of the arrow) of the graph the stronger the relationship, and relationships are weaker towards the left side of the axis. According to the biplot, all the nematode populations examined formed a group. The stability of R_f on plant species of the ADY1 and GAZ4 nematode populations was greater (Figure 1). The biplot analysis showed that the stability of the onion plant was higher and the stability of the daffodil and garlic plants was lower. Chickpea, lucerne and wheat, with low R_f, and lettuce and leek plants with no reproduction were grouped together. The stability of lucerne plant was found to be higher compared to chickpea and wheat.

Most of the plant growth parameters for daffodil were significantly lower with inoculation compared to the controls for the different populations of *D. dipsaci*. Plant height was not adversely affected by the presence of KAH2 whereas there was significant reduction with the ADY1, GAZ4 and KAS9 populations (Table 4). Similarly, root height was significantly reduced by ADY1 and GAZ4 populations (Table 4).

Table 4. Percentage change in plant growth parameters in plant species inoculated with four *Ditylenchus dipsaci* populations

Plant species	Nematode population	Shoot length	Number of leaves	Shoot diameter	Plant fresh	Root length	Number of roots
Chickpea	ADY1	-10.0	-13.0	-22.2	-37.1	-33.9	-25.9
	GAZ4	-2.8	0.0	5.5	-11.4	-53.9	-30.1
	KAH2	-20.3	-13.0	-38.8*	-34.3	-34.5	-24.9
	KAS9	-19.7	-56.5*	-38.8	-40.0	-51.5	-22.3
Daffodil	ADY1	-23.3*	-15.5	-44.9*	-57.7*	-30.5*	-50.7*
	GAZ4	-30.2*	-4.4	-31.2*	-57.1*	-40.6*	-46.5
	KAH2	-5.2	-4.4	-25.7*	-43.3*	-4.5	-33.4
	KAS9	-22.9*	-11.1	-34.8*	-57.4*	-33.7	-50.7*
Garlic	ADY1	-19.6	-11.4	-30.8	-25.0	-37.2	-46.4*
	GAZ4	-29.8	-11.1	-30.8*	-58.3	23.3	-38.7
	KAH2	-23.5*	-15.5	-38.5	-50.0	-37.2*	-40.5
	KAS9	-25.8*	-22.2	-30.8	-75.0*	-44.2*	-58.3*
Leek	ADY1	-16.9*	-22.4	-36.6	-50.0	13.3	-39.8
	GAZ4	-12.9	-22.4	-33.3	-54.2*	-20.0	-31.0
	KAH2	-11.9	-22.4	-23.3	-41.6	-20.0	-31.0
	KAS9	3.3	-8.6	-20.0	-16.6	13.3	-8.8
Lettuce	ADY1	11.7	-3.9	-18.8	-35.3	-4.2	40.0
	GAZ4	-16.9	-5.8	-8.3	-29.8	9.9	58.4
	KAH2	-14.8	-12.5	-10.4	-45.3	2.8	-9.6
	KAS9	-1.64	-7.8	10.4	-5.8	2.8	46.4
Lucerne	ADY1	-25.7*	-10.7	-40.0	-40.6	-25.4	-28.0
	GAZ4	-11.9*	-18.5	10.0	-21.8	-25.4	-37.6*
	KAH2	-19.2	-41.5	-20.0	-43.7	-2.9	-20.0
	KAS9	-7.7	-41.5	-10.0	-12.5	-12.3	-36.0
Onion	ADY1	-5.0	-3.3	-14.9	-37.4	-27.0	-15.7
	GAZ4	-8.3	-20.0	8.5	-23.1*	9.0	6.1
	KAH2	13.1	0.0	-10.6	-35.2*	-5.8	-25.2
	KAS9	-8.9	8.3	12.7	-19.2	3.7	-5.7
Wheat	ADY1	8.5	23.6	-20.0	-29.3	-12.3	-33.5
	GAZ4	16.1	36.4	33.3	-21.9	-33.8	-41.6
	KAH2	21.4	0.0	-20.0	-17.0	-4.6	2.7
	KAS9	8.1	5.5	-13.3	-34.1*	7.7	-28.1

* Differences between inoculated and uninoculated plants are significantly different according to the t-tests ($P < 0.05$).

With all nematode populations, stem diameter and plant fresh weight was reduced in inoculated daffodil. Mean stem diameter and shoot fresh weight reduced statistically significantly in all populations ($P < 0.05$) (Table 4). Other significant lower plant growth parameters in inoculated daffodil plants were the number of roots with ADY1 and KAS9 populations (Table 4).

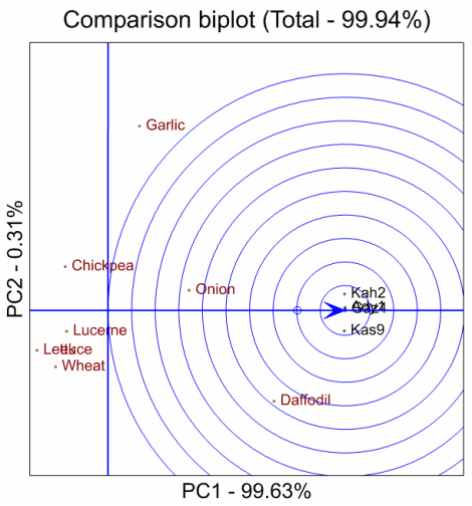

Figure 1. Biplot of reproduction factor of *Ditylenchus dipsaci* ADY1, GAZ4, KAH2 and KAS9 populations in chickpea, daffodil, garlic, leek, lettuce, lucerne, onion and wheat.

Garlic plant species had significantly lower plant growth parameters with nematode treatment. Mean shoot and root length decreased with KAH2 and KAS9 populations ($P < 0.05$) (Table 4). Number of roots in nematode inoculated plants with ADY1 and KAS9 populations was significantly lower (Table 4). Garlic shoot fresh weight was significantly lower in plants inoculated with KAS9 population ($P < 0.05$) (Table 4). Fresh weight of onion was significantly lower in plants inoculated with GAZ4 and KAH2 populations ($P < 0.05$) (Table 4).

Other significant changes in plant growth parameters with inoculation were lower stem diameter and number of leaves in chickpea with inoculation of KAH2 and KAS9 population, respectively. Although no nematode reproduction occurred in leek, shoot length (ADY1 population) and plant fresh weight (GAZ4 population) was found lower in inoculated plants (Table 4).

Mean shoot length of lucerne was significantly lower with inoculation with ADY1 and GAZ4 populations. Also, number of roots was significantly lower in nematode inoculated (GAZ4 population) lucerne plants ($P < 0.05$) (Tables 4).

Discussion

In this study, the host status of eight plant species of potential use in crop rotations for managing *D. dipsaci* in garlic was determined. Daffodil was found to be an excellent host, onion and garlic good hosts for *D. dipsaci* populations from garlic in South East Anatolia and Black Sea Regions in Turkey. In previous studies (Mennan, 2001; Yavuzaslanoglu & Aksay, 2021) similar results for *D. dipsaci* populations from other geographic regions of Turkey were obtained. However, Yavuzaslanoglu & Aksay (2021) did not obtain *D. dipsaci* reproduction daffodil, but it was found to be an excellent host in the current study. The reason for this could be the response of a different daffodil cultivar or difference in virulence of nematode populations applied. Whether this difference was due to the plant cultivar or nematode populations should be determined by investigating the host status of a range of daffodil cultivars to *D. dipsaci* populations. Also, in the current study, lower R_f values were determined for onion and garlic plants than by Yavuzaslanoglu & Aksay (2021) and were classified as good hosts rather than excellent hosts.

In a recent study (Poirier et al., 2019) in Canada, lucerne and lettuce were found to be non-hosts of a garlic population of *D. dipsaci*, similar to our study. Also, consistent with the findings of the present study, Hajihassani et al. (2016) reported that wheat was a non-host, chickpea cultivars were poor hosts and garlic a good host.

Ditylenchus dipsaci populations have been shown to decrease significantly with 3-4 years of rotation with non-host plants (Hooper, 1984; Roberts & Grathead, 1986). It is essential to know the host range of the population of *D. dipsaci* in an area in order to successfully design a crop rotation strategy to manage *D. dipsaci*. According to our results, lucerne, chickpea, wheat, lettuce and leek are non-hosts for *D. dipsaci* and this host status was not affected by the nematode population applied. Therefore, these plants can be recommended as rotational plants in garlic areas infested with *D. dipsaci*.

Shoot length, stem diameter, root length, number of roots and leaves, and whole plant fresh weight properties were used for evaluation of effect of *D. dipsaci* on the plants tested. Paralleling nematode reproduction, several plant growth parameters were identified to be affected by nematode inoculation. The non-host plant species in this study were unaffected.

To continue this work, it is necessary to test the non-host plant species identified in this study under natural infestation of *D. dipsaci* in the field and to consider their economic and agronomic value as rotational crops.

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Türk. entomol. derg., 2021, 45 (3): 351-360
DOI: http://dx.doi.org/10.16970/entoted.952885

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Descriptions of *Geostiba dindymosensis* sp. n. and *Geostiba yagmuri* sp. n. (Coleoptera: Staphylinidae: Aleocharinae), and additional records for *Geostiba* Thomson, 1858 from Turkey

Geostiba dindymosensis sp. n. ve *Geostiba yagmuri* sp. n. (Coleoptera: Staphylinidae: Aleocharinae) türlerinin deskripsiyonları ve Türkiye'den *Geostiba* Thomson, 1858 için ek kayıtlar

Semih ÖRGEL[1*]

Abstract

As a result of field survey in the western Anatolia, Turkey (Aydın, Balıkesir, Denizli, İzmir, Kütahya, Manisa, Muğla) between 2014 and 2016, two new species of the subgenus *Tropogastrosipalia* Scheerpeltz, 1951 belonging to the genus *Geostiba* Thomson, 1858 are described and illustrated: *Geostiba dindymosensis* sp. n. from Kütahya and *Geostiba yagmuri* sp. n. from Balıkesir and Manisa. These two new species are compared with morphologically similar and geographically close species. Also, a map illustrating the distributions of these species is provided. Additional records of *Geostiba aydinica* Assing, 2006, *Geostiba biformis* Assing, 2006 and *Geostiba nifica* Assing, 2006 are presented. These three species are recorded for the first time since their descriptions.

Keywords: Aleocharinae, *Geostiba*, new species, Staphylinidae, Turkey

Öz

Batı Anadolu (Türkiye)'da (Aydın, Balıkesir, Denizli, İzmir, Kütahya, Manisa, Muğla) 2014-2016 yılları arasında yapılan arazi çalışmaları sonucunda, *Geostiba* Thomson,1958 cinsinden *Tropogastrosipalia* Scheerpeltz,1951 alt cinsinin iki yeni türü, Kütahya'dan *Geostiba dindymosensis* sp. n. ile Balıkesir ve Manisa'dan *Geostiba yagmuri* sp. n. bilim dünyasına tanıtılmıştır. Bu yeni türler, morfolojik olarak benzer ve coğrafi olarak yakın yayılışa sahip türlerle karşılaştırılmıştır. Ayrıca, bu türlerin yayılışlarını gösteren bir harita da verilmiştir. *Geostiba aydinica* Assing, 2006, *Geostiba biformis* Assing, 2006 ve *Geostiba nifica* Assing, 2006 türleri için ek kayıtlar verilmiştir. Bu üç tür, tanımlanmalarından bu yana ilk kez kaydedilmiştir.

Anahtar sözcükler: Aleocharinae, *Geostiba*, yeni türler, Staphylinidae, Türkiye

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Received (Alınış): 15.06.2021 Accepted (Kabul ediliş): 11.08.2021 Published Online (Çevrimiçi Yayın Tarihi): 12.08.2021

Introduction

The genus *Geostiba* Thomson, 1858 (Coleoptera: Staphylinidae: Aleocharinae) is one of the most studied taxa of the subfamily Aleocharinae with 443 species in the Palearctic Region (Schülke & Smetana, 2015; Assing, 2018; 2019; Örgel, 2018; Assing et al., 2019; Örgel & Anlaş, 2020). These species are classified into 13 subgenera. Twenty-seven species are not included in any subgenus.

In Turkey, the genus *Geostiba* contains 86 species, with 81 species known only from Turkey. (Anlaş, 2009; Örgel & Anlaş, 2020) and these species belong to the subgenera *Sibiota* Casey, 1906, *Sipalotricha* Scheerpeltz, 1931, *Tropogastrosipalia* Scheerpeltz, 1951 and the nominal subgenus, with one species without subgeneric assignment (Schülke & Smetana, 2015). *Tropogastrosipalia* spp. are distinguished from those of other subgenera of *Geostiba* by the male primary and secondary sexual characters (presence of a process of abdominal tergite VII, an unmodified abdominal sternite VIII, and a crystal process of the aedeagus), have very restricted distributions and are represented a high diversity. In general, *Tropogastrosipalia* spp. inhabit the alpine and subalpine zones (Assing, 2016a, b; 2017a, b). The Anatolian mountain ranges provide appropriate habitats for the species belonging to the subgenus. Until 2000, only seven *Tropogastrosipalia* spp. had been known in Anatolia (Anlaş, 2009). Thirty-nine species were described in the studies carried out by Volker Assing between 2000-2011 (Assing, 2000; 2001; 2003; 2004; 2005; 2006; 2007; 2009; 2010; 2011). In addition, Assing's studies, four species were described from western Anatolia by Örgel (2018) and Örgel & Anlaş (2020). In all, 50 species are known from Anatolia and all of them are endemic to the certain mountains and their environs (Pace, 1983; Assing, 2000; 2001; 2003; 2004; 2009; 2011; 2016a, b; 2017a, b; Örgel, 2018; Örgel & Anlaş, 2020).

The main aims of this study were to contribute to Anatolian biodiversity studies and determine the Turkish *Geostiba* fauna.

Materials and Methods

The material studied was collected using aspirators in Aydın, Balıkesir, Denizli, İzmir, Kütahya, Manisa, Muğla Provinces of western Anatolia between 2014 and 2016. Dissection techniques followed that of Hanley & Ashe (2003). The morphological studies were carried out by a Stemi 508 (Zeiss Oberkochen, Germany) stereomicroscope. Photographs were taken with a Zeiss Axiocam ERC5s digital camera. Adobe Photoshop 2020 was used for focus stacking. CorelDRAW Graphics Suite X7 was used for editing photographs. Google Earth Pro was used to create the map. Primary and secondary sexual characters of the species are described following the terminology of Assing (2006; 2010). Head length was measured from the anterior margin of the frons to the posterior margin of the head, length of the pronotum was measured along the median line; elytral length was measured along suture from the apex of the scutellum to the posterior margin; the length of the median lobe of the aedeagus was measured from the apex of the ventral process to the base of the capsule. The material is deposited in Alaşehir Zoological Museum, Manisa, Turkey (AZMM).

RESULTS

Additional faunistic records for three species are given and two new species are described of the subgenus *Tropogastrosipalia* from western Anatolia. The subgenus *Tropogastrosipalia* is now represented by 52 species in Turkey.

Descriptions of new species

***Geostiba* (*Tropogastrosipalia*) *dindymosensis* sp. n. (Figures 1a-I and 3)**

Type material. Holotype: Turkey, ♂, "TR- Kütahya Province, Gediz district, 5 km SE of Uğurluca, Murat Mountain, 2082 m, 38°56'38" N, 29°38'22" E, 05.IV.2014, leg. Yağmur & Örgel / Holotypus ♂ *Geostiba* (*Tropogastrosipalia*) *dindymosensis* sp. n. det. S. Örgel 2021" (AZMM).

Paratypes (22 exs.). Turkey, 8♂♂, 8♀♀, same locality and date as holotype; ♂, Kütahya Province, Gediz district, 3 km E of Karaağaç, Murat Mountain, 1754 m, 38°56'15" N, 29°35'45" E, 03.V.2015, leg. Örgel; ♂, 2♀♀, Kütahya Province, Gediz district, 7 km SE of Uğurluca, Murat Mountain, 2191 m, 38°56'58" N, 29°40'18" E, 24.V.2015, leg. Örgel; ♂, Kütahya Province, Gediz district, 8 km E of Karaağaç, Murat Mountain, 1764 m, 38°56'11" N, 29°38'34" E, 24.V.2015, leg. Örgel; ♀, Kütahya Province, Gediz district, 3 km S of Uğurluca, Murat Mountain, 2073 m, 38°57'04" N, 29°36'26" E, 19.VI.2016, leg. Örgel (AZMM).

Etymology. Murat Mountain, where this new species was discovered, was called Dindymos in ancient times. The specific epithet is derived from this name.

Description. Body 2.5-3.2 mm. Head dark brown; pronotum and elytra reddish-brown, but pronotum darker than elytra; abdomen with segments I-III reddish-brown, IV-VII black VIII-IX dark brown, anterior portion of all abdominal segments darker than posterior; legs yellowish-brown; antennae with segments I, II yellowish-brown, III-XI reddish-brown.

Head 0.98 times as wide as long (Figure 1a), with fine microreticulation; eyes 1/3 as long as postocular region.

Pronotum distinctly oblong (Figure 1a), 1.23 times as long as wide; 1.28 times as wide as head; covering scutellum; posterior margin truncate in the middle; microreticulation more pronounced than that on the head.

Elytra 0.58 times as long as and 1.13 times as wide as pronotum (Figure 1a); lateral margins slightly elevated; sutural carina strongly elevated, extending about half length of elytral suture (Figure 1c); microreticulation less pronounced than that on the pronotum; punctuation distinctly granulose; hind wings absent.

Abdomen 0.95 times as wide as elytra; only tergites VII modified, process of tergite VII short and stout in lateral view (Figure 1d), wide and acute apically in dorsal view (Figure 1g); posterior margin of sternite VIII convex, setae unmodified (Figure 1e).

Median lobe of aedeagus 0.28 mm; crystal process wide, tall, acute apically and slightly closer to ventral process in lateral view (Figure 1h).

Spermatheca as in Figure 1i.

Sexual dimorphism. Pronotum, elytra, and abdomen with sexual dimorphism. Female pronotum distinctly shorter than male pronotum and posterior margin truncate in the middle. Female elytra without sutural carinae and female abdominal tergite VII unmodified.

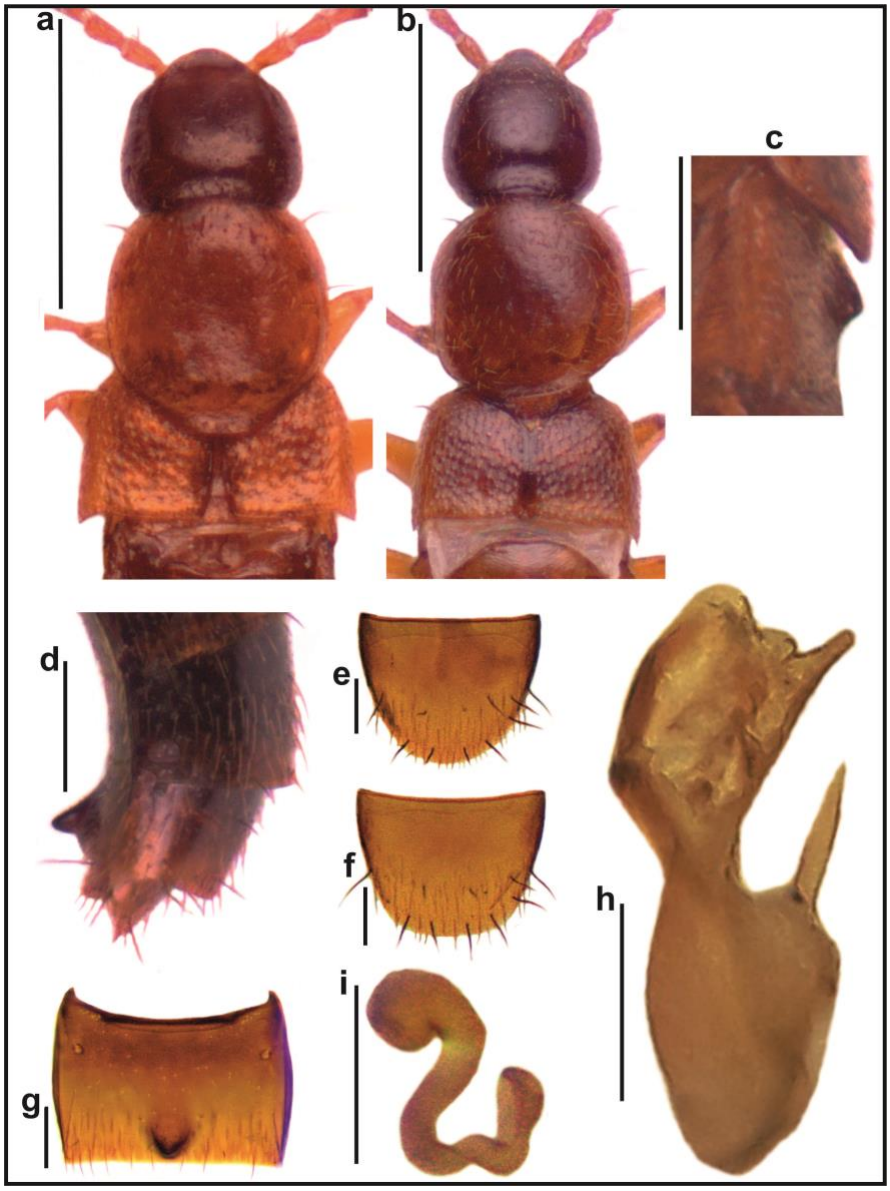

Figure 1. *Geostiba* (*Tropogastrosipalia*) *dindymosensis* sp. n.: a) male forebody; b) female forebody; c) male elytra in lateral view; d) posterior portion of abdominal segments of male in lateral view; e) male abdominal sternite VIII in dorsal view; f) female abdominal sternite VIII in dorsal view; g) male abdominal tergite VII in dorsal view; h) median lobe of aedeagus in lateral view; and i) spermatheca. Scale bars: 0.5 mm (a, b); 0.2 mm (c, d); 0.1 mm (e-i).

Differential diagnosis. Regarding similar external and sexual characters, the new species is similar to *Geostiba ahirensis* Örgel & Anlaş, 2020 and *Geostiba sandiklica* Örgel & Anlaş, 2020, but distinguished by the different shapes of the posterior margin of the male pronotum, elevations of the sutural carinae on the male elytra, modifications of the male abdominal tergites III and IV, widths of the process of the male abdominal tergite VII and different shapes of the crystal process of the median lobe of aedeagus. In *G*. *dindymosensis* sp. n. the posterior margin of the pronotum is truncate in the middle, whereas in *G*. *ahirensis* and *G*. *sandiklica* the posterior margin of the pronotum is convex in the middle. The sutural carinae on the elytra in *G*. *dindymosensis* sp. n. are more elevated than that in *G*. *ahirensis* and *G*. *sandiklica*. In *G*. *dindymosensis* sp. n. tergites III and IV are unmodified, whereas in *G*. *ahirensis* tergites III and IV have a tubercle. The process of the male abdominal tergite VII in *G*. *dindymosensis* sp. n. is wider than that of *G*.

ahirensis and *G*. *sandiklica*. The crystal process of the median lobe of aedeagus is similar to that of *G*. *sandiklica*. However, in *G*. *sandiklica* it is distinctly narrowed towards the apex, while in *G*. *dindymosensis* sp. n. it is narrowed only apically. In *G*. *ahirensis* the crystal process is wider than that of *G*. *dindymosensis* sp. n. and *G*. *sandiklica*. Morphologically (especially regarding the shape of the posterior margin of the male pronotum), this new species is the most similar to *Geostiba kazika* Assing, 2010 and *Geostiba extensicollis* Assing, 2010 (the posterior margin of the male pronotum truncate to indistinctly concave in both species). The new species is distinguished from these species by different shapes of the sutural carinae on the male elytra and crystal process of the median lobe. In *G*. *dindymosensis* sp. n. the sutural carinae (extending from apex of scutellum along approximately 1/2 of suture) are wide and highly elevated, whereas in *G*. *kazika* they extend from the apex of the scutellum along 2/3 of the suture and in *G*. *extensicollis* they extend from the apex of the scutellum almost to posterior margin of the elytra, and the sutural carinae are narrow and moderately elevated in both species. The crystal process in *G*. *dindymosensis* sp. n. is longer and wider than that in *G*. *kazika* and *G*. *extensicollis* (Table 1).

Distribution and bionomics. The new species was collected from Murat Mountain (Figure 3). This mountain is located in the eastern central division of western Anatolia. Murat Mountain has been an important area for endemism. For example, *Astenus kumlutasi* Anlaş, 2015, an endemic staphylinid species, is known from this mountain (Anlaş, 2015), and also this mountain has some other endemic insect species, e.g., *Camponotus ruseni* Karaman, 2012 (Karaman, 2012). Additionally, Murat Mountain is isolated by some valleys and rivers. Therefore, the new species is most probably endemic to Murat Mountain. As a result of more careful investigation of such isolated mountain systems, especially in terms of species with limited mobility and special habitat preferences, it is predicted that many new species will be detected in many different groups for the scientific world. In addition, the importance of detecting the insect fauna of Turkey is again revealed.

***Geostiba* (*Tropogastrosipalia*) *yagmuri* sp. n. (Figures 2a-l and 3)**

Type material. Holotype: Turkey, ♂, "TR- Balıkesir Province, Bigadiç district, 7 km N of Bozbük, Alaçam Mountains, 1548 m, 39°24'03" N, 28°33'15" E, 01.IV.2016, leg. Örgel & Yaman / Holotypus ♂ *Geostiba* (*Tropogastrosipalia*) *yagmuri* sp. n. det. S. Örgel 2021" (AZMM).

Paratypes (21 exs.). Turkey, 7♂♂, 11♀♀, same locality and date as holotype; 3♂♂, Manisa Province, Akhisar district, 20 km SW of Sındırgı, 408 m, 39°07'59" N, 28°00'33" E, 13.IV.2015, leg. Anlaş & Örgel (AZMM).

Etymology. The species is dedicated to Dr. Ersen Aydın Yağmur (Manisa), a specialist on scorpions, who have helped in the collection of some of the material used in this study.

Description. Body 2.7-3.3 mm. Head black; pronotum and elytra reddish-brown, but anterior portion of elytra darker than posterior portion; abdomen with segments I-III reddish-brown, IV-VII black, VIII-IX dark brown; legs and antennae reddish-brown.

Head approximately as wide as long, with fine microreticulation (Figure 2a); eyes half as long as postocular region in lateral view.

Pronotum weakly oblong; 1.09 times as long as wide (Figure 2a); 1.17 times as wide as head; not covering scutellum; posterior margin weakly convex; microreticulation more pronounced than that on the head.

Elytra 0.54 times as long as and 1.15 times as wide as pronotum (Figure 2a); lateral margins slightly elevated; sutural carina slightly elevated, extending about 1/3 length of elytral suture (Figure 2c); microreticulation less pronounced than that on the pronotum; punctuation distinctly granulose; hind wings absent.

Abdomen 0.98 times as wide as elytra; only tergites VII modified, process of tergite VII short and stout in lateral view (Figure 2d), narrow and acute apically in dorsal view (Figure 2g); posterior margin of sternite VIII convex, setae unmodified (Figure 2e).

Median lobe of aedeagus 0.31 mm; crystal process very thin, tall and acute apically, slightly closer to ventral process in lateral view (Figure 2h).

Spermatheca as in Figure 2i.

Sexual dimorphism. Pronotum (weakly), elytra, and abdomen with sexual dimorphism. Female pronotum weakly shorter than that in male. Female elytra without sutural carinae and female abdominal tergite VII unmodified.

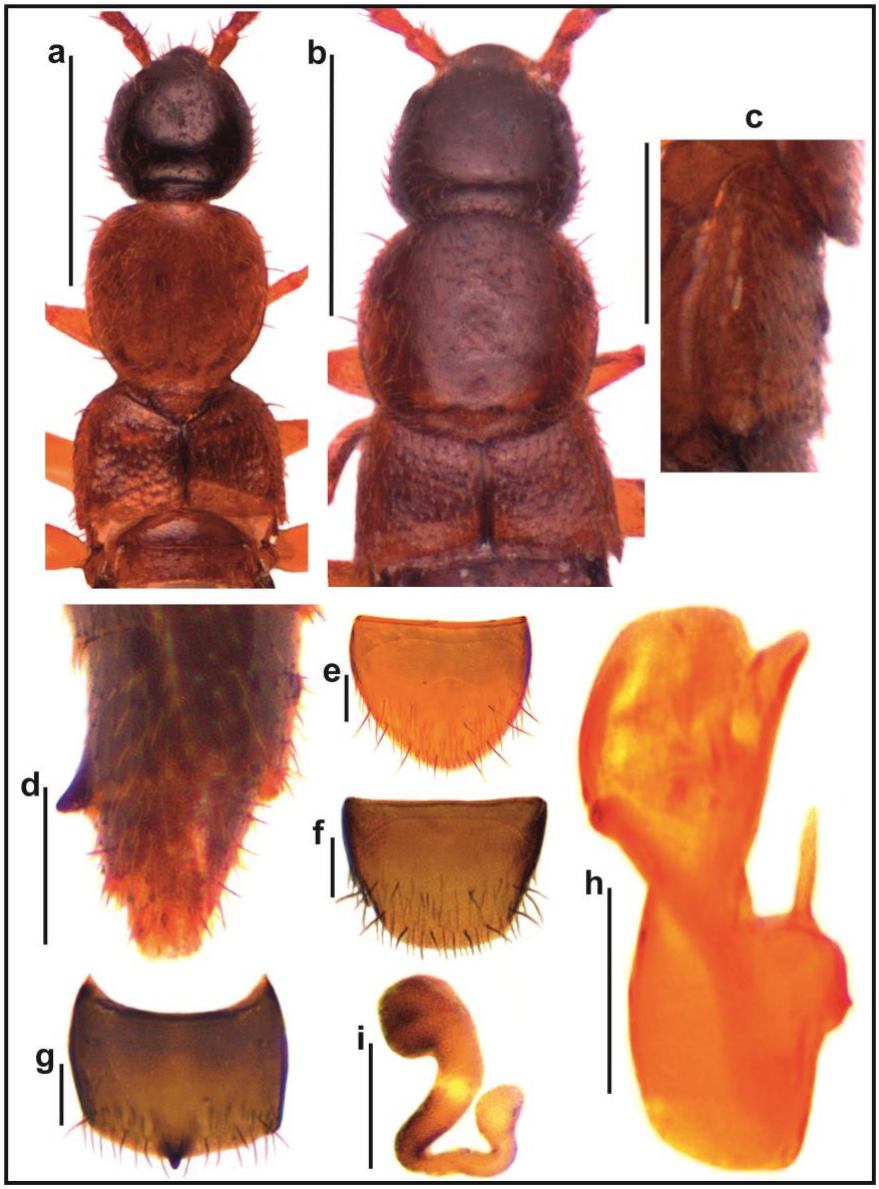

Figure 2. *Geostiba* (*Tropogastrosipalia*) *yagmuri* sp. n.: a) male forebody; b) female forebody; c) male elytra in lateral view; d) posterior abdominal segments of male in lateral view; e) male abdominal sternite VIII in dorsal view; f) female abdominal sternite VIII in dorsal view; g) male abdominal tergite VII in dorsal view; h) median lobe of aedeagus in lateral view; and i) spermatheca. Scale bars: 0.5 mm (a, b); 0.2 mm (c, d); 0.1 mm (e-i).

Differential diagnosis. Based on the shape of the posterior margin of the male pronotum, the new species is similar to *Geostiba atromontis* Assing, 2006. The posterior margin of the male pronotum is convex in the both species. But these species distinguished by the different shape of process of male abdominal tergite VII. In *G. yagmuri* sp. n. it is much shorter than that in *G. atromontis*. Additionally, the carinae in the posterior angles of the elytra of *G. yagmuri* sp. n. are narrower than those in *G. atromontis*. *G. yagmuri* sp. n. From these species *G. dindymosensis* sp. n. can be distinguished by the shape of the posterior margin in the male pronotum. In *G. yagmuri* sp. n. the posterior margin of the male pronotum is convex, whereas in *G. dindymosensis* sp. n. this part is truncate in the middle. In addition, the male pronotum in *G. yagmuri* sp. n. is shorter than that in *G. dindymosensis* sp. n. The sutural carinae on the male elytra and the crystal process of the median lobe of these two species are also different. In *G. yagmuri* sp. n. the sutural carinae on the male elytra are weakly elevated, whereas in *G. dindymosensis* sp. n. they are strongly elevated and the crystal process of the median lobe is thinner and shorter in *G. yagmuri* sp. n. than that in *G. dindymosensis* sp. n. (Table 1).

Distribution and Bionomics. The specimens were collected under stones in meadows between 408 and 1548 m. The new species is probably endemic of the Alaçam Mountains, Balıkesir and Manisa Provinces (Figure 3). Alaçam Mountains has been an important area for endemism. For example, *Sunius ciceki* Anlaş, 2016, an endemic staphylinid species, is known from this mountain (Anlaş, 2016, 2018).

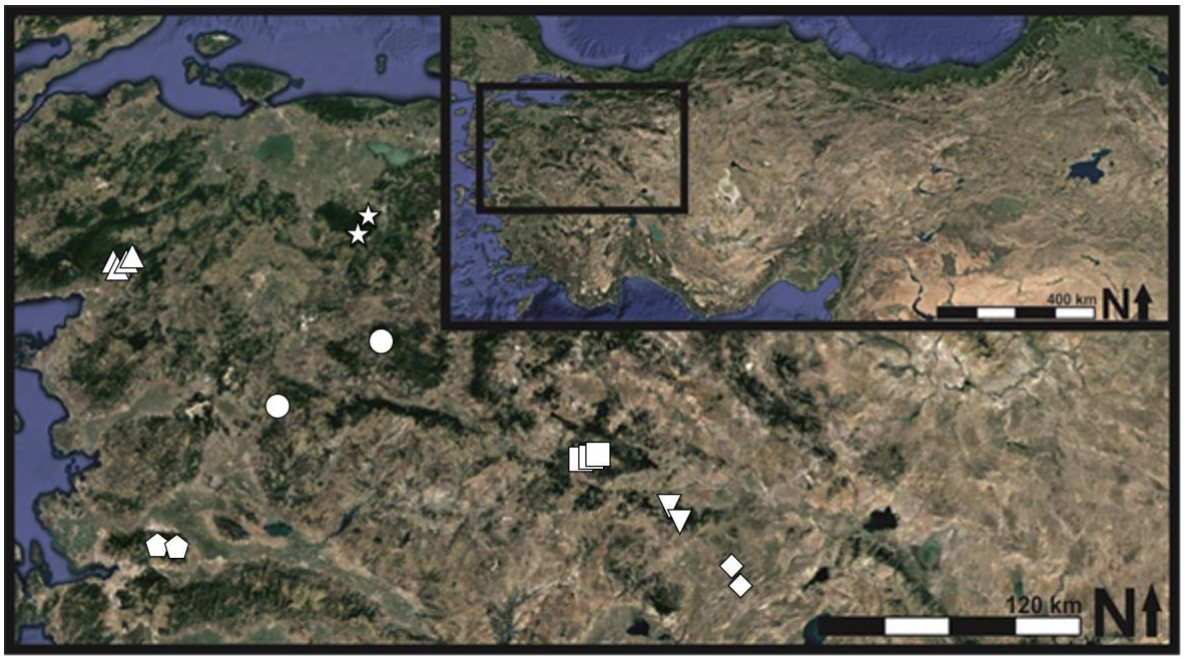

Figure 3. Distribution of *Geostiba dindymosensis* sp. n. (squares); *Geostiba yagmuri* sp. n. (circles); *Geostiba ahirensis* (inverted triangles); *Geostiba sandiklica* (diamonds); *Geostiba atromontis* (pentagons); *Geostiba kazika* (triangles); *Geostiba extensicollis* (stars).

Additional records

***Geostiba* (*Tropogastrosipalia*) *aydinica* Assing, 2006**

Material. Aydın: 4 km N of Karaköy, İmambaba Hill, 37°57’06" N, 27°53’56" E, 1644 m, 24.III.2014, 6♂♂, 3♀♀, leg. Anlaş & Örgel (AZMM).

Distribution. *Geostiba aydinica* is only known from Aydın Mountains (Aydın Province) (Assing, 2006) and recorded for the first time since its description.

***Geostiba* (*Tropogastrosipalia*) *biformis* Assing, 2006**

Material. Denizli: Çameli, 2 km SE of Kalınkoz, Değirmentaşı Hill, 37°07'21" N, 29°20'35" E, 1497 m, 04.V.2014, 3♂♂, ♀, leg. Yağmur & Örgel, same data but 18.IV.2015, 16♂♂, 46♀♀, 5 km SE of Kale, 37°25'37" N, 28°53'30" E, 1335 m, 11.IV.2015, 2♂♂, ♀, leg. Yağmur & Örgel, Tavas, 8 km SE of Nikfer, Bozdağ ski center road, 37°19'57" N, 29°10'47" E, 2033 m, 03.V.2014, 9♂♂, 26♀♀, leg. Yağmur & Örgel, Tavas, 3 km NE of Alpa, Gölgeli Mountains, 37°14'16" N, 29°04'07" E, 1900 m, 26.IV.2014, 2♂♂, 8♀♀, leg. Yağmur & Örgel; Muğla: 7 km SE of Özlüce, 37°15'56" N, 28°26'57" E, 1605 m, 22.III.2014, 7♂♂, 17♀♀, leg. Anlaş & Örgel (AZMM).

Distribution. Distribution of *G. biformis* is confined to Eastern Menteşe Mountains (Muğla Province) and Gölgeli Mountains (Denizli Province) (Assing, 2006) and is recorded for the first time since its description.

***Geostiba* (*Tropogastrosipalia*) *nifica* Assing, 2006**

Material. İzmir: Kemalpaşa, 7 km SW of Çiniliköy, Nif Mountain, 38°23'03" N, 27°21'56" E, 1274 m, 16.III.2014, 4♂♂, ♀, leg. Yağmur & Örgel (AZMM).

Distribution. *Geostiba nifica* was only known from Nif Mountain (İzmir Province) (Assing, 2006) and recorded for the first time since its description.

Table 1. Morphological features of *Geostiba dindymosensis* sp. n.; *Geostiba yagmuri* sp. n.; *Geostiba extensicollis*; *Geostiba kazika*; *Geostiba ahirensis*; *Geostiba atromontis* and *Geostiba sandiklica*

♂	Posterior margin of pronotum	Lateral margins of elytra	Sutural carinae	Abdominal tergite VII (lateral view)	Crystal process of aedeagus
G. dindymosensis sp. n.	truncate	weakly elevated	extending about half length of elytral suture	short and stout	strong, wide and tall
G. yagmuri sp. n.	weakly convex	weakly elevated	extending about 1/3 length of elytral suture	short and stout	narrow and short
G. extensicollis	truncate to indistinctly concave	not elevated	extending along elytral suture	short, stout, suberect	somewhat variable shape
G. kazika	truncate to indistinctly concave	not elevated	extending about 2/3 length of elytral suture	short and stout	short and slender
G. ahirensis	weakly convex	distinctly elevated	extending about half length of elytral suture	short and stout	very wide and tall
G. atromontis	broadly convex	weakly elevated	extending about half length of elytral suture	long, acute, and erect	thin
G. sandiklica	weakly convex	not elevated	extending about 1/3 length of elytral suture	short and stout	moderately broad

Acknowledgments

I am most grateful to my colleagues for making their staphylinid collections available to me. Special thanks to the anonymous reviewers provided helpful comments on earlier drafts of the manuscript.

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Türk. entomol. derg., 2021, 45 (3): 361-370
DOI: http://dx.doi.org/10.16970/entoted.927130

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Investigation of resistance to synthetic pyrethroids in *Blattella germanica* L., 1767 (Blattodea: Ectobiidae) and *Periplaneta americana* L., 1758 (Blattodea: Blattidae) populations in Turkey[1]

Türkiye'de *Blattella germanica* L., 1767 (Blattodea: Ectobiidae) ve *Periplaneta americana* L., 1758 (Blattodea: Blattidae) popülasyonlarında sentetik piretroidlere karşı direncin araştırılması

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Abstract

Cockroaches are widespread pests found in many houses and other buildings. They are known as a vector of many agents of disease like bacteria, viruses and fungi. The repeated usage of persistent and non-biodegradable insecticides has caused resistance in most of the cockroach populations. In this research, the resistance levels of five *Blattella germanica* L., 1767 (Blattodea: Ectobiidae) and five *Periplaneta americana* L., 1758 (Blattodea: Blattidae) cockroach populations against some synthetic pyrethroid insecticides (deltamethrin, permethrin, alpha-cypermethrin and lambda-cyhalothrin) were determined between 2014 and 2018 in Turkey. The resistance tests were performed by the standard glass jar surface method as recommended by World Health Organization. By exposing the test chemicals of the second and third instar nymphs of the cockroaches for 1 h, the median lethal dose 50% (LD_{50}) values, resistance ratios (RR) and resistance status were specified. The *P. americana* populations were all susceptible to tested chemicals with resistance ratios between 1 and 2-fold. In *B. germanica* populations, the toxic effects of tested chemicals were found very low and resistance status was found moderate (RR 7.7-9.0-fold) or high (RR ≥18.5-fold). This research is the most comprehensive study of the resistance status of the cockroaches in Turkey. In order to prevent the resistance to chemicals, the integrated pest management approach should be prioritized and chemical control should be kept at the lowest level.

Keywords: American cockroach, German cockroach, insecticides, nymph, susceptibility

Öz

Hamam böcekleri birçok ev ve yapılarda bulunan yaygın zararlılardır. Bakteriler, virüsler ve mantarlar gibi pek çok hastalık etkeninin vektörü olarak bilinirler. Kalıcı ve biyolojik olarak parçalanmayan insektisitlerin tekrar tekrar kullanılması, hamam böceği popülasyonlarının çoğunda dirence neden olmuştur. Bu araştırmada, 2014-2018 yılları arasında Türkiye'de beş *Blattella germanica* L., 1767 (Blattodea: Ectobiidae) ve beş *Periplaneta americana* L., 1758 (Blattodea: Blattidae) hamam böceği popülasyonunun bazı sentetik piretroid insektisitlere (deltamethrin, permethrin, alpha-cypermethrin ve lambda-cyhalothrin) karşı direnç seviyeleri belirlenmiştir. Direnç testleri Dünya Sağlık Örgütü tarafından önerilen standart cam kavanoz yüzey satıh yöntemi ile yapılmıştır. Hamam böceklerinin ikinci ve üçüncü dönem nimfleri bir saat test kimyasallarına maruz bırakılarak LD_{50} değerleri, direnç katsayıları ve direnç durumları belirlendi. *Periplaneta americana* popülasyonların tamamı test edilen kimyasallara duyarlıydı ve direnç katsayıları 1 ve 2 kat arasındadır. *Blattella germanica* popülasyonlarında, test edilen kimyasalların toksik etkisi çok düşüktü ve orta (7,7-9,0 kat) ve yüksek direnç (≥18,5 kat) bulunmuştur. Bu araştırma hamam böceklerinin direnç durumu hakkında Türkiye'de yapılan en kapsamlı çalışmadır. Kimyasallara karşı direnci önlemek için entegre zararlı mücadele yaklaşımına öncelik verilmeli ve kimyasal kontrol en düşük seviyede tutulmalıdır.

Anahtar sözcükler: Amerikan hamam böceği, Alman hamam böceği, insektisitler, nimf, duyarlılık

[1] This study was supported by Akdeniz University, Scientific Research Unit, Antalya, Turkey, Grant Project No: FDK-2015-410.
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Received (Alınış): 26.04.2021 Accepted (Kabul ediliş): 18.08.2021 Published Online (Çevrimiçi Yayın Tarihi): 26.08.2021

Introduction

There are about 4,000 species of cockroaches (Blattodea) most of them are exophilic, feeding on vegetable debris on the forest floor, but approximately 30 species are pests that live in places where people interact each other, such as houses, basements, restaurants and bakeries (WHO, 2006). Cockroaches, one of the most serious public health pests, are mechanical vectors of many disease pathogens like bacteria, viruses and fungi (Fotedar & Banerjee, 1992; Wahab et al., 2016). Most of these pathogens can survive or persist for a long time on the body surface of cockroaches. Additionally, the feces, saliva and shed body parts of cockroaches may cause allergic reactions, including asthma, sneezing, irritation of eyes and blocked nasal passages reactions in many people (WHO, 2006). For these reasons, it has been necessary to control cockroaches, which are vectors of many agents of disease.

The main groups of insecticides used for cockroach control are organophosphates, carbamates, organochlorines, neonicotinoids and insect growth regulators (chitin synthesis inhibitors and juvenile hormone analogs) (WHO, 2006). Synthetic pyrethroids consist of the major group used in controlling cockroaches and other vectors like mosquitoes, houseflies and ticks in Turkey, which have considerable advantages such as high toxicity to pests, low toxicity to mammals and low persistence in the environment (WHO, 2013). Synthetic pyrethroids are neurotoxic insecticides that alter the properties of the voltage-gated sodium channels in nerve cell membranes and cause the channel to remain open longer (van den Bercken & Vijverberg, 1988; Silver et al., 2014).

Excessive amounts of pesticides have been used around the world to control cockroaches (Lee et al., 1996). Although the usage of the pesticides against cockroaches gives good results initially, excessive and frequent application of these products has caused resistance in cockroach populations in many regions of the world (Silverman & Ross, 1994; Lee et al., 1996; Valles & Strong, 2001; Pai et al., 2005; Chai & Lee, 2010). In Turkey, there has been limited research on pesticide resistance in cockroaches (Garrett et al., 1968; Erdogan & Kocak, 1989), and no data on the resistance status of cockroaches to synthetic pyrethroids, except tetramethrin. Since cockroaches have adapted to most insecticides through the development of physiological and behavioral changes and cross -resistance, it is becoming quite difficult to control them. That is why it is necessary to monitor the resistance of field populations for a sustainable cockroach control program.

In this study, resistance to synthetic pyrethroid insecticides (alpha-cypermethrin, deltamethrin, lambda-cyhalothrin, and permethrin) in *Blattella germanica* L., 1767 (Blattodea: Ectobiidae) and *Periplaneta americana* L., 1758 (Blattodea: Blattidae) cockroaches collected from Antalya, Turkey were determined. This was the first research in Turkey on resistance to alpha-cypermethrin, deltamethrin, lambda-cyhalothrin and permethrin in *B. germanica* and *P. americana* cockroaches.

Materials and Methods

Cockroach populations

Blattella germanica cockroaches were collected from restaurants and bakeries in Güllük (restaurant), Dokuma (bakery), Uncalı (bakery), Ahatlı (restaurant) and Lara (restaurant), and *P. americana* cockroaches were collected from manholes and basements in Toros (basement), 100. Yıl (manhole), Dokuma (manhole), Ahatlı (manhole), Arapsuyu (manhole) in Antalya, Turkey between April and September 2014 (Tables 1-8). There was at least 2 km between the locations where the specimens were collected. Even though control with *P. americana* has been regularly conducted by the Pest Control Department of Antalya Metropolitan Municipality for more than 10 years with synthetic pyrethroids insecticides were applied at 1-3 months intervals, control of *B. germanica* has been done by public and pest control applicators 2-4 weeks intervals. Cockroaches were cultured by providing cat food and water ad libitum at 25±2°C and 60±10% RH with a 12:12 h L:D photoperiod. Ootheca (egg capsules) obtained from adult cockroaches were hatched

in about 3-4 months. To obtain enough individuals of second and third instar nymphs, they have been cultured for 12-18 days under laboratory conditions. Bioassays were performed when the hatchlings reached the second and third stage nymphs in the first generation. An insecticide-susceptible population of *B. germanica* were obtained from Hacettepe University, Pesticide Test Laboratory, Ankara, Turkey in 2008. As there was no insecticide-susceptible population of *P. americana* in our laboratory, the population which had the lowest LD_{50} value was considered a susceptible population.

Chemicals

Four synthetic pyrethroid insecticides used in this research were alpha-cypermethrin (purity 98.69%), deltamethrin (purity 96%), lambda-cyhalothrin (purity 95%), and permethrin (purity 93%), which were purchased Sigma-Aldrich (Chemie GmbH Riedstrasse 2 D-89555 Steinheim Company). These tested chemicals are the most common insecticides used in pest management and, in Turkey, are applied as residual sprays. Analytical acetone was used as a solvent of tested insecticides and control.

Resistance Tests

Resistance tests were performed using the standard glass jar surface method recommended by World Health Organization (WHO, 1981) in Akdeniz University Vector Ecology and Control Laboratory between 2014-2018. Stock solutions of each chemical were prepared in acetone for the tests. From these solutions, according to the application dose (g ai/m^2), 1 ml of the solutions were applied to the surface of the jars. The jars were then rotated horizontally until the acetone vaporized, so that the insecticide completely covered the inner surface of the jars. For the control group, only acetone was applied. After 24 h, 10 second and third instar nymphs of cockroaches were released to jars and exposed to insecticides for 1 h. After 1-h exposure, nymphs were transferred to clean jars (250 ml) provided a cotton ball saturated with water. Ten mixed individuals from both second and third instar nymphs of cockroaches were used for each replicate (according to preliminary studies, there is no difference between stages in terms of mortality rates). Four replicates were used for each tested dose and control group. At least five application doses that caused ≥0% and ≤100% mortality were used for the determination of LD_{50} values in the trials. Mortality was recorded after 24 h. A cockroach was considered dead if it was unable to reach its normal position after touching the abdomen with forceps.

Data analysis

LD_{50} values were calculated by the StatPlus probit analysis program. Resistance ratios (RR) were calculated by dividing LD_{50} values of the field populations by the LD_{50} value of the susceptible population. Resistance levels were classified based on the standard of Lee et al. (1999): RR <2-fold, very little or no resistance; RR = 2-5-fold, low resistance; RR = 5-10-fold, moderate resistance; and RR >10, high resistance.

Results

According to the results, the tested chemicals were highly toxic to *P. americana*, resulting in a mortality of ≥95% at the WHO recommended doses. Therefore, we had to use lower doses than recommended by WHO. LD_{50} values were 0.0001 g ai/m^2 for deltamethrin, 0.0002-0.0003 g ai/m^2 for alpha-cypermethrin, 0.0001-0.0002 g ai/m^2 for lambda-cyhalothrin and 0.0006-0.0011 g ai/m^2 for permethrin (Tables 1-4). Resistance ratios of all the populations were 1-2-fold, so all populations were classified as having no resistance, very low resistance or low resistance.

Table 1. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Periplaneta americana* nymphs to alpha-cypermethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
Arapsuyu	320	0.0002-0.0005	0.0003	1.5	No resistance or very low resistance	11.1 (3)	2.39 (0.52)
Toros	320	0.0002-0.0002	0.0002	1.0	No resistance or very low resistance	11.1 (3)	3.60 (0.30)
Ahatlı	320	0.0002-0.0003	0.0003	1.5	No resistance or very low resistance	11.1 (3)	3.46 (0.27)
Dokuma	320	0.0002-0.0003	0.0002	1.0	No resistance or very low resistance	11.1 (3)	3.17 (0.26)
100. Yıl	320	0.0002-0.0004	0.0003	1.5	No resistance or very low resistance	11.1 (3)	2.70 (0.40)

Table 2. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Periplaneta americana* nymphs to deltamethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
Arapsuyu	240	0.0001-0.0001	0.0001	1	No resistance or very low resistance	7.82 (3)	4.10 (0.33)
Toros	240	0.0001-0.0006	0.0001	1	No resistance or very low resistance	7.82 (3)	1.96 (0.47)
Ahatlı	240	0.0001-0.0003	0.0001	1	No resistance or very low resistance	7.82 (3)	2.76 (0.63)
Dokuma	240	0.0001-0.0002	0.0001	1	No resistance or very low resistance	7.82 (3)	2.75 (0.42)
100. Yıl	240	0.0001-0.0002	0.0001	1	No resistance or very low resistance	7.82 (3)	2.29 (0.24)

Table 3. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Periplaneta americana* nymphs to lambda-cyhalothrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
Arapsuyu	280	0.0001-0.0002	0.0002	2	Low resistance	9.49 (3)	4.51 (0.79)
Toros	280	0.0001-0.0002	0.0002	2	Low resistance	9.49 (3)	4.32 (0.77)
Ahatlı	280	0.0001-0.0001	0.0001	1	No resistance or very low resistance	9.49 (3)	3.70 (0.54)
Dokuma	280	0.0001-0.0001	0.0001	1	No resistance or very low resistance	9.49 (3)	3.81 (0.31)
100. Yıl	280	0.0001-0.0002	0.0002	2	Low resistance	9.49 (3)	4.71 (0.49)

Table 4. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Periplaneta americana* nymphs to permethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
Arapsuyu	320	0.0004-0.0009	0.0006	1.00	No resistance or very low resistance	11.1 (3)	3.71 (0.61)
Toros	320	0.0006-0.0012	0.0009	1.50	No resistance or very low resistance	11.1 (3)	1.65 (0.19)
Ahatlı	320	0.0008-0.0010	0.0009	1.50	No resistance or very low resistance	11.1 (3)	1.85 (0.61)
Dokuma	320	0.0001-0.0043	0.0007	1.17	No resistance or very low resistance	11.1 (3)	1.23 (0.52)
100. Yıl	320	0.0003-0.0043	0.0011	1.83	No resistance or very low resistance	11.1 (3)	2.08 (1.04)

In field *B. germanica* populations, the toxicity of the tested chemicals was very low to moderate (0 to 80% mortality), although the WHO recommended doses of the tested chemicals were generally assessed as highly toxic (≥96.7% mortality) on the susceptible population. Higher application doses than recommended by WHO were used to calculate LD_{50} values.

Alpha-cypermethrin gave between 0 and 50% mortality at the WHO recommended doses (0.024 and 0.048 g ai/m^2) in field-collected populations although 100% mortality was shown in the susceptible

population at these doses. LD_{50} were 0.0002 g ai/m^2 for the susceptible population and between 0.109-13.4 g ai/m^2 for field-collected populations. When evaluated according to the resistance ratios, high resistance ratios (≥545-fold) were observed in all populations (Table 5).

Table 5. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Blattella germanica* nymphs to alpha-cypermethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
WHO	240	0.0001-0.0002	0.0002			7.82 (3)	4.56 (0.51)
Uncalı	360	3.42-46.40	12.60	≥1000	High	12.6 (3)	2.26 (1.02)
Ahatlı	360	4.54-10.70	7.59	≥1000	High	9.49 (3)	0.35 (0.11)
Dokuma	360	2.27-78.50	13.40	≥1000	High	12.6 (3)	1.90 (0.86)
Lara	360	1.40-4.19	2.27	≥1000	High	9.49 (3)	0.56 (0.06)
Güllük	360	0.0057-2.09	0.11	545	High	7.82 (3)	0.65 (0.25)

Deltamethrin had very low toxicity (≤5%) to all populations at the WHO recommended dose (0.024 g ai/m^2) but 96.7% mortality in the susceptible population at the same dose. LD_{50} value was 0.0004 g ai/m^2 for the susceptible population. All of the populations were in the high resistance category (≥1000-fold) (Table 6).

Table 6. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Blattella germanica* nymphs to deltamethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
WHO	240	0.0001-0.0037	0.0004			7.82 (3)	1.51 (0.98)
Uncalı	240	1.00-78.4 x 10^{12}	54.8 x 10^3	≥1000	High	7.82 (3)	0.36 (0.41)
Ahatlı	240	0.0046-6.54 x 10^9	5.51 x 10^3	≥1000	High	7.82 (3)	0.34 (0.17)
Dokuma	240	973-119 x 10^{12}	225 x 10^3	≥1000	High	7.82 (3)	0.28 (0.13)
Lara	240	0.160-11.1 x 10^6	1.33 x 10^3	≥1000	High	7.82 (3)	0.44 (0.18)
Güllük	240	0.412-677	16.7	≥1000	High	7.82 (3)	0.43 (0.14)

Lambda-cyhalothrin demonstrated a very low toxic effect (≤10%) on populations of Uncalı and Dokuma at the WHO recommended doses (0.012 and 0.024 g ai/m^2), while high mortality (100 and 92.5%) to populations of Ahatlı and Güllük, respectively, at 0.024 g ai/m^2. LD_{50} was 0.0027 g ai/m^2 for the Güllük population, and this population was categorized as having moderate resistance (9.0-fold). According to the resistance ratios, the other populations were in the high resistance category (≥34.7-fold) (Table 7).

Table 7. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Blattella germanica* nymphs to lambda-cyhalothrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
WHO	320	0.0001-0.0006	0.0003			7.82 (3)	1.65 (0.28)
Uncalı	400	1.78-1.50 x 10^3	5.13	≥1000	High	7.82 (3)	1.31 (0.35)
Ahatlı	400	0.0075-0.0919	0.0209	69.7	High	11.1 (3)	1.23 (0.25)
Dokuma	400	2.98-2.37 x 10^3	20.7	≥1000	High	9.49 (3)	0.51 (0.09)
Lara	400	0.0068-0.0176	0.0104	34.7	High	9.49 (3)	1.87 (0.27)
Güllük	400	0.0008-0.0051	0.0027	9.0	Moderate	9.49 (3)	2.04 (0.48)

Permethrin gave low mortality (between 0 and 42.5%) in Uncalı, Dokuma, Lara, and Ahatlı populations at the WHO recommended doses (0.1 and 0.2 g ai/m^2). When evaluated according to the resistance ratios, high resistance (≥18.5-fold) was observed at all the populations except the Güllük population that has moderate resistance (7.7-fold) (Table 8).

Table 8. LD_{50} values, LD_{50} (min-max), resistance ratios and resistance status of *Blattella germanica* nymphs to permethrin

Population	n	LD_{50} (g ai/m^2) min-max	LD_{50} (g ai/m^2)	Resistance ratio	Resistance status	χ^2 (df)	Slope (SE)
WHO	240	0.0121-0.0177	0.0148			7.82 (3)	2.50 (0.22)
Uncalı	360	13.5-133	31.2	≥1000	High	9.49 (3)	0.53 (0.08)
Ahatlı	360	0.0441-1.66	0.273	18.5	High	7.82 (3)	1.69 (0.43)
Dokuma	360	37.0-984	109	≥1000	High	9.49 (3)	0.70 (0.13)
Lara	360	0.312-0.598	0.426	28.8	High	11.1 (3)	2.43 (0.24)
Güllük	360	0.0774-0.170	0.114	7.7	Moderate	7.82 (3)	2.99 (0.48)

Discussion

In recent years, large quantities of chemical pesticides have been used to control agriculture, forest and public health pests. Although successful pest control is achieved, resistance to insecticides, which is a result of genetic selection, has become a major problem. According to various studies, many pest species developed resistance to insecticides including pyrethroids, carbamates, microbials and insect growth regulators (Brogdon & McAllister, 1998; Cetin et al., 2019; Ser & Cetin, 2019; Erdogan & Cetin, 2020).

In this research, all of the *P. americana* populations were very susceptible to the tested chemicals and had no resistance, very low resistance or low resistance. In the literature there are few studies on the resistance of *P. americana*. Syed et al. (2014) investigated the insecticidal efficacy of four insecticides including deltamethrin on three *P. americana* populations collected from Pakistan and reported that the the LC_{50} were 2.07, 2.50 and 4.15 µl/ml, and resistance ratios were 1.21-2-fold for deltamethrin. Kawther et al. (2013) investigated the toxicity of permethrin on *P. americana* and reported that the LC_{50} was 2.217 mg/l, and the high toxicity for permethrin was shown at 0.1 mg/l whereas low toxicity of permethrin was recorded at 0.000001 mg/l. Also, Doroudgar et al. (1998) studied the toxicity of a commercial product containing permethrin and reported resistance ratios of 1.64-3.04-fold, which was classified as susceptible as in our research. Azza et al. (2010) studied susceptibility of *P. americana* collected from Wad Medani (Sudan Gezira) to lambda-cyhalothrin and deltamethrin, and found that adult *P. americana* populations had acceptable levels of susceptibility to all the tested insecticides (LC_{50} 0.02 and 0.04 µg/individual, respectively).

The absence of selection pressure may be the main reason for the low resistance levels and low LD_{50} of *P. americana* populations tested in Antalya, Turkey. According to another study, Strong et al. (1997) monitored the level of cypermethrin resistance and found that the LC_{50} value of the selected F_6 generation adults was elevated 3-fold compared with the parent generation. The Pest Control Department of Antalya Metropolitan Municipality was consulted to obtain information about the history of the control of *P. americana*. The control with *P. americana* has been regularly undertaken for more than 10 years by with the help from pest control experts, and synthetic pyrethroids insecticides were applied in rotation (personal communication). If the environment in the residential houses is not particularly humid, *P. americana* does not normally infest these housed. For this reason, biocidal pesticides are not often used often by pest control applicators. As a result, the resistance is considered less in *P. americana* because the selection pressure on *P. americana* is much less than on *B. germanica*.

Another reason may be related to the annual number of generations of American cockroaches. *Periplaneta americana* has only one generation per year whereas *B. germanica* has three to four generations per year. At 25°C, the longevity of the *B. germanica* ranged from 95 and 142 days, and each female may deposit 4-9 oothecae with an average of 38 eggs each. These characteristics facilitate the development of resistance to insecticides (Mallis, 1990).

While American cockroaches were found to be sensitive to the application doses recommended by the World Health Organization and the Ministry of Health, less than 80% mortality was detected in German cockroaches. According to our survey, there was no resistance study to the alpha-cypermethrin on *B. germanica*.

Many studies have demonstrated that the most of *B. germanica* populations have developed some resistance to deltamethrin (Diaz Pantoja et al., 2000; Wei et al., 2001; Chang et al., 2010). Chai & Lee (2010) studied the resistance levels of *B. germanica* collected from 22 different localities of Singapore and found low to very high resistance for deltamethrin (4.5 to 468-fold). Jang et al. (2017) picked up the *B. germanica* from a restaurant in the Republic of Korea and found that female cockroaches have 450-fold resistance (extremely high levels of resistance) for deltamethrin. Hu et al. (2020) studied the resistance levels of 24 populations of *B*. *germanica* collected from in Taiwan and reported that the deltamethrin resistance ratio of 1.5 to 817.5-fold.

Resistance to lambda-cyhalothrin has been reported in many populations in different countries. Valles (1999) studied resistance levels of 13 field-collected populations of *B. germanica* for lambda-cyhalothrin, and found that the resistance levels from 21 to 67-fold using a topical insecticide bioassay and 12.9 to 15.6-fold using the residue jar bioassay. Diaz Pantoja et al. (2000) studied that the toxicities for the 9 populations of the *B. germanica* measured by topical application, and a test with lambda-cyhalothrin indicated that nearly 50% of the populations had RR >30.

Moderate or high resistance to permethrin has been observed in many populations worldwide (Ladonni, 2001; Wei et al., 2001; Chang et al., 2010; Gondhalekar et al., 2011). Nasirian et al. (2006) studied the susceptibility of eleven populations of *B. germanica* collected from nine infested student dormitories and two infested hospitals in Tehran, Iran to permethrin. They reported that the two populations had moderate resistance (8.6-9.8-fold) and the rest were highly resistant (10.5 to 17.7-fold). Limoee et al. (2012) reported that two hospital-collected populations of the *B. germanica* have low and moderate resistance (3.15 and 3.36-fold) to permethrin. The low resistance was attributed to the fact that the populations were not exposed to the permethrin for at least a few generations. Jang et al. (2017) found 569-fold resistance ratio (LD_{50} 3.64 µg/individual) to permethrin in female *B. germanica* collected from a restaurant in the Republic of Korea.

Globally there have been many resistance and toxicity studies on *B. germanica* but only limited research has been done in Turkey. Garrett et al. (1968) reported that *B. germanica* collected from İzmir was resistant to dieldrin. Erdogan & Kocak (1989) reported that an Ankara population of *B. germanica* had 9.2-11.2-fold resistance to Sumithion and tetramethrin.

The high resistance was demonstrated in nearly all *B. germanica* populations in our experiments. These results reveal that resistant populations were not isolated and can be found in all parts of the city. *Blattella germanica* disturbs people because it is of constantly active in environments such as homes, restaurants, and bakeries. For this reason, pest control applicators have used insecticides extensively against *B. germanica* for many years. Some bad practices (e.g., not using the appropriate dose or repeated use of the same active substance) may increase the number of surviving resistant individuals, which is thought to increase the level of resistance in *B. germanica*.

Higher resistance was found in Uncalı and Dokuma populations (collected from bakeries) compared to Ahatlı, Lara and Güllük populations (collected from restaurants). The reason for this situation could be that the cockroach populations might have been much more exposed to insecticides due to the more frequent inspections of bakeries. Therefore, it is thought that individuals that survive after insecticide application may increase the resistance by transferring the resistance genes to the next generation.

Effective resistance management depends on the early detection of the problem and rapid acquisition of information. To prevent or reduce the development of resistance to insecticides in cockroaches, an integrated pest management program should be used, in which chemical use should be minimized. It is necessary to have information about the source of resistance by conducting biochemical or molecular studies on resistant populations. The lethal effect of active substances should be increased by using synergistic substances. Insecticide applications should be made in more limited areas rather than large areas, and the same active substance should not be used for a long time. Insecticides with a different mode of action should be used in rotation, so resistance selection can be reduced. Biocidal products should be applied according to the label recommended doses, the use of higher may trigger resistance. In addition, new groups of insecticides (neonicotinoid and phenylpyrazole) which are non-persistent, fast-acting, environmentally-friendly should be used in the high resistance populations, and resistance levels should be checked periodically.

In conclusion, *P. americana* populations were found to be in the category of no resistance, very low resistance or low resistance to the tested chemicals while high resistance was found in all *B.* germanica populations except for permethrin and lambda-cyhalothrin in the Güllük population. As a result, inappropriate and extended use of synthetic pyrethroids may lead to high resistance in cockroaches. To prevent resistance to chemicals, the integrated pest management should be prioritized and chemical control should be kept at the lowest level. Also, insecticide resistance maps should be prepared by regularly monitoring the resistance of cockroach populations to insecticides used in a control program.

Acknowledgments

The authors are thankful to the Scientific Projects Administration Unit of Akdeniz University (Antalya, Turkey) (Project No: FDK-2015-410) for their financial support.

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Türk. entomol. derg., 2021, 45 (3): 371-387
DOI: http://dx.doi.org/10.16970/entoted.942701

ISSN 1010-6960
E-ISSN 2536-491X

Original article (***Orijinal araştırma***)

Aphid (Hemiptera: Aphididae) species in Burdur urban parks with three records for the fauna of Turkey, their host plants and predators[1]

Türkiye faunası için üç yeni kayıt ile birlikte Burdur kent parklarındaki yaprak biti türleri (Hemiptera: Aphididae), konukçu bitkileri ve avcıları

Gülser PATLAR[2] Şükran OĞUZOĞLU[2*] Mustafa AVCI[2] Özhan ŞENOL[3]

Abstract

This study was conducted to identify the aphid species on 34 ornamental plants in 16 urban parks in the provincial center of Burdur and their predators in April-November 2018-2019. Forty-eight species in 23 genera of Aphididae were detected. *Aphis craccivora* Koch, 1854, *Cinara* (*Cupressobium*) *tujafilina* (Del Guercio, 1909) and *Macrosiphum rosae* (L., 1758) were most abundant species. *Aphis berberidorum* Ortego & Mier Durante, 1997, *Hannabura alnicola* Matsumura, 1917 and *Prociphilus fraxinifolii* (Riley, 1879) were three new records for the aphid fauna of Turkey. The genus *Hannabura* was recorded for the first time in Turkey. Twenty-nine insect predators of aphids were identified from Coccinellidae (24), Cantharidae (1) (Coleoptera), Nabidae (1), Miridae (1) (Hemiptera), Sryphidae (1) (Diptera) and Forficulidae (1) (Dermaptera). No predators were seen on 12 aphid species and just a single predator each for 11 aphid species. The highest host plant diversity was observed for *A. craccivora* and *Aulacorthum solani* (Kaltenbach, 1843), with three plant species each. The highest number of aphid species (8 species) was found on *Pinus nigra* subsp. *pallasiana* (Lamb.) Holmboe.

Keywords: Aphid, Burdur, predator species, Turkey, urban parks

Öz

Bu çalışma 2018-2019 Nisan-Kasım aylarında Burdur İli merkezinde 16 kent parkındaki 34 ağaç ve çalı üzerindeki yaprak bitlerini belirlemek amacıyla yapılmıştır. Araştırmada, Aphididae familyasından 23 cinse ait 48 tür belirlenmiştir. En fazla popülasyona sahip olan türler *Aphis craccivora* Koch, 1854, *Cinara* (*Cupressobium*) *tujafilina* (Del Guercio, 1909) ve *Macrosiphum rosae* (L., 1758) olmuştur. *Aphis berberidorum* Ortego & Mier Durante, 1997, *Hannabura alnicola* Matsumura, 1917 ve *Prociphilus fraxinifolii* (Riley, 1879) türleri Türkiye afit faunası için üç yeni kayıttır. *Hannabura* cinsi de Türkiye'de ilk kez bu çalışma ile kaydedilmiştir. Yaprak bitlerinin Coccinellidae (24), Cantharidae (1) (Coleoptera), Nabidae (1), Miridae (1) (Hemiptera), Sryphidae (1) (Diptera) ve Forficulidae (1) (Dermaptera) familyalarından 29 avcı türü tespit edilmiştir. 12 yaprak biti türünün avcısı görülmemiş, 12 yaprak biti türünün sadece bir avcı türü görülmüştür. En fazla konukçu bitki çeşitliliği 3 bitki türü ile *A. craccivora* ve *Aulacorthum solani* (Kaltenbach, 1843) türlerinde görülmüştür. En yüksek yaprak biti tür sayısı (8 tür) *Pinus nigra* subsp. *pallasiana* (Lamb.) Holmboe'da bulunmuştur.

Anahtar sözcükler: Yaprak biti, Burdur, avcı türler, Türkiye, kent parkları

[1] This study was produced by the Master thesis of the first author accepted by Isparta University of Applied Sciences, The Institute of Graduate Education, Department of Forest Engineering.

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Received (Alınış): 27.05.2021 Accepted (Kabul ediliş): 03.09.2021 Published Online (Çevrimiçi Yayın Tarihi): 07.09.2021

Introduction

Parks and gardens give opportunities for people to meet nature in urban environments, giving aesthetic and visual pleasure from encountering both living and inanimate materials. Living materials consist of ornamental plants which are generally under physiological stress in urban ecosystems with their green parts exposed to high concentrations of many undesirable chemicals due to air pollution; this exposure can result in proliferation of several harmful species. The most common harmful species found in parks and landscape areas include aphids, white flies, Thripidae, Coccoidea and onion flies (Yaşar, 2017).

More than 5 600 species of aphids are known globally, over 75% of which are found in the Palearctic (Holman, 2009; Özdemir, 2020; Blackman & Eastop, 2021; Favret, 2021). In Turkey, 591 species with 26 aphid subspecies in 147 genera in 3 families and 15 subfamilies have been reported (Kök & Özdemir, 2021). Most of these species are of foreign origin within only about 2% of Turkey's aphid fauna originating in Turkey (Görür et al., 2020). Aphids cause direct harm by sucking plant sap while indirect harm arises from secreted honeydew leading to sooty mold formation; aphids also transmit many plant diseases, particularly viruses (Uygun et al., 2000). Sooty mold obstructs plant stomata with honeydew and fungal growth, inhibiting photosynthesis and transpiration. Also, gall formation, leaf roll, yellowing and dehydration due to aphid feeding, can, in turn, decrease seed yield, shoot formation photosynthetic rates, chlorophyll quantities and nutrient concentrations. All these effects result in quality and yield loss in plants (Görür, 2008). Biological methods, however, can be crucial for controlling aphids, since the organisms are small, reproduce rapidly, including by cyclic parthenogenesis, and adapt easily to climate change (Dixon, 1998; Uygun et al., 2000). Aphids can feed on many parts of trees such as leaves, branches, shoots, trunks and roots, according to their mouth structure. For this reason, more than one aphid species can be found on a tree (Carter & Maslen, 1982). Especially the species in the Lachninae subfamily of the Aphididae family feed on both the leaves and stems of needle and broadleaf trees (Chen et al., 2016). Many species from Coleoptera, Hemiptera, Neuroptera, Diptera and Hymenoptera are fed with aphids, and some of these species are used as biological control agents (Aslan & Uygun, 2005; Aslan, 2015; Kök et al., 2020). Of known aphid species globally, 56% feed on trees (Blackman & Eastop, 2021); it is important, therefore, to identify aphid species damaging trees, determine the natural enemies and implement biological control methods with a view to protecting forests.

Turkey is noted for having a remarkable diversity of flora and fauna. Within this diversity, it is important to identify potentially damaging pest species in natural ecosystems and in landscape areas, parks and gardens, and to determine the species of natural enemies present so that appropriate, sustainable measures can be taken against problematic species. In Turkey, harmful and beneficial species were identified in landscape areas, parks and gardens in several cities; in contrast, no comprehensive study has been conducted to date in the parks and gardens of Burdur Province. Various harmful insects were observed on trees and shrubs in the parks and landscape areas in Burdur, which occasionally reduced the aesthetics of these parks' gardens, sometimes killing the affected plants (pers. observations). No detailed study has been conducted to date with a view to identifying and controlling pest insects in Burdur. However, there are certain records reported in some studies. The aim for the word described here, therefore, was to conduct a comprehensive survey of aphid pests and associated predator species in parks and gardens of Burdur.

Materials and Methods

The study focused on 34 ornamental trees and shrubs located in 16 parks near the center of Burdur. Surveys were conducted in April-November 2018-2019 (land surveys conducted 3-4 times on different dates) and aphid and predator species collected. In order to collect samples, sites were visited on dry and sunny days and trunks, branches, shoots, leaves and flowers of the plants examined. Insects in pre-adult stages were collected from the plants on which the insects were found. Plant samples were labeled and

placed in polyethylene bags for transport to the laboratory. Voucher specimens were deposited at the Entomology Department of Forestry Faculty in Isparta University. For collection and transport of insects, polyethylene bags, secateurs, sweep nets, suction tubes, soft brushes, pliers, Falcon tubes, Japanese umbrellas, killing jars, insect needles, labels, Petri dishes, 70% ethanol, paper bags, a notebook and GPS were used. Where possible, adult insects were collected manually, flying insects were collected with a sweep net. After preparation, insects were numbered and placed in insect boxes. Smaller insects were caught with an aspirator and suction bottles, numbered and placed in insect boxes. Winged and wingless insects on the plants contaminated with aphids were collected with a number zero brush and placed in tubes containing 96% ethanol along with necessary label information (location, date of collection and host plant). During the collection of predators, if a living organism that they could feed on was observed on the same plant, this species was also noted as prey.

All adult insects collected were preserved as museum specimens through penetration methods, such as needling and attaching on cards. Cotton impregnated with lavender oil was placed in boxes to avoid the exposure of the samples stored in collection boxes to damage by the pests. After aphids were stored in 96% alcohol and separated under the microscope, they were prepared according to Martin (1983). Prepared samples were identified based on an existing identification key (Blackman & Eastop, 2021). For scientific nomenclature, the literature and online databases (fauna-eu.org and aphidspeciesfile.org; access date: 20 April 2021) were used as a reference. Families of predator species were segregated and identified based on morphological characteristics using a Nikon SMZ445 model stereo microscope. Morphologies were identified based on literature and existing museum material in the Faculty of Forestry, Isparta Applied Sciences University. Samples that could not be identified were referred to other experts. All samples were prepared as museum materials and placed in collection boxes after labeling in Entomology Museum in Faculty of Forestry.

Results and Discussion

The trees and shrubs in the urban parks of Burdur yielded 48 aphid species were found from Aphidinae (22 species), Calaphidinae (7 species), Chaitophorinae (2 species), Lachninae (14 species), Mindarinae (1 species), Eriosomatinae (1 species) and Thelaxinae (2 species) subfamilies in the Aphididae. The data about the species is presented below.

Subfamily: Aphidinae

Tribe: Aphidini

***Aphis berberidorum* Ortego & Mier Durante, 1997**

Material examined. Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 20.04.2018, *Berberis thunbergii* DC. (18 specimens).

Aphis berberidorum is new species for the Turkish aphid fauna.

***Aphis* (*Aphis*) *craccivora* Koch, 1854**

Material examined. Cemil District Park, 37°43’13” N, 30°17'43" E, 975 m, 02.06.2018, *Gleditsia triacanthos* L. (98 specimens); 26.08.2018, *Robinia pseudoacacia* L. (87 specimens); 27.07.2019, *R. pseudoacacia* L. (88 specimens); 03.08.2019, *R. pseudoacacia* L. (51 specimens); Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 07.07.2019, *Punica granatum* L. (14 specimens); Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 16.06.2019, *R. pseudoacacia* L. (46 specimens); Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 29.06.2019, *R. pseudoacacia* L. (42 specimens) (426 specimens in total).

***Aphis* (*Aphis*) *fabae* Scopoli, 1763**

Material examined. Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 01.06.2019, *Ligustrum japonicum* Thunb. (7 specimens).

***Aphis* (*Aphis*) *gossypii* Glover, 1877**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 19.07.2019, *Salix babylonica* L. (23 specimens).

***Aphis* (*Aphis*) *hederae* Kaltenbach, 1843**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 12.05.2018, *Hedera helix* L. (25 specimens); Cumhuriyet Park, 37°43'07" N, 30°16'54" E, 960 m, 14.08.2018, *H. helix* (13 specimens) (38 specimens in total).

***Aphis* (*Aphis*) *punicae* Passerini, 1863**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 12.05.2018, *P. granatum* (105 specimens).

***Aphis* (*Aphis*) *sambuci* L., 1758**

Material examined. Cumhuriyet Park, 37°43'07" N, 30°16'54" E, 960 m, 02.05.2018, *Pittosporum tobira* (Thunb.) W. T. Aiton (2 specimens); 18.05.2019, *H. helix* (25 specimens) (27 specimens in total).

***Aphis* (*Aphis*) *viburni* Scopoli, 1763**

Material examined. Barış Park, 37°43'15" N, 30°17'08" E, 957 m, 18.05.2019, *Viburnum tinus* L. (7 specimens).

***Hyalopterus amygdali* (E. Blanchard, 1840)**

Material examined. Emekevler Park, 37°43'10" N, 30°15'11" E, 917 m, 04.08.2019 (26 specimens); 16.06.2019 (20 specimens), *Prunus dulcis* (Mill.) D.A.Webb (46 specimens) (92 specimens in total).

***Hyalopterus arundiniformis* (Ghulamullah, 1942)**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 16.06.2019, *Prunus armeniaca* L. (12 specimens).

***Rhopalosiphum padi* (L., 1758)**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 12.05.2018, *P. granatum* (11 specimens).

***Hyalopterus pruni* (Geoffroy, 1762)**

Material examined. Cemil District Park, 37°43'13" N, 30°17'43" E, 975 m, 02.06.2018, *Prunus domestica* L. (56 specimens).

Tribe: Macrosiphini

***Acyrthosiphon* (*Acyrthosiphon*) *gossypii* Mordvilko, 1914**

Material examined. Fevzi Çakmak Park, 37°43'31" N, 30°14'24" E, 882 m, 16.06.2019, *Rosa* sp. (15 specimens).

***Acyrthosiphon* (*Acyrthosiphon*) *malvae* (Mosley, 1841)**

Material examined. Üçgen Park, 37°43'20" N, 30°17'14" E, 952 m, 12.05.2019, *B. thunbergii* (6 specimens).

***Cavariella* (*Cavariella*) *aegopodii* (Scopoli, 1763)**

Material examined. Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 21.11.2018, *Salix babylonica* L. (9 specimens); Emekevler Park, 37°43'10" N, 30°15'11" E, 917 m, 21.04.2018 (77 specimens), 19.05.2019 (12 specimens) and 04.08.2019 (3 specimens), *S. babylonica* L.; Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 12.05.2019, *S. babylonica* L. (69 specimens); Pazaryeri Park, 37°43'13" N, 30°17'10" E, 960 m, 12.05.2019, *Salix alba* L. (110 specimens) (280 specimens in total).

***Chaetosiphon* (*Pentatrichopus*) *tetrarhodum* (Walker, 1849)**

Material examined. Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 19.07.2019, *Rosa* sp. (10 specimens).

***Liosomaphis berberidis* (Kaltenbach, 1843)**

Material examined. Pazaryeri Park, 37°43'13" N, 30°17'10" E, 960 m,19.05.2019, *B. thunbergii* (30 specimens).

***Aulacorthum* (*Aulacorthum*) *solani* (Kaltenbach, 1843)**

Material examined. Cemil District Park, 37°43'13" N, 30°17'43" E, 975 m, 26.08.2018, *Ligustrum vulgare* L. (102 specimens); Aşıklar Park, 37°43'12" N, 30°16'50" E, 953 m, 03.05.2019, *Prunus laurocerasus* L. (72 specimens); Pazaryeri Park, 37°43'13" N, 30°17'10" E, 960 m,12.05.2019, *P. laurocerasus* (12 specimens); Üçgen Park, 37°43'20" N, 30°17'14" E, 952 m, 12.05.2019, *Viburnum opulus* L. (31 specimens); Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 12.05.2019, *R. pseudoacacia* (42 specimens) (259 specimens in total).

***Macrosiphum* (*Macrosiphum*) *euphorbiae* (Thomas, 1878)**

Material examined. Üçgen Park, 37°43'20" N, 30°17'14" E, 952 m, 27.04.2018, *P. laurocerasus* (10 specimens); Aşıklar Park, 37°43'12" N, 30°16'50" E, 953 m, 09.05.2018 (12 specimens) and 28.10.2018 (9 specimens), *P. laurocerasus* (31 specimens in total).

***Macrosiphum* (*Macrosiphum*) *rosae* (L., 1758)**

Material examined. Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 22.04.2018 (11 specimens), 18.05.2018 (23 specimens) and 19.07.2019 (10 specimens), *Rosa* sp.; Barış Park, 37°43'15" N, 30°17'08" E, 957 m, 20.11.2018 (8 specimens), 18.05.2019 (243 specimens) and 04.08.2019 (21 specimens), *Rosa* sp.; Öğretmenevi Park, 37°43'04" N, 30°16'32" E, 959 m, 03.08.2019, *Rosa* sp. (9 specimens); İstasyon Çay Bahçesi, 37°43'25" N, 30°17'03" E, 946 m, 27.07.2019, *Rosa* sp. (60 specimens); Fevzi Çakmak Park, 37°43'31" N, 30°14'24" E, 882 m, 16.06.2019, *Rosa* sp. (15 specimens); Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 27.04.2018, *R. pseudoacacia* (15 specimens) (415 specimens in total).

***Macrosiphum pallidum* (Oestlund, 1887)**

Material examined. Barış Park, 37°43'15" N, 30°17'08" E, 957 m, 02.05.2018, *V. tinus* (2 specimens); Öğretmenevi Park, 37°43'04" N, 30°16'32" E, 959 m, 18.05.2018, *P. tobira* "Nana" (20 specimens) (22 specimens in total).

***Ovatus* (*Ovatus*) *insitus* (Walker, 1849)**

Material examined. Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 19.05.2019, *Chaenomeles japonica* (Thunb.) Lindl. ex Spach (23 specimens).

Subfamily: Calaphidinae

Tribe: Calaphidini

****Hannabura alnicola* Matsumura, 1917**

Material examined. Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 20.11.2018, *Alnus glutinosa* (L.) Gaertn. (62 specimens).

Hannabura alnicola is new species for the Turkish aphid fauna.

Tribe: Panaphidini

***Hoplochaitophorus dicksoni* (Quednau, 1999)**

Material examined. Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 03.05.2019, *Quercus robur* L. (108 specimens).

***Myzocallis* (*Myzocallis*) *boerneri* Stroyan, 1957**

Material examined. Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 20.10.2018, *Q. robur* (20 specimens).

***Tuberculatus maximus* Hille Ris Lambers, 1974**

Material examined. Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 20.04.2018 (9 specimens) and 20.10.2018 (25 specimens), *Q. robur* (34 specimens in total).

***Panaphis juglandis* (Goeze, 1778)**

Material examined. Cemil District Park, 37°43'13" N, 30°17'43" E, 975 m, 02.06.2018, *Juglans regia* L. (36 specimens); Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 16.06.2019, *J. regia* (14 specimens) (50 specimens in total).

***Eucallipterus tiliae* (L., 1758)**

Material examined. Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 21.09.2018 (20 specimens), 12.05.2019 (65 specimens) and 29.06.2019 (7 specimens), *Tilia platyphyllos* Scop.; Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 16.06.2019, *T. platyphyllos* (22 specimens); Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 10.06.2019, *T. platyphyllos* (6 specimens); Barış Park, 37°43'15" N, 30°17'08" E, 957 m, 18.05.2019, *T. platyphyllos* (8 specimens); Öğretmenevi Park, 37°43'04" N, 30°16'32" E, 959 m, 10.06.2019, *T. platyphyllos* (50 specimens); Fevzi Çakmak Park, 37°43'31" N, 30°14'24" E, 882 m, 16.06.2019, *Tilia tomentosa* Moench (14 specimens) (192 specimens in total).

***Sarucallis kahawaluokalani* (Kirkaldy, 1907)**

Material examined. Öğretmenevi Park, 37°43'04" N, 30°16'32" E, 959 m, 19.05.2019, *Lagerstroemia indica* L. (one specimen).

Subfamily: Chaitophorinae

Tribe: Chaitophorini

***Capitophorus elaeagni* (Del Guercio, 1894)**

Material examined. Emekevler Park, 37°43'10" N, 30°15'11" E, 917 m, 16.06.2019, *Elaeagnus angustifolia* L. (4 specimens).

***Chaitophorus lapponum* (Ossiannilsson, 1959)**

Material examined. Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 04.08.2019, *Salix babylonica* L. (63 specimens).

Subfamily: Lachninae

Tribe: Eulachnini

***Cinara* (*Cinara*) *cedri* Mimeur, 1936**

Material examined. Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 21.11.2018, *Cedrus libani* A. Rich. (3 specimens); Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 27.07.2019, *C. libani* (48 specimens) (51 specimens in total).

***Cinara* (*Cinara*) *curvipes* (Patch, 1912)**

Material examined. Cumhuriyet Park, 37°43'07" N, 30°16'54" E, 960 m, 02.05.2018, *Abies nordmanniana* subsp. *equi-trojani* (Asch. & Sint. Ex Boiss.) Coode & Cullen (4 specimens); Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 01.06.2019, *C. libani* (4 specimens) (8 specimens in total).

***Cinara* (*Cinara*) *occidentalis* (Davidson, 1909)**

Material examined. Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 02.09.2018, *A. nordmanniana* subsp. *equi-trojani* (1 specimen).

***Cinara* (*Cinara*) *pilicornis* (Hartig, 1841)**

Material examined. Cumhuriyet Park, 37°43'07" N, 30°16'54" E, 960 m, 18.05.2019, *Picea glauca* 'Conica' (Moench) Voss (3 specimens); 04.08.2019, *Picea orientalis* (L.) Peterm. (12 specimens) (15 specimens in total).

***Cinara* (*Schizolachnus*) *pineti* (Fabricius, 1781)**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 18.04.2018, *Pinus nigra* Arnold subsp. *pallasiana* (Lamb.) Holmboe (47 specimens).

***Cinara* (*Cinara*) *piniphila* (Ratzeburg, 1844)**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 18.04.2018, *P. nigra* subsp. *pallasiana* (8 specimens).

***Cinara* (*Cinara*) *pinivora* (Wilson, 1919)**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 20.04.2018, *P. nigra* subsp. *pallasiana* (12 specimens).

***Cinara* (*Cupressobium*) *tujafilina* (Del Guercio, 1909)**

Material examined. Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 06.04.2018 (13 specimens), 26.08.2018 (30 specimens) and 01.06.2019 (3 specimens), *Platycladus orientalis* (L.) Franco; Fevzi

Çakmak Park, 37°43'31" N, 30°14'24" E, 21.04.2018 (11 specimens), 21.11.2018 (84 specimens) and 16.06.2019 (39 specimens), *P. orientalis*; Forest Office Garden, 37°43'05" N, 30°16'38" E, 956 m, 20.11.2018, *P. orientalis* (98 specimens); Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 19.07.2019, *P. orientalis* (9 specimens); Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 12.05.2019 (145 specimens), 29.06.2019 (52 specimens) and 27.07.2019 (45 specimens), *P. orientalis;* Cumhuriyet Park, 37°43'07" N, 30°16'54" E, 960 m, 18.05.2019, *P. orientalis* (5 specimens) (534 specimens in total).

***Cinara wahluca* (Hottes, 1952)**

Material examined. Öğretmenevi Park, 37°43'04" N, 30°16'32" E, 959 m, 18.05.2018, *Juniperus foetidissima* Willd. (13 specimens).

***Cinara watanabei* (Inouye, 1970)**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 20.04.2018, *P. nigra* subsp. *pallasiana* (24 specimens).

***Eulachnus cembrae* Börner, 1950**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 20.04.2018 (22 specimens) and 05.10.2018 (23 specimens), *P. nigra* subsp. *pallasiana* (45 specimens in total).

***Eulachnus nigricola* (Pasek, 1953)**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, *P. nigra* subsp. *pallasiana,* 07.07.2018 (14 specimens) and 05.10.2018 (20 specimens)*;* Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 27.04.2018, *P. nigra* subsp. *pallasiana* (28 specimens); Gençlik Park, 37°42'59" N, 30°16'15" E, 958 m, 21.04.2018, *Pinus brutia* Ten. (68 specimens) (137 specimens in total).

***Eulachnus pumilae* (Inouye, 1939)**

Material examined. Özgür District Park, 37°43'27" N, 30°17'18" E, 948 m, 27.04.2018 (7 specimens) and 12.05.2019 (12 specimens), *P. nigra* subsp. *pallasiana* (19 specimens in total).

***Eulachnus tuberculostemmatus* (Theobald, 1915)**

Material examined. Hospital Park, 37°43'26" N, 30°17'38" E, 959 m, 26.08.2018 (8 specimens) and 01.06.2019 (38 specimens), *P. nigra* subsp. *pallasiana* (46 specimens in total).

Subfamily: Mindarinae

***Mindarus abietinus* Koch, 1857**

Material examined. Güzelleştirme Park, 37°43'21" N, 30°16'55" E, 948 m, 03.05.2019, *A. nordmanniana* subsp. *equi-trojani* (16 specimens).

Subfamily: Eriosomatinae

Tribe: Pemphigini

***Prociphilus* (*Meliarhizophagus*) *fraxinifolii* (Riley, 1879)**

Material examined. Pazaryeri Park, 37°43'13" N, 30°17'10" E, 960 m, 27.07.2019 (105 specimens) and 04.08.2019 (178 specimens), *Fraxinus excelsior* L. (283 specimens).

Prociphilus (*M.*) *fraxinifolii* is new species for the Turkish aphid fauna.

Subfamily: Thelaxinae

Tribe: Thelaxini

***Thelaxes suberi* (Del Guercio, 1911)**

Material examined. Eczacı Nurhan Çiftçibaşı Park, 37°43'17" N, 30°16'43" E, 947 m, 20.10.2018, *Q. robur* (45 specimens).

In all, 3698 aphid individuals were collected. The species with the highest population were *C. tujafilina* (534 individuals; 14,4%), *A. craccivora* (426; 11.5%) and *M. rosae* (415; 11.2%). *Cinara occidentalis* and *S. kahawaluokalani* were the least common aphid species with one individual each. Across the 16 parks examined, *M. rosae*, *E. tiliae* and *C. tujafilina* were found in six parks and the most common aphid species in all parks. Thirty-two aphid species were observed in 2018, compared with 30 in 2019: 10 were found in both years. Across the years, 1468 individuals were found in 2018, 2230 in 2019. According to months, it was seen that the greatest number of specimens (1029 specimens) is in May 2019. Aphid was not determined in November 2018 and in April, September, October and November 2019 (Table 1).

Table 1. Aphid species and the number of specimens identified in 2018-2019 (April-November)

Species	2018								2019							Total	%
	A	M	J	J	A	S	O	N	A	M	J	J	A	S	O	N		
Aphidinae: Aphidini																		
**Aphis berberidorum*	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	0.5
Aphis (*Aphis*) *craccivora*	-	-	98		87	-	-	-	-	-	88	102	51	-	-	-	426	11.5
Aphis (*Aphis*) *fabae*	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	7	0.2
Aphis (*Aphis*) *gossypii*	-	-	-	-	-	-	-	-	-	-	-	23	-	-	-	-	23	0.6
Aphis (*Aphis*) *hederae*	-	25	-	-	13	-	-	-	-	-	-	-	-	-	-	-	38	1.0
Aphis (*Aphis*) *punicae*	-	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	105	2.8
Aphis (*Aphis*) *sambuci*	-	2	-	-	-	-	-	-	-	25	-	-	-	-	-	-	27	0.7
Aphis (*Aphis*) *viburni*	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	7	0.2
Hyalopterus amygdali	-	-	-	-	-	-	-	-	-	-	20	-	26	-	-	-	46	1.2
Hyalopterus arundiniformis	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	12	0.3
Hyalopterus pruni	-	-	56	-	-	-	-	-	-	-	-	-	-	-	-	-	56	1.5
Rhopalosiphum padi	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	0.3
Aphidinae: Macrosiphini																		
Acyrthosiphon (*Acyrthosiphon*) *gossypii*	-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	15	0.4
Acyrthosiphon (*Acyrthosiphon*) *malvae*	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	6	0.2
Cavariella (*Cavariella*) *aegopodii*	77	-	-	-	-	-	-	9	-	191	-	-	3	-	-	-	280	7.6
Chaetosiphon (*Pentatrichopus*) *tetrarhodum-*		-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	10	0.3
Liosomaphis berberidis	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	30	0.8
Aulacorthum (*Aulacorthum*) *solani*	-	-	-	-	102	-	-	-	-	157	-	-	-	-	-	-	259	7.0
Macrosiphum (*Macrosiphum*) *euphorbiae*	10	12	-	-	-	-	9	-	-	-	-	-	-	-	-	-	31	0.8
Macrosiphum pallidum	-	2	20	-	-	-	-	-	-	-	-	-	-	-	-	-	22	0.6
Macrosiphum (*Macrosiphum*) *rosae*	26	23	-	-	-	-	-	8	-	243	15	70	30	-	-	-	415	11.2
Ovatus (*Ovatus*) *insitus*	-	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	23	0.6

Table 1. (Continued)

Species	2018								2019								Total	%
	A	M	J	J	A	S	O	N	A	M	J	J	A	S	O	N		
Calaphidinae: Calaphidini																		
**Hannabura alnicola*	-	-	-	-	-	-	-	62	-	-	-	-	-	-	-	-	62	1.7
Hoplochaitophorus dicksoni	-	-	-	-	-	-	-	-	-	108	-	-	-	-	-	-	108	2.9
Myzocallis (*Myzocallis*) *boerneri*	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	20	0.5
Tuberculatus maximus	9	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	34	0.9
Panaphis juglandis	-	-	36	-	-	-	-	-	-	-	14	-	-	-	-	-	50	1.4
Eucallipterus tiliae	-	-	-	-	-	20	-	-	-	73	99	-	-	-	-	-	192	5.2
Sarucallis kahawaluokalani	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	0.0
Chaitophorinae: Chaitophorini																		
Chaitophorus elaeagni	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	0.1
Chaitophorus lapponum	-	-	-	-	-	-	-	-	-	-	-	-	63	-	-	-	63	1.7
Lachninae: Eulachnini																		
Cinara (*Cinara*) *cedri*	-	-	-	-	-	-	-	3	-	-	-	48	-	-	-	-	51	1.4
Cinara (*Cinara*) *curvipes*	-	4	-	-	-	-	-	-	-	-	4	-	-	-	-	-	8	0.2
Cinara (*Cinara*) *occidentalis*	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	0.0
Cinara (*Cinara*) *pilicornis*	-	-	-	-	-	-	-	-	-	3	-	-	12	-	-	-	15	0.4
Cinara (*Schizolachnus*) *pineti*	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47	1.3
Cinara (*Cinara*) *piniphila*	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.2
Cinara pinivora	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0.3
Cinara (*Cupressobium*) *tujafilina*	24	-	-	-	30	-	-	182	-	150	94	54	-	-	-	-	534	14.4
Cinara wahluca	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	0.4
Cinara watanabei	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	0.6
Eulachnus cembrae	22	-	-	-	-	-	23	-	-	-	-	-	-	-	-	-	45	1.2
Eulachnus nigricola	96	-	-	14	-	-	20	-	-	-	-	-	-	-	-	-	130	3.5
Eulachnus pumilae	7	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	19	0.5
Eulachnus tuberculostemmatus	-	-	-	-	8	-	-	-	-	-	38	-	-	-	-	-	46	1.2
Mindarinae																		
Mindarus abietinus	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	16	0.4
Eriosomatinae: Pemphigini																		
**Prociphilus* (*Meliarhizophagus*) *fraxinifolii*	-	-	-	-	-	-	-	-	-	-	-	105	178	-	-	-	283	7.7
Thelaxinae: Thelaxini																		
Thelaxes suberi	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	45	1.2
TOTAL	380	197	210	14	240	21	142	264	0	1029	426	412	363	0	0	0	3698	100
	1468											2230					3698	100,0

When the distribution of the number of aphid specimens by parks is examined, the highest number of individuals (479 specimens) was found in Özgür District Park (P14) in 2019. In 2018, the highest number of specimens (379 specimens) was seen in the Cemil District Park (P3). When looking at the number of species in parks, Güzelleştirme Park (in 2018) and Gençlik Park (in 2019) were detected six and seven, respectively (Figure 1).

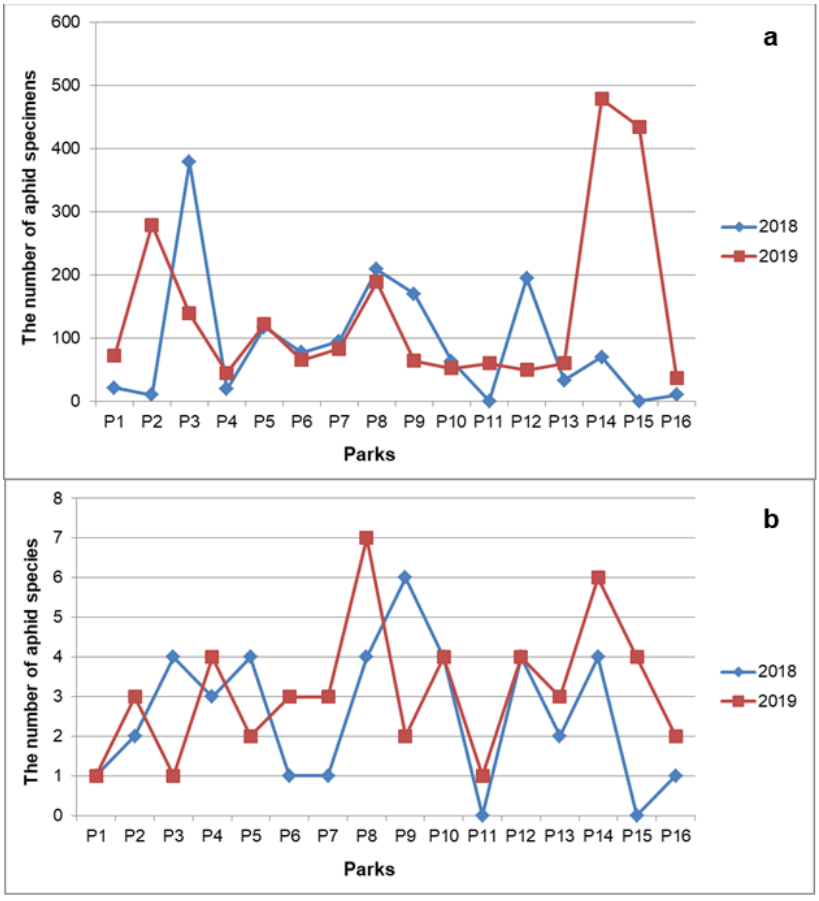

Figure 1. Number of aphid specimens (a) and species (b) in parks in 2018-2019 (P1, Aşıklar Park; P2, Barış Park; P3, Cemil District Park; P4, Cumhuriyet Park; P5, Eczacı Nurhan Çiftçibaşı Park; P6, Emekevler Park; P7, Fevzi Çakmak Park; P8, Gençlik Park; P9, Güzelleştirme Park; P10, Hospital Park; P11, İstasyon Çay Bahçesi; P12, Forest Office Garden; P13, Öğretmenevi Park; P14, Özgür District Park; P15, Pazaryeri Park; and P16, Üçgen Park).

In this work, 29 predator species comprising 289 individuals were detected with one species of Nabidae and one species of Miridae in the order Hemiptera, 24 species of Coccinellidae and one species of Cantharidae family in the Coleoptera, one species of Syrphidae in the Diptera order and one species of Forficulidae in the Dermaptera. The most common predator species found were *Stethorus gilvifrons* with 72 individuals (24.9%), *Propylaea quatuordecimpunctata* (L., 1758) with 42 individuals (14.5%) and *Oenopia conglobata* (L., 1758) (Coleoptera: Coccinellidae) with 28 individuals (9.7%) (Table 2).

Table 3 presents the host plant species and predators of aphid species found in Burdur. Forty-eight aphid species and 29 predator species were detected on 34 host plant species. In terms of tritrophic interactions, 36 aphid species were found on one host plant species. No predators were found on 12 aphids. For 11 aphid species, only a single predator species was found. The highest host plant diversity was observed for *A. craccivora* and *A. solani* species which occurred on three plant species each. The highest predator diversity was found in *E. tiliae* with 11 species, *C. tujafilina* and *E. tuberculostemmatus* each with seven species, and *A. craccivora* and *M. rosae* with five species. The highest number of aphid species (8 species) was observed on *P. nigra*. subsp. *pallasiana* (Table 3).

Table 2. Number of individual predator species sampled and their relative abundance

Order: Family	Predator Species	Number of Specimens	Presence (%)
Hemiptera: Nabidae	*Nabis* (*Nabis*) *pseudoferus* Remane, 1949	1	0,3
Hemiptera: Miridae	*Deraeocoris* (*Knightocapsus*) *lutescens* (Schilling, 1837)	1	0,3
Coleoptera: Coccinellidae	*Adalia* (*Adalia*) *bipunctata* (L., 1758)	25	8,7
	Adalia (*Adalia*) *decempunctata* (L., 1758)	3	1,0
	Adalia fasciatopunctata revelierei (Mulsant,1866)	25	8,7
	Chilocorus bipustulatus (L., 1758)	10	3,5
	Clitostethus arcuatus (Rossi, 1794)	1	0,3
	Coccinella (*Coccinella*) *septempunctata* L., 1758	2	0,7
	Exochomus quadripustulatus (L., 1758)	4	1,4
	Harmonia axyridis (Pallas, 1773)	3	1,0
	Harmonia quadripunctata (Pontoppidan, 1763)	7	2,4
	Hippodamia (*Hippodamia*) *variegata* (Goeze, 1777)	4	1,4
	Hippodamia undecimnotata (Schneider, 1792)	1	0,3
	Myrrha (*Myrrha*) *octodecimguttata* (L., 1758)	6	2,1
	Oenopia conglobata (L., 1758)	28	9,7
	Oenopia lyncea (Olivier, 1808)	2	0,7
	Propylaea quatuordecimpunctata (L., 1758)	42	14,5
	Scymnus (*Scymnus*) *apetzi* (Mulsant, 1846)	3	1,0
	Scymnus (*Scymnus*) *bivulnerus* (Baudi, 1894)	6	2,1
	Scymnus (*Mimopullus*) *flagellisiphonatus* (Fursch, 1969)	1	0,3
	Scymnus (*Scymnus*) *frontalis* (Fabricius, 1787)	10	3,5
	Scymnus (*Scymnus*) *interruptus* (Goeze, 1777)	4	1,4
	Scymnus (*Scymnus*) *rubromaculatus* (Goeze, 1778)	14	4,8
	Scymnus (*Pullus*) *subvillosus* (Goeze, 1777)	8	2,8
	Scymnus pallipediformis (Gunther, 1958)	1	0,3
	Stethorus gilvifrons (Mulsant, 1850)	72	24,9
Coleoptera: Cantharidae	*Cantharis* (*Cantharis*) *livida* (L., 1758)	2	0,7
Diptera: Syrphidae	*Scaeva dignota* (Rondani, 1857)	1	0,3
Dermaptera: Forficulidae	*Forficula auricularia* L., 1758	2	0,7
TOTAL		289	100

Several recent publications have emphasized that Turkey has a diverse aphid fauna (Görür et al., 2020; Özdemir, 2020; Kök & Özdemir, 2021). Three new Turkish records of species in this study are also consistent with this finding. Two of these species originated from South America and one from the Far East (Cœur d'acier, 2010; Blackman & Eastop, 2021). *Aphis berberidorum* was identified by Ortego & Mier Durante (1997) in Chile and Argentina, and subsequently detected in Turkey after this time (Ortego & Mier Durante, 1997; Blackman & Eastop, 2021).

The genus *Hannabura* comprises two species as *H. alnicola* and *Hannabura alnosa* (Pepper, 1950). *Hannabura alnicola* is an East Asia-originated species and *H. alnicola* is North America-originated one. The genus *Hannabura* recorded from Turkey firstly with this study. *H. alnicola* was firstly described in 1917 from Japan and has not been recorded from any country up to date (Matsumura, 1917; Blackman & Eastop, 2021). *Prociphilus* (*M*.) *fraxinifolii* widely distributed in North America, and also occurs in Chile, South Africa, Europe (Hungary, England, Slovenia, Serbia, Spain, Romania, Bulgaria), Russia, Iran, and China (Baker & Martin, 2011; Seljak, 2017; Olenici et al., 2018; Bienkowskaja & Orlova-Bienkowskaja, 2018; Blackman & Eastop, 2021). In this study, *Oenopia conglobata* and *S.* (*S.*) *subvillosus* were recorded for the first time as predators of *A. berberidorum*. Predators associated with aphids have all been previously reported except *O. conglobata* and *S.* (*S.*) *subvillosus* (Coleoptera: Coccinellidae).

Table 3. Aphid species, host plants and predators found in parks and gardens of Burdur

Aphid species	Host Plants	Predators
Acyrthosiphon (*Acyrthosiphon*) *gossypii*	*Rosa* sp.	*Hippodamia undecimnotata, H.* (*Hippodamia*) *variegata*
Acyrthosiphon (*Acyrthosiphon*) *malvae*	*Berberis thunbergii*	-
**Aphis berberidorum*	*B. thunbergii*	*Oenopia conglobata, Scymnus* (*Scymnus*) *subvillosus*
Aphis (*Aphis*) *craccivora*	*Gleditsia triacanthos, Punica granatum, Robinia pseudoacacia*	*Exochomus quadripustulatus, H.* (*H.*) *variegata, O. conglobata, Scymnus* (*Scymnus*) *apetzi, Scymnus* (*Scymnus*) *rubromaculatus*
Aphis (*Aphis*) *fabae*	*Ligustrum japonicum*	*Scymnus* (*Scymnus*) *bivulnerus*
Aphis (*Aphis*) *gossypii*	*Salix babylonica*	*Adalia fasciatopunctata revelierei*
Aphis (*Aphis*) *hederae*	*Hedera helix*	*Coccinella* (*Coccinella*) *septempunctata, O. conglobata*
Aphis (*Aphis*) *punicae*	*Punica granatum*	*Adalia* (*Adalia*) *decempunctata*, *A. fasciatopunctata revelierei*, *Adalia* (*Adalia*) *bipunctata*, *O. conglobata*
Aphis (*Aphis*) *sambuci*	*Hedera helix, Pittosporum tobira* ("nana")	*Clitostethus arcuatus*
Aphis (*Aphis*) *viburni*	*Viburnum tinus*	-
Aulacorthum (*Aulacorthum*) *solani*	*Prunus laurocerasus,* L. vulgare, *V. opulus*	*A. fasciatopunctata revelierei*, *A.* (*A.*) *bipunctata, O. conglobata, S.* (*S.*) *subvillosus*
Cavariella (*Cavariella*) *aegopodii*	*S.babylonica, S. alba*	*A. fasciatopunctata revelierei, A.* (*A.*) *bipunctata, Harmonia axyridis, O. conglobata*
Cinara (*Cinara*) *cedri*	*Cedrus libani*	*E. quadripustulatus*
Cinara (*Cinara*) *curvipes*	*Abies nordmanniana* subsp. *equi-trojani*	*O. conglobata*, *Stethorus gilvifrons*
Cinara occidentalis	*A. nordmanniana* subsp. *equi-trojani*	*S. gilvifrons*
Cinara (*Cinara*) *pilicornis*	*Picea glauca '*Conica', *P. orientalis*	*E. quadripustulatus*, *Scymnus* (*Mimopullus*) *flagellisiphonatus*, *S. gilvifrons*
Cinara (*Schizolachnus*) *pineti*	*Pinus nigra* subsp. *pallasiana*	*C.* (*C.*) *septempunctata, H. quadripunctata, S. gilvifrons*
Cinara (*Cinara*) *piniphila*	*P. nigra* subsp. *pallasiana*	*C.* (*C.*) *septempunctata*
Cinara pinivora	*P. nigra* subsp. *pallasiana*	*C.* (*C.*) *septempunctata*
Cinara (*Cupressobium*) *tujafilina*	*Platycladus orientalis*	*A.* (*A.*) *decempunctata, Chilocorus bipustulatus, C.* (*C.*) *septempunctata, H. quadripunctata, O. conglobata, S.* (*S.*) *subvillosus, Scymnus interruptus, S. gilvifrons*
Cinara wahluca	*Juniperus foetidissima*	*A.* (*A.*) *bipunctata*, *E. quadripustulatus*, *O. conglobata*, *S.* (*S.*) *rubromaculatus*
Cinara watanabei	*P. nigra* subsp. *pallasiana*	*Scaeva dignota*
Chaitophorus elaeagni	*Elaeagnus angustifolia*	*A. fasciatopunctata revelierei*, C. *bipustulatus*, *O. conglobata*
Chaitophorus lapponum	*S. babylonica*	-
Chaetosiphon (*Pentatrichopus*) *tetrarhodum*	*Rosa* sp.	*S.* (*S.*) *rubromaculatus*
Eulachnus cembrae	*P nigra* subsp. *pallasiana*	*S. gilvifrons*
Eulachnus nigricola	*P nigra* subsp. *pallasiana, P. brutia*	*Nabis* (*Nabis*) *pseudoferus, O.conglobata, S. gilvifrons*
Eulachnus pumilae	*P nigra* subsp. *pallasiana*	-
Eulachnus tuberculostemmatus	*P nigra* subsp. *pallasiana, P. brutia*	*C. bipustulatus*, *Myrrha* (*Myrrha*) *octodecimguttata*, *H. quadripunctata*, *S. gilvifrons*
Eucallipterus tiliae	*Tilia platyphyllos, T. tomentosa*	*A.* (*A*). *decempunctata*, *A. fasciatopunctata revelierei*, *A.* (*A.*) *bipunctata*, *M.* (*M.*) *octodecimguttata*, *H. quadripunctata*, *O. conglobata*, *Propylaea quatuordecimpunctata*, *S.* (*S.*) *rubromaculatus, S.* (*S.*) *subvillosus, S. gilvifrons, Cantharis* (*Cantharis*) *livida*

Table 3. (Continued)

Aphid species	Host Plants	Predators
**Hannabura alnicola*	*Alnus glutinosa*	-
Hoplochaitophorus dicksoni	*Quercus robur*	*Deraeocoris* (*Knightocapsus*) *lutescens, O. lyncea*
Hyalopterus amygdali	*Prunus dulcis*	*A. fasciatopunctata revelierei*, *A.* (*A.*) *bipunctata*, *O. conglobata*
Hyalopterus arundiniformis	*P. armeniaca*	-
Hyalopterus pruni	*P. domestica*	-
Liosomaphis berberidis	*B. thunbergii* var. *atropurpurea*	-
Macrosiphum (*Macrosiphum*) *euphorbiae*	*P. laurocerasus*	*P. quatuordecimpunctata*, *S. interruptus, Forficula auricularia*
Macrosiphum pallidum	*V. tinus, P. tobira "nana"*	-
Macrosiphum (*Macrosiphum*) *rosae*	*R. pseudoacacia, Rosa sp.*	*A.* (*A.*) *bipunctata*, *C. bipustulatus*, *H. undecimnotata*, *H.* (*H.*) *variegata*, *P. quatuordecimpunctata*, *S.* (*S.*) *rubromaculatus*, *F. auricularia*
Mindarus abietinus	*A. nordmanniana* subsp. *equi-trojani*	*A.* (*A.*) *bipunctata*, *H. quadripunctata*, *S.* (*S.*) *bivulnerus*
Myzocallis (*Myzocallis*) *boerneri*	*Q. robur*	*P. quatuordecimpunctata*, *S. gilvifrons*
Ovatus (*Ovatus*) *insitus*	*Chaenomeles japonica*	-
Panaphis juglandis	*Juglans regia*	*A. fasciatopunctata revelierei*, *O. conglobata*
**Prociphilus* (*Meliarhizophagus*) *fraxinifolii*	*Fraxinus excelsior*	-
Rhopalosiphum padi	*P. granatum*	*A.* (*A.*) *decempunctata*, A. *fasciatopunctata revelierei*, *A.* (*A.*) *bipunctata*, *O. conglobata*
Sarucallis kahawaluokalani	*Lagerstroemia indica*	-
Thelaxes suberi	*Q. robur*	*P. quatuordecimpunctata*, *S. gilvifrons*
Tuberculatus maximus	*Q. robur*	*P. quatuordecimpunctata*, *S.gilvifrons*

* New records for Turkey fauna.

Aphis (*A.*) *hederae*, *A.* (*A.*) *sambuci*, *A.* (*A.*) *viburni*, *H. arundiniformis*, *H. pruni*, *R. padi*, *A.* (*A.*) *gossypii*, *Ac.* (*Ac.*) *malvae*, *L. berberidis*, *A.* (*A.*) *solani*, *M.* (*M.*) *euphorbiae*, *M. pallidum*, *O.* (*O.*) *insitus*, *H. dicksoni*, *M.* (*M.*) *boerneri*, *T. maximus*, *P. juglandis*, *E. tiliae*, *S. kahawaluokalani*, *C. lapponum*, *C*. (*C.*) *curvipes*, *C. occidentalis*, *C.* (*C.*) *pilicornis*, *C.* (*S.*) *pineti*, *C.* (*C.*) *piniphila*, *C. pinivora*, *C.* (*C.*) *tujafilina*, *C. wahluca*, *C. watanabei*, *E. cembrae*, *E. nigricola*, *E. pumilae* and *E. tuberculostemmatus* species were found for the first time in Burdur Province.

New host records in the present study were as follow; *A.* (*A.*) *sambuci* on *P. tobira*, *R. padi* on *P. granatum*, *A.* (*A.*) *malvae* on *B. thunbergii*, *A.* (*A.*) *solani* on *L. vulgare* and *P. laurocerasus*, *M.* (*M.*) *euphorbiae* on *P. laurocerasus*, *M.* (*M.*) *rosae* on *R. pseudoacacia*, *M. pallidum* on *V. tinus* and *P. tobira*.

Several species of Coccinellidae (Coleoptera) are known to feed on aphids (Uygun, 1981; Giorgi et al., 2009; Weber & Lundgren, 2009; Honek et al., 2017). *Coccinella septempunctata* was the most commonly detected and most widespread species found in many studies (Aslan & Uygun, 2005; Başţuğ & Kasap, 2015; Kök et al., 2017, 2020) whereas only two individuals of this species was found in this study. The most commonly detected predator species in present work were *S. gilvifrons, P. quatuordecimpunctata* and *O. conglobata*. Nine predator species (*Adalia decempunctata* (L., 1758)*, Clitostethus arcuatus* (Rossi, 1794)*, Harmonia axyridis* (Pallas, 1773), *Oenopia lyncea* (Olivier, 1808), *Scymnus rubromaculatus* (Goeze, 1778), *Scymnus frontalis* (Fabricius, 1787)*, Scymnus flagellisiphonatus* (Fursch, 1969)*, Scymnus interruptus* (Goeze, 1777) and *Scaeva dignota* (Rondani, 1857)) were first records for Burdur Province. The *H. axyridis*, a species from East Asia, was detected in the current study, but this species recorded from Turkey in 2014 from the Inner Anatolian part of Turkey (Cappadocia). This species is currently being used for biological control of aphid species in many countries of Europe and North America (Brown et al., 2007; Bukejs & Telnov, 2014). It has now been observed in Bartın, Çanakkale, Düzce, Isparta, Nevşehir and

Tekirdağ (Aysal & Kıvan, 2014; Başţuğ & Kasap, 2015; Kaygın & Kaptan, 2017; Öztemiz & Yayla, 2018; Oğuzoğlu & Avcı, 2019).

In this study, *S. dignota* from the Syrphidae (Diptera) was detected; *Scaeva* spp. have been reported to be among important aphid predators (Demirsoy, 1990; Yetkin, 2006). In this study, *S. dignota* found to predate *C. watanabei* has previously been reported feeding on *A. solani, A. gossypii, Aphis nasturtii* Kaltenbach, 1843 and *Myzus* (*Nectarosiphon*) *persicae* Sulzer, 1776 (Alaserhat et al., 2021). *Forficula auricularia* L., 1758 (Dermaptera: Forficulidae) feeds on aphids (Mueller et al., 1988; Dib et al., 2011; Aslan, 2015; Ölmez-Bayhan et al., 2015), and has been reported as a predator of *A. craccivora* (Ölmez-Bayhan et al., 2015), *Myzus* (*Myzus*) *cerasi* (Fabricius, 1775)*, Dysaphis pyri* (Boyer de Fonscolombe, 1841) and *Dysaphis devecta* (Walker, 1849) (Aslan, 2015) in Turkey. In our study, *F. auricularia* was found feeding on *M. rosae* and *M. euphorbia*. In the present work, *N. pseudoferus* was found to be a predator of *E. nigricola*, while *Deraeocoris* (*Knightocapsus*) *lutescens* (Schilling, 1837) (Hemiptera: Miridae) was predating *H. dicksoni*. It is argued that *N. pseudoferus* is a generalist predator and feeds on several organisms, including aphids (Mahdavi & Madadi, 2016; Mahdavi et al., 2020). *Nabis pseudoferus* is recorded as predator of *A. craccivora* (Kök et al., 2020). The prey of *Cantharis* larvae is known to include aphids and Mollusca species (Traugott, 2002; 2003). In this study, *Cantharis livida* was found as a predator of *E. tiliae*.

Increasing global trade over the last 50 years, and ecological changes as a result of climate change have enabled a varied group of organisms, including aphids, to invade new geographical areas and become invasive. The geographical location and floristic richness of Turkey makes the country suitable for numerous invasive species. The work presented here adds support to this hypothesis as *A. berberidorum*, *H. alnicola* and *P. fraxinifolii* were recorded for the first time in the state and are clearly invasive species in the aphid fauna of Turkey, with origins in the Nearctic and Orient. These findings are consistent with previous reports, since about 9% of recent new records added to the Turkey aphid fauna are invasive (Akyıldırım et al., 2013; Görür et al., 2017). The number of the aphid species listed for Turkey increased to about 594 with these new records. Further detailed studies are required to clarify the potential of these invasive aphid species to cause damage and to understand the full extent of host plant relationships, including trees growing in natural environments and in parks and gardens.

Acknowledgments

We thank Prof. Dr. Gazi Görür (Niğde Ömer Halisdemir University) for his contributions in the identification of aphid species, faculty member Dr. Derya Şenal (Bilecik Şeyh Edebali University) for the preparation and identification of Coccinellidae species, Prof. Dr. Rüstem Hayat (Akdeniz University) for the identification of Syrphidae samples, Prof. Dr. Ahmet Dursun (Amasya University) for the identification of Hemiptera species, Prof. Dr. Hüseyin Fakir (Isparta Applied Sciences University) and Prof. Dr. Ünal Akkemik (Istanbul University-Cerrahpaşa) for the identification of plant species. We are grateful to Prof. Dr. Stephen Woodward (University of Aberdeen) for editing of the English version and his valuable suggestions.

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Türk. entomol. derg., 2021, 45 (3): 389-396
DOI: http://dx.doi.org/10.16970/entoted.970210

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Implementing local entomopathogenic nematodes to control Mediterranean fruit fly *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae)[1]

Akdeniz meyve sineği *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae)'yı kontrol etmek için yerel entomopatojen nematodların uygulanması

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Abstract

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae), is one of the world's most destructive fruit pests. *Ceratitis capitata* pupates in the soil, making it a target of many soilborne pathogens like entomopathogenic nematodes (EPNs). Entomopathogenic nematodes are highly lethal to many important pests, safe to non-target organisms and they might be good alternatives for control of *C. capitata*. In this study, the efficacy of four local EPN species; *Steinernema affine* Bovien, 1937, *Steinernema carpocapsae* Weiser, 1955, *Steinernema feltiae* Filipjev, 1934 (Rhabditida: Steinernematidae) and *Heterorhabditis bacteriophora* Poinar, 1976 (Rhabditida: Heterorhabditidae) against the third instar larvae and pupae of *C. capitata* were evaluated. The study was conducted in 2019-2020 both in the laboratory (in plastic cups) and in a climate room (in wooden cages with plastic pots) at doses of 100 and 200 IJs/larva-pupa and 7,650 and 15,300 IJs/pot, respectively. Larvae of *C. capitata* were found more susceptible to EPNs than pupae in the study. *Steinernema feltiae* isolate 113 and *H. bacteriophora* isolate 12 showed the highest efficacy while *S. affine* isolate 47 showed the least efficacy against the pest larvae and pupae. Suppression of *C. capitata* population by EPNs indicates that these EPNs can be considered as a biological control agent potentially useful for the control of this pest. After further support by field studies, these two local EPN isolates could be used as promising eco-friendly biological agents against *C. capitata.*

Keywords: Biological control, *Ceratitis capitata*, efficacy, entomopathogenic nematodes, local isolates

Öz

Akdeniz meyve sineği, *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae), dünyanın en tahripkar meyve zararlılarından biridir. *Ceratitis capitata* toprakta pupa olur ve bu durum onu entomopatojen nematodlar (EPN) gibi toprak kökenli birçok patojenin hedefi haline getirir. Entomopatojen nematodlar birçok önemli zararlı için oldukça öldürücü, hedef dışı organizmalar içinse güvenlidir ve *C. capitata*'yı kontrol etmek için iyi bir alternatif olabilirler. Bu çalışmada, dört yerel EPN türü; *Steinernema affine* Bovien, 1937, *Steinernema carpocapsae* Weiser, 1955, *Steinernema feltiae* Filipjev, 1934 (Rhabditida: Steinernematidae) ve *Heterorhabditis bacteriophora* Poinar, 1976 (Rhabditida: Heterorhabditidae)'nın *C. capitata*'nın üçüncü dönem larvalarına ve pupalarına karşı etkinlikleri değerlendirilmiştir. Çalışma 2019-2020 yıllarında hem laboratuvarda (plastik kaplarda) hem de iklim odasında (plastik saksılarda ahşap kafeslerde) sırası ile 100 ve 200 IJs/larva-pupa ile 7.650 ve 15.300 IJs/saksı dozunda yürütülmüştür. Çalışmada EPN'lere karşı *C. capitata*'nın larvalarının pupalarından daha duyarlı olduğu bulunmuştur. Zararlı larva ve pupalara karşı en yüksek etkinliği *S. feltiae* 113 ve *H. bacteriophora* 12 izolatları gösterirken, *S. affine* 47 izolatı en düşük etkinliği göstermiştir. Entomopatojen nematodlar tarafından *C. capitata* popülasyonunun baskılanması, bu EPN'lerin zararlının kontrolü için potansiyel olarak faydalı biyolojik mücadele etmenleri olarak kabul edilebileceğini göstermektedir. İleride yapılacak arazi çalışmaları ile desteklendikten sonra bu iki yerel EPN izolatı, *C. capitata*'ya karşı ümit var çevre dostu biyolojik etmenler olarak kullanılabilir.

Anahtar sözcükler: Biyolojik kontrol, *Ceratitis capitata*, etkinlik, entomopatojen nematodlar, yerel izolatlar

[1] This study was financially supported by University Scientific Research Project, BAP-Project Number: FBA-2019-2865.
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Received (Alınış): 12.07.2021 Accepted (Kabul ediliş): 07.09.2021 Published Online (Çevrimiçi Yayın Tarihi): 10.09.2021

Introduction

Mediterranean fruit fly, *Ceratitis capitata* Wiedemann, 1824 (Diptera: Tephritidae), is a devastating fruit fly with a broad global distribution. It is a cosmopolitan quarantine pest that causes damage to more than 360 different hosts ranging from citrus to soft and stone fruits and vegetables (Liquido et al., 1991; Papadopoulos et al., 1998; Satar et al., 2016). It is able to tolerate climatic conditions better than most other fruit flies and the introduction of *C. capitata* to the almost all parts of the world have negative impacts on fruit production.

Turkey has suitable ecological conditions for many fruit species because of its geographical location and *C. capitata* is one of the zero-tolerance species on the quarantine list of Turkey (Anonymous, 2013). It significantly affects the export of fresh fruit; therefore, the control of the pest is crucial but controlling *C. capitata* remains problematic due to the degree and frequency of damage, and the complications of applying control methods (Harbi et al., 2018).

Control strategies of this pest are mainly based on an integrated pest management (IPM) approach using different methods. Chemical control (Magaña et al., 2007), mass trapping (Navarro-Llopis et al., 2008), sterile insect technique (Katsoyannos et al., 1999; Hendrichs et al., 2002) and biological control (Montoya et al., 2005) are the most commonly used methods. However, due to the problems and the failures occurring in these methods scientists have been focused on different studies on alternative biological control agents like entomopathogenic nematodes (EPNs) against *C. capitata* under laboratory and field conditions (Lindengren, 1990; Laborda et al., 2003; Kepenekçi & Susurluk, 2006; Karagöz et al., 2009; Malan & Manrakhan, 2009; Rohde et al., 2010, 2012; Mokrini et al., 2020).

Entomopathogenic nematodes of the genus *Steinernema* and *Heterorhabditis* (Nematoda: Rhabditida) find their hosts in cryptic habitats, sometimes in soil and kill them within 2-3 days by their mutualistic bacteria in the genera *Xenorhabdus* and *Photorhabdus*, respectively (Dillman et al., 2012; Lacey et al., 2015). Nematode and bacteria both deal with the host by producing specific compounds. The bacteria kill host larvae and start reproduce inside the hemocoel and it also create better environmental conditions for nematode development of inside the hemocoel (Boemare, 2002; Bode, 2009; Lu et al., 2017). These nematodes are non-polluting and safe, can be applied by agronomic equipment, and EPNs are also adaptable with many pesticides (Forschler et al., 1990; Georgis, 1990; Rovesti & Deseo, 1991). The host range of a species/strain is generally quite limited so they do not produce untargeted deaths (Smart, 1995). These safe agents are successful in controlling many agricultural pests belonging to different orders/families (Belair et al., 2003; Head et al., 2004; Lacey et al., 2010; Shapiro-Ilan et al., 2010; Gözel & Kasap, 2015; Gözel & Gözel, 2019).

This study aimed to evaluate the control potential of local EPNs on the third instar larvae and pupae of *C. capitata*. The efficacy of *Steinernema affine* (Bovien, 1937) isolate 47 (İstanbul), *Steinernema feltiae* (Filipjev, 1934) isolate 113 (Balıkesir), *Steinernema carpocapsae* (Weiser, 1955) isolate 1133 (Sakarya) (Rhabditida: Steinernematidae) and *Heterorhabditis bacteriophora* (Poinar, 1976) isolate 12 (Çanakkale) (Rhabditida: Heterorhabditidae) obtained from different locations in Turkey was investigated both in laboratory and climate room conditions.

Materials and Methods

Entomopathogenic nematodes

The study was conducted between 2019 and 2020 under laboratory and climate room conditions at Faculty of Agriculture. Four local EPN isolates from different provinces of Turkey were reared at 25±1ºC and 65±5% RH on the final instar larvae of *Galleria mellonella* L. (Lepidoptera: Pyralidae) (Kaya & Stock, 1997). Freshly emerged infective juveniles (IJs) were harvested and used in the bioassays.

Mediterranean fruit fly, *Ceratitis capitata*

Ceratitis capitata colony was previously established on its natural hosts (Genc & Yücel, 2017) and then adapted to the artificial diet in Insect Molecular Biology Laboratory (Tsitsipis & Kontos, 1983; Tzanakakis, 1989; Genc, 2008). Daily collected eggs from the adult cages were transferred to the artificial diet and reared until the third instar in the laboratory at 25±1ºC and 60±5% RH. Mature larvae or pupae were collected from the artificial diet with 2 mm diameter sieve for the bioassays.

Bioassays

Laboratory bioassay

The bioassay was conducted at 10% moisture in sterile sand in 60 ml plastic cups with 20 individuals (third instars or pupae). Two EPN doses of 100 and 200 IJs per larva or pupa were used in this study. Cups were capped by a lid, then punctured with a needle for aeration and kept at room temperature (23-24ºC). Mortality was recorded 7 days after EPN inoculation, to approve the infection the dead larvae and pupae that shown typical infection signs were placed to White traps (White, 1927).

Emerged adults were counted, and mortality calculated by subtracting the emerged adults from the initial number of larvae or pupae. Mortality of larvae and pupae and the efficiency of EPNs were also determined according to the EPN harvested from cadavers. In control groups, only distilled water was given to *C. capitata* larvae and pupae. Four replicates for each nematode isolate were used and the bioassay was performed twice.

Climate room bioassay

The bioassay in a climate room was conducted in plastic pots, with a depth of 13 cm, a diameter of 14 cm and a surface area of 153 cm^2. Pots were filled with autoclaved sand at 10% moisture, by 50 individuals (third instars or pupae) for each application. Two EPN doses used for application were 7,650 and 15,300 IJs per pot. Pots were covered by tulle, placed in wooden cages and kept at climate room (23-24ºC). All other procedures were similar as the laboratory bioassay. Mortality was recorded 21 days after EPN inoculation. Three replicates for each nematode isolate were used and the bioassay was performed twice.

Statistical analysis

The experiment was conducted by a completely randomized design. The mortality resulted from the effect of EPNs was calculated and corrected according to Abbott's formula (Abbott, 1925) and ANOVA analysis was performed on Minitab 17 Statistical Software. Significant means were compared by Tukey's comparison test ($p \leq 0.05$).

Results

The mortality of third instars and pupae of *C. capitata* (Figure 1) caused by EPNs in the laboratory bioassays are shown in Figure 2 (upper panels). It was determined that the third-order interaction of EPN isolate, *C. capitata* stage and EPN dose was significant, which means that mortality of *C. capitata* changed with biological stages of the *C. capitata* and the EPN dose in each EPN isolate. Significant differences were determined between doses. Among the EPNs doses, 200 IJs caused the highest mortality both on mature larvae and pupae of *C. capitata*.

In the larval stage at dose of 100 IJs, the mortality was recorded as the highest by *H. bacteriophora* 12 (79%) and *S. feltiae* 113 (83%). The similar trend was also observed in 200 IJs and the highest mortality was reached 91 and 96% for the same isolates, respectively. The lowest mortality was reported by *S. affine* 47 with 49 and 77% at dose of 100 and 200 IJs, respectively.

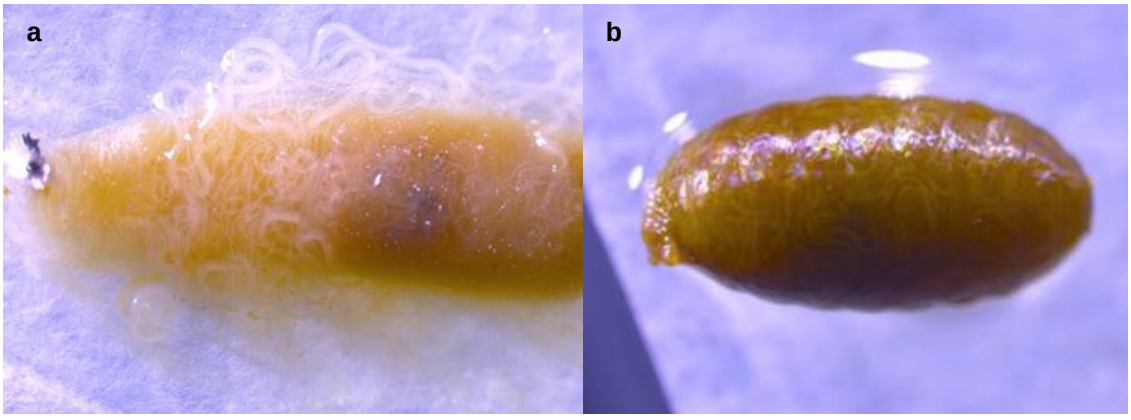

Figure 1. Entomopathogenic nematode-infested a) larva; b) pupa.

The mortality was lower in pupae of *C. capitata*, the dose of 100 IJs the mortality was recorded as the highest by *H. bacteriophora* 12 (21%) and *S. feltiae* 113 (23%). Similar rise occurred with 200 IJs and the highest mortality reached 34% with these two isolates. The lowest mortality was obtained by *S. affine* 47 with 8 and 15% with 100 and 200 IJs, respectively.

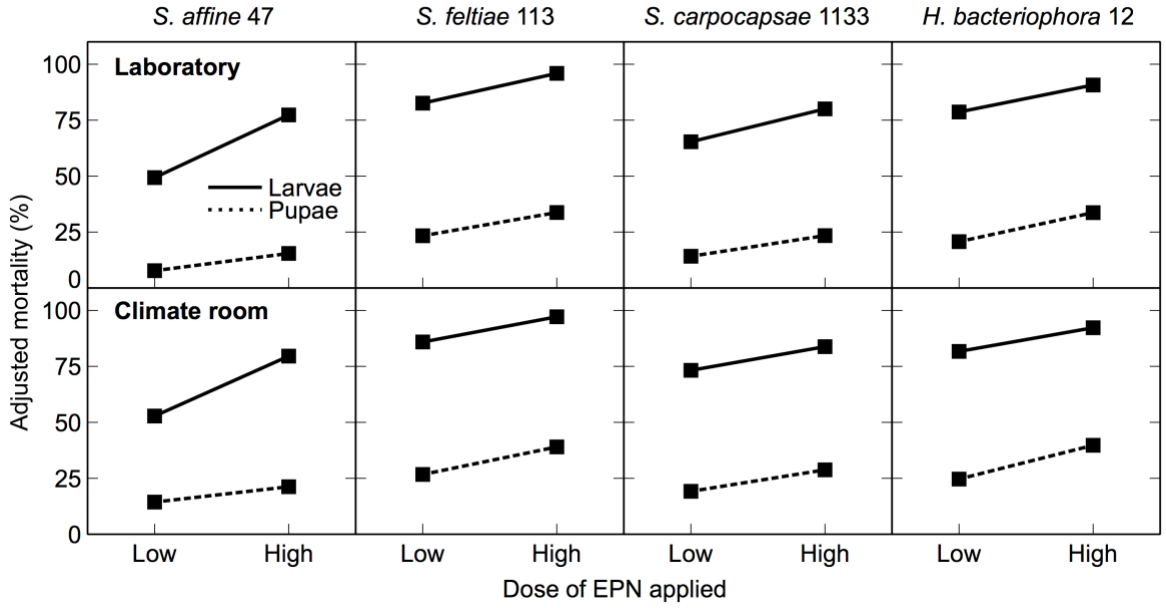

Figure 2. Mean adjusted mortality *Ceratitis capitata* larvae and pupae exposed to entomopathogenic nematodes in the laboratory (low, 100 IJs/larva-pupa, and high 200 IJs/larva-pupa) and climate room (low, 7,650 IJs/pot; and high, 15,300 IJs/pot).

The mortality of third instar larva and pupa of *C. capitata* caused by EPNs occurred in a climate room bioassay are shown in Figure 2 (lower panels). The third-order interaction of EPN isolate, *C. capitata* stage and EPN dose was significant for mortality as in the laboratory bioassay. In the larval stage with 7,650 IJs, the mortality was recorded as the highest by *H. bacteriophora* 12 (82%) and *S. feltiae* 113 (86%). The similar tendency was also observed with 15,300 IJs and the highest mortality was reached 92 and 97% by the same isolates, respectively. The lowest mortality was reported by *S. affine* 47 with 53 and 80% with 7,650 and 15,300 IJs, respectively.

Mortality was lower in pupae of the pest, and with 7,650 IJs the mortality was recorded as the highest by *H. bacteriophora* 12 (25%) and *S. feltiae* 113 (27%). With 15,300 IJs, the highest mortality was 40% by *H. bacteriophora* 12 and 39% by *S. feltiae* 113. The lowest mortality was 14 and 21% by *S. affine* 47 with 7,650 and 15,300 IJs, respectively.

Discussion

A member of Tephritidae family, Mediterranean fruit fly is considered one of the most important and cosmopolitan pests of the fruits throughout the world (Zucchi, 2001) and it is also a key pest of citrus and many other fruit species in Turkey. Entomopathogenic nematodes are beneficial biological control agents that adapted to soil and can be safely used against numerous pests (Kaya & Gaugler, 1993; Koppenhöfer, 2007).

This study showed the potential of EPNs as biopesticides against *C. capitata.* All tested EPN isolates caused mortality, however, the third instar larvae were more susceptible to infection than pupae under both laboratory and climate room conditions. This result is similar with the studies of Gazit et al. (2000), Karagöz et al. (2009), Rohde et al. (2012), Nouh & Hussein (2014) and Minas et al. (2016).

It was emphasized by Yee & Lacey (2003) that the higher susceptibility of larvae to EPNs may be related with the higher release of CO_2 at that stage, attracting the nematodes. Also, large natural openings and the poorly sclerotized integument of the larva enable EPNs infect more easily. In contrast, the lower susceptibility of pupae could be due to the small spiracle opening size for nematode penetration (Toledo et al., 2005). The closure of all-natural openings owing largely to sclerotization and thickening of the cuticle into puparial cells is a main reason of pupal resistance (Grewal et al., 2005). It was also confirmed by Chergui et al. (2019), who used a Turkish *S. feltiae* isolate and observed that the final instar larvae and newly formed pupae of *C. capitata* were more susceptible to EPNs than old pupae under laboratory conditions.

Steinernema feltiae and *H. bacteriophora* species gave better performance than *S. carpocapsae* and *S. affine* in the present study and this was similar to the findings of Glazer (1992) that *S. carpocapsae* isolate All was less effective than *H. bacteriophora* isolated HP88 against different lepidopteran pests. Karagöz et al. (2009) found that mortality was higher with *S. feltiae* (78%) compared to *S. carpocapsae* (56%) on the last instar larvae of *C. capitata*. Rohde et al. (2012) observed that *Heterorhabditis* sp. isolate PI, *Heterorhabditis* sp. isolated JPM4, *H. bacteriophora* isolate HP88 and *S. feltiae* were the best against pupal stage of *C. capitata* (ranging from 35 to 44% mortality). Mokrini et al. (2020) found high larval mortality (80%) by *S. feltiae* isolate SF-MOR9 under the laboratory conditions.

Based on our findings, *H. bacteriophora* was able to cause higher pupal mortality than *S. carpocapsae* and *S. affine*. This can be explained by dorsal tooth of *Heterorhabditis* species used to penetrate the host cuticle more easily (Griffin et al., 2005). Mortality of larvae and pupae caused by all nematode isolates increased as the dose increased. Studies conducted by Nouh & Hussein (2014) and Minas et al. (2016) gave similar results with higher mortality with higher IJs doses. Kepenekçi & Susurluk (2006) used two Turkish isolates against *C. capitata* pupae and obtained higher mortality with 100 IJs/insect compared to 50 IJs/insect.

Similar trends in the efficacy of the EPN isolates were observed in the bioassays performed under different conditions. The findings of the present study demonstrated that EPNs, specifically *S. feltiae* isolate 113 and *H. bacteriophora* isolate 12, can effectively control *C. capitata.* In conclusion, implementing these biopesticides as part of an IPM program of *C. capitata* might successful reduce pest damage to acceptable levels. The findings of this study need to be further evaluated by testing the most effective isolates under field conditions.

Acknowledgments

This study was financially supported by University Scientific Research Project, BAP-Project Number: FBA-2019-2865.

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Türk. entomol. derg., 2021, 45 (3): 397-402
DOI: http://dx.doi.org/10.16970/entoted.987592

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Leptobium thracicum sp. n. (Coleoptera: Staphylinidae: Paederinae) from Thrace Region of Turkey and additional records for the genus[1]

Türkiye'nin Trakya Bölgesi'nden *Leptobium thracicum* sp. n. türü (Coleoptera: Staphylinidae: Paederinae) ve bu cinse ait ek kayıtlar

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Abstract

The genus *Leptobium* Casey, 1905 (Coleoptera: Staphylinidae: Paederinae) is represented in the Palearctic Region by 73 species and two subspecies. As a result of field survey in the north and southern Turkey between 2008 and 2021, a new species of the genus *Leptobium* is described and illustrated from Tekirdağ Province (Ganos Mountains, northwestern Turkey), and distinguished from related congeners: *Leptobium thracicum* sp. n. Additional records of five species of *Leptobium* from Turkey are presented. The genus is now represented in Turkey by 20 species with 15 of them endemic.

Keywords: Fauna, *Leptobium*, new species, Paederinae, Turkey

Öz

Leptobium Casey (Coleoptera: Staphylinidae: Paederinae) cinsi Palearktik Bölgede 73 tür ve iki alttür ile temsil edilen bir cinstir. Bu yayında, kuzey ve güney Türkiye'de 2008-2021 yılları arasında yapılan arazi çalışmaları sonucunda, *Leptobium* Casey cinsinden *Leptobium thracicum* sp. n. türü kuzeybatı Türkiye'de bulunan Tekirdağ İli'nden (Ganos Dağları) tanımlanarak şekillendirilmiş ve yakın türlerden farklılıkları gösterilmiştir. Ayrıca, Türkiye'deki beş *Leptobium* türüne ait faunistik kayıtlar sunulmuştur. Böylece, bu cins şu anda Türkiye'de 20 türle temsil edilmekte olup bunların 15'i bu ülkeye endemiktir.

Anahtar sözcükler: Fauna, *Leptobium*, yeni tür, Paederinae, Türkiye

[1] This study was partly supported by the Scientific and Technological Research Council of Turkey. Grant Project No: 119Z253.
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Received (Alınış): 26.08.2021 Accepted (Kabul ediliş): 09.09.2021 Published Online (Çevrimiçi Yayın Tarihi): 10.09.2021

Introduction

According to recent contributions, the genus *Leptobium* Casey, 1905 (Coleoptera: Staphylinidae: Paederinae) currently includes 73 species and two subspecies from the Palearctic region (Schülke & Smetana, 2015; Anlaş, 2017; Assing, 2017; Anlaş & Gusarov, 2020; Anlaş & Örgel, 2020). The vast majority of the species are known from the Mediterranean region. Regarding its *Leptobium* fauna, Turkey is the most diverse territory in the Mediterranean region. In 2017, this genus was represented in Turkey by 17 species and 12 of which are endemic to Turkey (Anlaş, 2017). Since then, three additional species have been described from Turkey, and *Leptobium tauricum* Gusarov, 1988 was removed from the list of Turkish *Leptobium* (Anlaş & Gusarov, 2020; Anlaş & Örgel, 2020).

In this paper, a new species is described from Thrace, in northwestern Turkey, and some new and additional faunistic records for the genus are reported from Anatolia. The genus is now represented in Turkey by 20 species of which 15 are endemic.

Materials and Methods

The study examined material collected between 2008 and 2021 in the north and southern Turkey. These specimens were collected using aspirator and sifter methods. Morphological examination was made with a Stemi 508 microscope (Zeiss, Oberkochen, Germany). Zeiss Axiocam ERC5s digital camera was used for photographs of the habitus and the aedeagus of the new species. All of the photographs were edited using Helicon Focus 6.0 (Kharkiv, Ukraine) and Corel Draw X7 software (Ottawa, Canada). Nomenclature of the terminalia and the style of the description follows Assing (2005).

Head length was measured from the anterior margin of the frons to the posterior margin of the head, pronotum length along the median line and elytral length at the suture from the apex of the scutellum to the posterior margin of the elytra. The length of the median lobe of the aedeagus was measured from the apex of the ventral process to the base of the capsule. The material examined is deposited in Alaşehir Zoological Museum, Manisa, Turkey (AZMM).

RESULTS

Faunistic Records

Leptobium assingi Bordoni, 1994

Material. Gaziantep: Islahiye, Kabaklar, 37°01'56" N, 36°33'44" E, 840 m, 22.III.2008, ♂, 2♀♀, leg. Yağmur.

Distribution. *Leptobium assingi* is distributed in Antalya, Gaziantep, Hatay, Kahramanmaraş and Osmaniye Provinces in southern Anatolia (Assing, 2005, 2017; Anlaş, 2017).

Leptobium bicarinatum Assing, 2005

Material. Gaziantep: Oğuzeli, Çaybaşı 2 km S, 37°00'16" N, 37°31'03" E, 808 m, 15.IV- 23.VIII.2017, ♂, ♀, leg. Yağmur, pitfall traps.

Distribution. This species is known from northern Syria and from Gaziantep, Hatay, Kilis Provinces in southern Turkey (Assing, 2005; Anlaş, 2012, 2017).

Leptobium carinatum Assing, 2005

Material. Antalya: Kaş, Yeşilköy, Fırnaz Bay, 36°15'16" N, 29°22'01" E, 120 m, 26.II.2015, ♂, leg. Kunt, Elmalı, 36°34'37" N, 29°55'49" E, 1070 m, 12.III.2016, ♀, leg. Kunt.

Distribution. *Leptobium carinatum* is known from Antalya and Muğla Provinces in southwestern Turkey (Assing, 2005, 2017; Anlaş, 2017).

***Leptobium gracile* (Gravenhorst, 1802)**

Material Amasya: Taşova, Borabay Gölü 9 km E, 40°49'48" N, 36°04'42" E, 1700 m, 17.VI.2020, ♂, 2♀♀, leg. Örgel & Kacar; Hamamözü, Yemişen 1 km N, 40°45'50" N, 35°08'11" E, 1300 m, 27.IV.2021, 2♀♀, leg. Anlaş, Kacar & Çelik; Hamamözü, Tekçam 1 km NE, 40°42'50" N, 35°06'12" E, 1562 m, 27.IV.2021, ♂, leg. Anlaş, Kacar & Çelik; Hamamözü, Tekçam 1 km SE, 40°42'50" N, 35°06'12" E, 1562 m, 27.IV.2021, 2♂♂, 6♀♀, leg. Anlaş, Kacar & Çelik. Bartın: Ulus, Uluyayla, 41°32'24" N, 32°48'16" E, 1000 m, 07.IV.2021, 2♂♂, 3♀♀, leg. Örgel, Kacar & Çelik. Bilecik: Bozhöyük, Cihangazi 4 km E, 39°44'17" N, 29°52'32" E, 1376 m, 03.IV.2021, ♂, 3♀♀, leg. Örgel, Kacar & Çelik. Bolu: Mudurnu, Abant Gölü 1 km N, 40°35'30" N, 31°16'40" E, 1430 m, 04.IV.2021, 2♂♂, ♀, leg. Örgel, Kacar & Çelik; Mudurnu, Karapınarkavağı 2 km SW, 40°32'19" N, 31°07'57" E, 1300 m, 04.IV.2021, ♂, leg. Örgel, Kacar & Çelik. Bursa: Mustafakemalpaşa, Çakallar 3 km W, 39°47'07" N, 28°29'35" E, 710 m, 22.III.2021, 2♂♂, leg. Örgel & Kacar; Gemlik, Şükriye 1 km NW, 40°20'24" N, 29°16'01" E, 570 m, 20.III.2021, ♂, ♀, leg. Örgel & Kacar; Keles, Gelemiç 2 km NW, 39°52'51" N, 29°17'05" E, 375 m, 21.III.2021, 5♂♂, 8♀♀, leg. Örgel & Kacar. Çorum: Osmancık, Danişment 3 km S, 41°04'36" N, 34°55'48" E,1490 m, 01.V.2021, 3♂♂, 3♀♀, leg. Örgel, Kacar & Çelik; Osmancık, Danişment 3 km E, 41°04'37" N, 34°56'04" E,1461 m, 01.V.2021, ♂, leg. Örgel, Kacar & Çelik. Karabük: Keltepe Kayak Merkezi, 41°30'30" N, 32°27'59" E, 1474 m, 06.IV.2021, 2♂♂, 5♀♀, leg. Örgel, Kacar & Çelik, Eskipazar, Sallar 1 km SW, 40°57'41" N, 32°45'44" E, 1277 m, 06.IV.2021, 11♂♂, 13♀♀, leg. Örgel, Kacar & Çelik. Kastamonu: Tosya, Kilkuyu, 40°56'17" N, 34°13'40" E, 1660 m, 10.IV.2017, 3♂♂, 2♀♀, leg. Örgel & Yaman; Tosya, Kayaönü 6 km NE, 40°55'54" N, 34°12'16" E, 1665 m, 08.V.2021, ♀, leg. Örgel, Kacar & Çelik. Sinop: Sinop Üniversitesi, Fen-Edebiyat Fakültesi Kampüsü, 07.II.2014, 2♂♂, leg. Koç. Tekirdağ: Malkara, Karacahalil, 40°48'09" N, 26°56'51" E, 185 m, 11.IV.2021, 11♂♂, 10♀♀, leg. Örgel, Kacar & Çelik; Şarköy, Güzelköy 5 km SE, 40°46'26" N, 27°15'41" E, 658 m, 12.IV.2021, ♂, 4♀♀, leg. Örgel, Kacar & Çelik, Şarköy, Güzelköy 4 km S, 40°46'43" N, 27°17'43" E, 754 m, 04.VI.2021, ♂, ♀, leg. Kacar & Çelik. Zonguldak: Ayvatlar 2 km SW, 41°17'54" N, 31°49'19" E, 364 m, 08.IV.2021, ♂, 2♀♀, leg. Örgel, Kacar & Çelik.

Distribution. *Leptobium gracile* is known from Canary Islands to Central Asia (Assing, 2005; Schülke & Smetana, 2015; Anlaş, 2017).

***Leptobium mutabile* Assing, 2005**

Material. Antalya: Kaş, Yeşilköy, Fırnaz Bay, 36°15'16" N, 29°22'01" E, 120 m, 26.II.2015, ♂, leg. Kunt, Kumluca, Sarnıçtepe, 11.III.2016, ♂, leg. Kunt.

Distribution. *Leptobium mutabile* is confined to Antalya Province of southwestern Anatolia (Assing, 2005; Anlaş, 2017).

Description of a new species

***Leptobium thracicum* sp. n. (Figures 1a-f)**

Type material.

Holotype: Turkey, ♂, TR. Tekirdağ, Şarköy, Uçmakdere 3 km SE 40°48'55" N, 27°20'43" E, 662 m, 04.VI.2021, leg. Kacar & Çelik; Holotypus ♂, *Leptobium thracicum* sp. n. det. S. Anlaş & S. Örgel 2021 (AZMM).

Paratypes: 5♂♂, 5♀♀, same data as holotype (AZMM).

Description. Habitus as in Figure 1a. Forebody as in Figure 1b. Body 6.4-6.6 mm long. Coloration: head, pronotum, and abdominal segments III-VI black; elytra and abdominal segments VIII-X rufous, tergite VII distinctly bicoloured, with black anterior and rufous posterior portions; appendages reddish yellow; antennae reddish and legs yellowish brown.

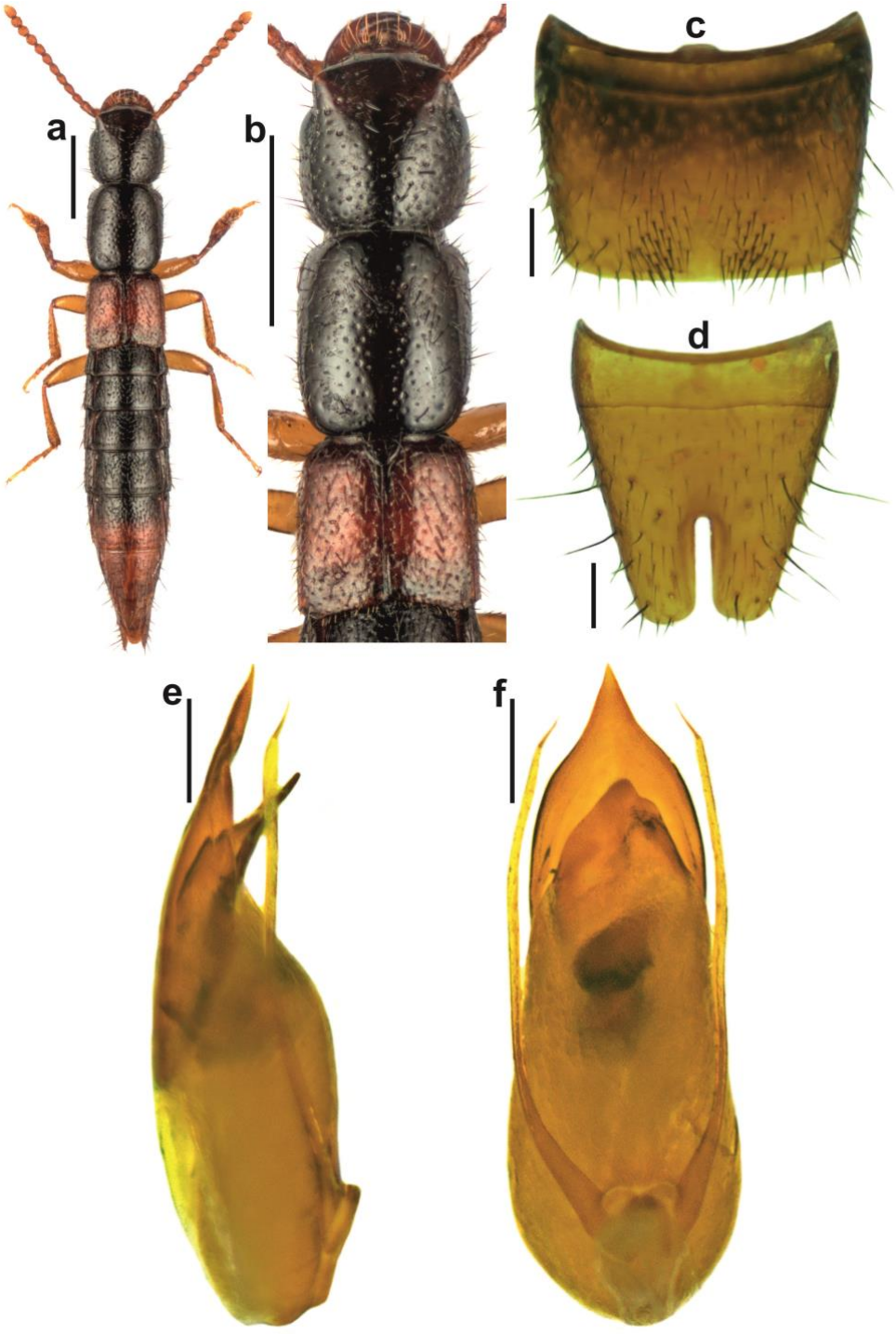

Figure 1. *Leptobium thracicum* sp. n. a) habitus; b) forebody; c) male sternite VII; d) male sternite VIII; e) aedeagus in lateral view; and f) aedeagus in ventral view. Scale bars: 1 mm (a-b) and 0.2 mm (c-f).

Head weakly oblong, 1.05-1.10 times as long as wide (Figures 1a-b); eyes average size (Figure 1a), weakly projecting from lateral outline of head, approximately half the length of postocular region in dorsal view; punctuation coarse and sparse, irregularly spaced, slightly denser and finer in lateral than that in central dorsal areas; interstices between punctures on dorsal surface about 2-2.5 times as wide as nearest puncture; microsculpture absent; pubescence black and sparse. Antennae approximately 1.6-1.7 mm long; antennomere III distinctly longer than II, approximately 1.5 times as long as II, antennomeres IV-VI longer than wide, antennomeres VII-X about as wide as long; antennomere XI almost twice as long as wide.

Pronotum oblong, approximately 1.3 times as long as wide and as wide as head (Figures 1a-b); lateral margins subparallel in dorsal view; dorsal surface without distinct impressions; punctuation similar to that of head, but sparser; microsculpture absent; pubescence blackish and sparse.

Elytra slightly wider than pronotum, approximately 1.05 times as wide as pronotum (Figures 1a-b) and shorter than pronotum, at suture about 0.75 times as long as pronotum; punctuation not granulose, finer and denser than that on pronotum and head; microsculpture absent; pubescence reddish, more distinct than that on head and pronotum. Hind wings reduced. Tarsi relatively long (Figure 1a).

Abdomen wider than elytra, approximately 1.1 times as wide as elytra (Figure 1a), widest at segment VI; punctuation moderately dense and fine; microsculpture present, composed of dense and fine transverse meshes and striae; pubescence moderately dense; posterior margin of tergite VII without palisade fringe.

♂: Sternite VII weakly modified, in posterior median area with cluster of sparse and darkened setae, without concave posterior margin and weakly depressed in posterior median area (Figure 1c); sternite VIII with posterior incision, not reaching middle of the sternite, slightly more than one third the length of sternite (Figure 1d); aedeagus approximately 1.25-1.30 mm long (Figures 1e-f).

♀: Sternite VII in posterior median area indistinctly concave, without modified pubescence and median impression; sternite VIII without posterior incision and modified pubescence.

Comparative notes. This new species is distinguished from all its congeners by the different morphology of the aedeagus, especially by the shape of the ventral process of the aedeagus. Based on the similar morphology of the male primary and secondary sexual characters, the new species is closely related to *Leptobium graecum* Gusarov, 1988, *Leptobium melanocephalum* (Reiche & Saulcy, 1856) and *L. assingi*. The new species is readily distinguished from these species as follows [For description and illustrations of *L. graecum*, *L. melanocephalum* and *L. assingi* see Gusarov (1988), Assing (2005), Anlaş (2017)].

Leptobium graecum is known from “Graecia” (without specified locality), and the Oros Elikonas in Voiotiai in southern Greece (Gusarov, 1988; Assing, 2005). The new species is distinguished from *L. graecum* by a longer antennomere III (in *L. graecum*, antennae with antennomere II as long as or slightly shorter than III), longer pronotum (in *L. graecum*, pronotum 1.15-1.18 times as long as wide), different shape of the male sternite VII (in *L. graecum*, sternite VII with broadly concave posterior margin, in posterior median area with small triangular depression without pubescence, on either side of this depression with a cluster of a few dark setae), and different morphology of the aedeagus, especially the differently shaped ventral process.

Leptobium melanocephalum is distributed in the surroundings of Athens in southern Greece (Assing, 2005). The new species is distinguished from *L. melanocephalum* by different coloration of body (in *L. melanocephalum*, head blackish brown to black, abdominal segments III-VI black, pronotum, elytra, and abdominal segments VII-X rufous, appendages yellowish brown), longer antennomere III (in *L. melanocephalum*, antennae with antennomere II as long as or only slightly shorter than III), different shape of the male sternite VII (in *L. melanocephalum*, sternite VII with broadly concave posterior margin, in posterior median area with small depressed area of triangular shape), and different morphology of the aedeagus.

Leptobium assingi is only known from southern Anatolia (Antalya, Gaziantep, Hatay, Kahramanmaraş, Osmaniye Provinces). The new species is distinguished from *L. assingi* by longer antennae (in *L. assingi,* antennae on average 1.1-1.3 mm long), longer antennomere III (in *L. assingi,* antennae with antennomere III approximately as long as II or slightly longer), slightly smaller eyes, sparser punctuation of whole body, slightly larger aedeagus (in *L. assingi,* aedeagus approximately 1 mm long), and differently shaped dorsal plate and ventral process of the aedeagus.

Etymology. The name is derived from Thrace in the northwestern Turkey, where the type locality is situated.

Distribution and bionomics. The new species was collected only from the type locality in southwestern slope of Ganos (Işıklar) Mountains, Tekirdağ Province, northwestern Turkey. Specimens were sifted from leaf litter under *Quercus petraea* (Mattuschka) Liebl. subsp. iberica (Steven ex Bieb.) Krassilin at an altitude of 662 m.

Acknowledgments

We are most grateful to Enes Zafer Kacar, Mutlu Çelik, Ersen A. Yağmur, (Manisa) and Kadir B. Kunt (Eskişehir) for making their staphylinid collections available for examination. This study was partly supported by the Scientific and Technological Research Council of Turkey (TUBITAK, project number 119Z253).

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10. Bir eser yayıma kabul edildiğinde, telif hakları formu tüm yazarlar tarafından imzalanıp dergimize gönderilmeden yayımlanmaz. Sorumlu yazara eserin pdf formatında hazırlanmış hali e-posta ile gönderilir, ayrıca telif ücreti ödenmez. Yayımlanan eserlere ait şekil dışı sorumluluklar yazarlarına aittir.

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