ISPEC Tarım Bilimleri Dergisi, 10(1): 183-199, 2026
ISPEC Journal of Agricultural Sciences, 10(1): 183-189, 2026
DOI: https://doi.org/10.5281/zenodo.18465472

Diversity and DNA Barcoding of Syrphidae (Diptera) Species in Cotton Agroecosystems of the Harran Plain, Türkiye

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Abstract
The family Syrphidae is among the most important insect groups due to its significant contributions to pollination and its role as natural enemies. In cotton agroecosystems, syrphids play an important predatory role by contributing to the biological control of aphids and other soft-bodied pests. The material examined in this study was collected from the Harran Plain, Şanlıurfa, between August and October, 2025. In this study, Syrphidae specimens were sampled using 200 sweep-net samplings in the Harran Plain, one of Türkiye's major cotton-growing regions. Collected specimens were initially identified to species level based on morphological characteristics by expert taxonomists. Subsequently, total genomic DNA was extracted from each specimen, and the mitochondrial cytochrome oxidase subunit I (COI) gene region was amplified using universal primers through PCR. The obtained sequences were compared with reference sequences in GenBank using BLAST. As a result, a total of 10 species belonging to 7 genera within two subfamilies of Syrphidae (Diptera) were identified in cotton cultivation areas of the Harran Plain. The recorded species within the subfamily Eristalinae were *Eristalinus megacephalus*, *Eristalis arbustorum*, *Eristalis tenax*, and *Syritta pipiens*, whereas those within the subfamily Syrphinae included *Eupeodes corollae*, *Eupeodes luniger*, *Melanostoma mellina*, *Paragus bicolor*, *Sphaerophoria rueppellii*, and *Sphaerophoria scripta*. In this study, carried out in the Harran Plain, particularly in cotton-growing areas, *Eristalinus megacephalus* and *Eupeodes luniger* were recorded for the first time from Şanlıurfa Province. These findings indicate that natural biological control agents are actively present in cotton fields of the Harran Plain, suggesting a promising potential for sustainable pest management in the region.

Research Article

Article History
Received :25.11.2025
Accepted :10.01.2026

Keywords
DNA barcoding
biological control
cotton
harran plain
Syrphidae

Citation: Kara, H., 2026. Diversity and DNA Barcoding of Syrphidae (Diptera) Species in Cotton Agroecosystems of the Harran Plain, Türkiye. *ISPEC Journal of Agricultural Sciences,* 10(1): 183-199.
DOI: https://doi.org/10.5281/zenodo.18465472

1. Introduction

The order Diptera represents one of the largest and most diverse insect orders, comprising species with significant ecological and economic importance. Within Diptera, the family Syrphidae (hoverflies) belongs to the superfamily Syrphoidea of the suborder Brachycera and includes insects that play key roles as pollinators and natural enemies in both agricultural and natural ecosystems. The family is divided into four subfamilies-Eristalinae, Microdontinae, Pipizinae, and Syrphinae-based on morphological and biological characteristics (Van Veen, 2010). Globally, Syrphidae comprises more than 250 genera and approximately 6.300 species, making it one of the most species-rich families within Diptera. The diversity of Syrphidae varies markedly among biogeographical regions. The Palearctic region hosts the highest number of species, followed by the Nearctic, Oriental, Afrotropical, and Australasian regions (Smith and Vockeroth, 1980; Peck, 1988; Thompson and Rotheray, 1998; Courtney et al., 2009; Ssymank and Nielsen, 2012; Mengual et al., 2014, 2022). Adult syrphids are easily recognized by the presence of the vena spuria, a diagnostic wing character unique to the family, as well as by their often conspicuous coloration and flower-visiting behavior (Speight, 2020a). Syrphid research in Türkiye has a relatively long history, beginning with studies conducted by foreign researchers in the early twentieth century (Bischof, 1902; Sack, 1932). However, comprehensive investigations of the Türkiye syrphid fauna have intensified mainly in recent decades. Early catalogues of the Palearctic region reported only 54 syrphid species from Türkiye (Peck, 1988). Subsequent faunistic surveys and taxonomic revisions substantially increased this number, with 314 species listed in the first comprehensive national checklist (Sarıbıyık, 2014). More recent studies have further expanded the known fauna, and the number of syrphid species recorded from Türkiye has now exceeded 350 (Yetkin, 2006; Reemer et al., 2009; Özkan and Çalışkan, 2011; Pehlivan and Atakan, 2014; Gözüaçık and Özgen, 2018; Vujic et al., 2020; Uzun Yiğit et al., 2023). Despite these advances, Syrphid diversity in Türkiye remains incompletely documented, particularly at the regional level, indicating a continued need for detailed faunistic and taxonomic studies. The Harran Plain is one of Türkiye's most important cotton (*Gossypium hirsutum* L.) growing areas, accounting for approximately a quarter of the country's cotton production (Aydogdu et al., 2018). Cotton cultivation in the region rapidly expanded after the mid-1990s with the completion of irrigation infrastructure under the Southeastern Anatolia Project (GAP) (Bilgen, 2018). Favorable climatic conditions, large irrigable agricultural areas, and high support premiums given to cotton production have enabled cotton to become the dominant crop in the Harran Plain (Daccache et al., 2014; Cetin, 2020). With these characteristics, the Harran Plain is a strategic region both in terms of national cotton production and in terms of evaluating the effects of irrigation-based agricultural policies. Given the intensive cotton cultivation in the Harran Plain, understanding the diversity and ecological role of natural enemies such as Syrphidae is of particular importance. Syrphidae are effective biological control agents against cotton pests in cotton fields, particularly through their larval predation on aphids such as *Aphis gossypii*. Syrphid larvae are aphidophagous and constitute an important component of the natural enemy complex associated with the cotton aphid, contributing to the natural regulation of pest populations (Joshi and Ballal, 2013; Singh et al., 2014; Joshi et al., 2023; Singh et al., 2023; Singh, 2024). DNA barcoding using a 650-bp fragment of the mitochondrial cytochrome c oxidase I (COI) gene has been widely adopted as a universal tool for species identification in Metazoa (Hebert et al., 2003; Hebert et al., 2004). In Syrphidae, COI barcodes facilitate accurate identification of morphologically similar species and enable the association of unknown immature stages, such as eggs and larvae, with adult specimens. This approach significantly enhances taxonomic resolution and supports faunistic and biodiversity studies of hoverflies (Vujić et al., 2007; Marcos-

García et al., 2007). Therefore, the present study aims to assess the diversity and species composition of Syrphidae in cotton-growing areas of the Harran Plain using an integrative approach based on morphological identification carried out by expert taxonomists and COI-based DNA barcoding, with the broader objective of contributing to the understanding of their potential role in biological control and sustainable pest management in cotton agroecosystems.

2. Material and Methods

2.1. Study area, sampling, and morphological ıdentification

The material examined in this study was collected from the Harran Plain between August and October 2025, following a sampling design intended to represent the general cotton agroecosystem of the region (Figure 1). Sampling was carried out in cotton-producing areas by selecting fields of at least 10 decares in size and spaced at approximately 10 km intervals to ensure spatial representativeness across the study area. A total of 200 sweep-net samples were obtained from these fields using standard sweep-netting techniques. The captured specimens were killed in ethyl acetate killing jars, after which larger specimens were pinned and smaller specimens were mounted on small triangular paper points. All specimens were subsequently placed in collection boxes as standard museum material and identified using the relevant literature. Species identification was carried out using a stereomicroscope. Identifications were performed by Assoc. Prof. Dr. Mustafa Cemal Çiftçi (Department of Entomology, Plant Protection Division, Faculty of Agriculture, Siirt University) and Fatma Erbek (M.Sc.).

Figure 1. Sampling of Syrphidae species was conducted in cotton production areas located in the Harran Plain, Şanlıurfa, Türkiye (Google Maps)

2.2. DNA extraction and PCR analysis

DNA isolation of the morphologically identified Syrphidae species was performed using the Invitrogen DNA PureLink™ Genomic DNA Mini Kit. For DNA extraction, insect legs were detached and placed in a -86 °C ultra-low temperature (ULT) freezer to increase tissue brittleness, after which they were mechanically disrupted using metal forceps. Total genomic DNA was then extracted following the manufacturer's protocol. The quantity and quality of the extracted DNA were assessed using a Nano-400A spectrophotometer and agarose gel electrophoresis, respectively. The mitochondrial cytochrome c oxidase subunit I (COI) gene region was amplified by PCR using the universal primers LCO1490-F (5′-GGTCAACAAATCATAAAGATATTGG-3′) and HCO2198-R (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′) (Folmer et al., 1994). The PCR protocol consisted of an initial pre-denaturation step at 95 °C for 5 min, followed by 35 amplification

cycles comprising denaturation at 95 °C for 30 s, annealing at 50 °C for 30 s, and extension at 72 °C for 60 s. A final extension was carried out at 72 °C for 10 min. The amplified products were resolved by electrophoresis on a 1% agarose gel prepared in 1× TAE buffer and run at 100 V for approximately 60 min. A 100 bp DNA ladder was used as a molecular size marker. After electrophoresis, the gel was stained with ethidium bromide for 20 min, and DNA bands were visualized under UV illumination. The PCR products of the COI region were subsequently submitted for Sanger sequencing by a commercial sequencing service. The resulting sequence data were edited and analyzed using MEGA12 software for phylogenetic analyses (Kumar et al., 2024).

3. Results and Discussion

3.1. Syrphidae species ıdentified in cotton agroecosystems of the harran plain

In this study, a total of 10 species belonging to 7 genera within two subfamilies of the Syrphidae (Diptera) were identified in cotton cultivation areas of the Harran Plain. The recorded species comprised the genera *Eristalinus*, *Eristalis*, and *Syritta* within the subfamily Eristalinae, and *Eupeodes*, *Melanostoma*, *Paragus*, and *Sphaerophoria* within the subfamily Syrphinae (Table 1).

Table 1. Syrphidae species identified in cotton production areas of the Harran Plain.

Order	Family	Subfamily	Species
Diptera	Syrphidae	Eristalinae	*Eristalinus megacephalus*
			Eristalis arbustorum
			Eristalis tenax
			Syritta pipiens
		Syrphinae	*Eupeodes corollae*
			Eupeodes luniger
			Melanostoma mellina
			Paragus bicolor
			Sphaerophoria rueppellii
			Sphaerophoria scripta

Subfamily: Eristalinae

Genus: *Eristalinus* Rondani, 1845

***Eristalinus megacephalus* (Rossi, 1794)**

Examined

Harran Plain, Şanlıurfa (N37° 07.214' E38° 49.587').

Distribution in Türkiye

Eristalinus megacephalus has been recorded from different regions of Türkiye. The species was previously reported from Muğla Province (Aktas and Sarıbıyık, 1996). Additional material confirms its presence in southeastern Anatolia, with a male specimen collected from Diyarbakır (Ergani, Demirciler) on 27 July 2007 from a rice field. These records indicate that *E. megacephalus* is distributed across both western and southeastern parts of Türkiye, occurring in agricultural habitats (Gözüaçık and Özgen, 2018).

Global distribution

This species has an exceptionally wide geographic distribution. It occurs throughout the circum-Mediterranean region, including coastal areas of Europe, North Africa (including Egypt), Anatolia, the Middle East, and the islands of Crete, Corsica, Cyprus, Malta, and Sicily, and extends southwards through the Afrotropical region to South Africa (Van Steenis et al., 2019; Speight, 2020a). In Asia, its range spans from Türkiye through Iraq and Iran to India, Nepal, and other regions (Dyola et al., 2024). In Europe, the species is confined to the Mediterranean basin (Speight, 2020a), and to our knowledge, there are no records from areas with a continental climate. However, with the recent recording of *Eristalinus taeniops* in Serbia (Vujić et al., 2021), all European species of the genus *Eristalinus* are now known to occur within the Serbian fauna.

Ecological role

Eristalinus megacephalus plays an ecological role primarily as a pollinator in natural and semi-natural ecosystems. Adults frequently visit flowers to feed on nectar and

pollen and may contribute to the pollination of a variety of flowering plants, particularly in Mediterranean and subtropical regions. The larvae are saprophagous and typically develop in stagnant or organically enriched aquatic habitats, where they participate in the breakdown of decaying organic matter and contribute to nutrient recycling. Through their larval feeding activity, *E. megacephalus* may also play a role in the regulation of microbial communities in eutrophic water bodies. Given its wide geographic distribution and ecological plasticity, this species can be considered a functional component of pollination networks and detritus-based aquatic food webs. (Azo'o Ela et al., 2022)

Genus: *Eristalis* Latreille, 1804

***Eristalis arbustorum* (Linnaeus, 1758)**

Examined

Harran Plain, Şanlıurfa (N37° 05.815' E38° 50.179').

Distribution in Türkiye

This species has been recorded from a wide range of regions in Türkiye, including Adana, Adıyaman, Afyonkarahisar, the coastal zone of the Mediterranean Region, Aksaray, Ankara, Antalya, Artvin, Bartın, Bolu, Burdur, Çankırı, the Çukurova Region, Denizli, Diyarbakır, the Eastern Mediterranean Region, Edirne, Elazığ, Erzincan, Erzurum, Eskişehir, Hatay, Iğdır, Isparta, İzmir, Kahramanmaraş, Karabük, Kars, Kastamonu, Kayseri, Konya, Mardin, the Marmara Region, Mersin, Muğla, Nevşehir, Niğde, Ordu, Osmaniye, Sinop, Sivas, Şanlıurfa, Tokat, Zonguldak, Çanakkale, and Siirt (Toth, 2013; Pehlivan and Atakan, 2014; Sarıbıyık, 2014; Gözüaçık and Özgen, 2018; Kök and Kasap, 2021; Erbek, 2023).

Global distribution

The species is widely distributed from Iceland through Fennoscandia and the Faroe Islands, extending southwards to the Iberian Peninsula, the Mediterranean region, Madeira, and the Canary Islands. Its range further includes North Africa and coastal regions of Africa down to South Africa and Mauritius. From Ireland, it extends eastwards across much of Europe, including the European parts of Russia, and continues through Siberia, the Ural Mountains, and the Pacific coast, reaching Iran, Azerbaijan, Japan, China, and Formosa (Speight, 2020a; Dousti, 2023).

Ecological role

Eristalis arbustorum (Diptera: Syrphidae) is a flower-visiting hoverfly that occupies an ecological niche similar to that of bees, owing to its comparable morphology, foraging behavior, and reliance on shared floral resources. By visiting the same flowers as both solitary and social bees, *E. arbustorum* may interact with pollinator-associated parasites present on floral surfaces. Recent evidence suggests that flower flies can harbor and carry bee-associated pathogens, indicating their potential role in the ecology and epidemiology of multi-host pollinator parasites. In particular, *E. arbustorum* has been identified as a species that defecates on flowers, a behavior that may facilitate the mechanical transmission of fecal-orally transmitted parasites such as *Crithidia bombi* at floral hubs. Through this indirect role, *E. arbustorum* may contribute to parasite persistence and redistribution within pollinator communities, thereby influencing pollinator health and disease dynamics at the community level rather than acting solely as a pollination service provider (Davis et al., 2021).

***Eristalis tenax (*Linnaeus, 1758)**

Examined

Harran Plain, Şanlıurfa (N37° 04.301' E38° 51.444').

Distribution of Türkiye

Kayseri (Bischof, 1902); İzmir, Ankara (Tuatay et al., 1972); Adana, Antalya, Mersin and Antakya (Özgür, 1986); Erzurum (Hayat and Alaoglu, 1990); Kayseri, Kahramanmaras and Kastamonu (Sarıbıyık and Aktas, 1996); Bartın, Bolu, Karabük, Kastamonu, Sinop, Zonguldak (Sarıbıyık, 1999); Tokat (Candemir and Kara, 2003) and Kayseri (Karabıyık, 2005) and Şanlıurfa (Yetkin, 2006).

Global distribution

Eristalis tenax exhibits a broad geographic distribution across the Palearctic region and adjacent areas. The species has been recorded from East Asia, including Japan and the Far East, extending westwards through Central Asia, with occurrences in Turkmenistan, Kazakhstan and Kyrgyzstan. Its range further encompasses the Caucasus and neighbouring

countries, such as Armenia, Azerbaijan, Georgia and Iran. In Europe, *E. tenax* is widely distributed, occurring in northern regions around the Baltic Sea, Scandinavia and the Kola Peninsula in northern Russia, as well as in southern and southeastern Europe, including Spain, Italy, Portugal (Madeira and the Azores), the Canary Islands, Greece and the countries of the former Yugoslavia (Soós and Papp, 1988; Sarıbıyık, 1998; Dousti, 2023).

Ecological role

Eristalis tenax plays an important ecological role through its contributions to pollination and organic matter decomposition across a wide range of ecosystems. Adult individuals feed on floral nectar and function as efficient pollinators, particularly under unfavourable ecological conditions where other pollinator groups are scarce. Their pollination efficiency is enhanced by numerous palynophilic hairs on the body surface, which facilitate pollen adhesion and retention for extended periods, enabling effective pollen transfer between flowers. Owing to its high mobility and pronounced migratory behaviour, *E. tenax* also acts as a long-distance pollen disperser, contributing to plant gene flow at the landscape scale. The species has been reported as a principal pollinator in high-mountain and alpine environments and plays a significant role in urban ecosystems and agricultural landscapes by providing consistent pollination services. In contrast, the larvae of *E. tenax* are saprophagous and develop in stagnant, organic-rich water bodies, where they feed on decomposing organic material and contribute to nutrient cycling. Through these combined life-history functions, *E. tenax* represents an ecologically versatile species that supports ecosystem functioning, particularly in marginal, disturbed and environmentally challenging habitats (Pérez-Bañón et al., 2013)

Genus: *Syritta* Lepeletier & Serville, 1828

***Syritta pipiens* (Linnaeus, 1758)**

Examined

Harran Plain, Şanlıurfa (N37° 00.056' E38° 51.580').

Distribution in Türkiye

In Türkiye, *Syritta pipiens* is widely distributed and has been recorded from numerous provinces across different geographical regions. The species has been reported from Adana, Afyonkarahisar, Aksaray, Ankara, Antalya, Aydın, Bartın, Bolu, Çanakkale, Çankırı, Denizli, Eskişehir, Erzurum, Hatay, Isparta, İzmir, Kahramanmaraş, Konya, Karabük, Kastamonu, Kayseri, Mersin, Muğla, Osmaniye, Sinop, Tokat and Zonguldak (Sarıbıyık, 2014), as well as from Şanlıurfa (Yetkin, 2006) and Siirt (Erbek, 2023). These records indicate that *S. pipiens* is widespread throughout Türkiye and occurs in a variety of habitats, ranging from coastal and lowland areas to inland and montane regions.

Global distribution

Syritta pipiens is a cosmopolitan hoverfly species with a broad geographic distribution across multiple biogeographical regions. It is widely known from large parts of the Palearctic region and has been recorded in North Africa, most of North America, South America and eastern regions beyond its native range. The species' extensive distribution reflects its high ecological adaptability and tolerance to a wide range of climatic and environmental conditions, allowing it to successfully colonise both natural and anthropogenic habitats (Speight, 2020a).

Ecological role

Syritta pipiens is a widespread syrphid species whose ecological role is primarily associated with the decomposition of organic matter and pollination in terrestrial ecosystems. The larvae develop in a variety of decaying organic substrates, including rotting plant material and other semi-liquid organic matter, contributing to nutrient recycling processes, although their biology remains poorly documented. Adults are commonly found in gardens, meadows and agricultural fields, where they visit flowers and potentially act as pollinators. Recent forensic findings indicate that *S. pipiens* may also behave as an opportunistic coloniser of decomposing animal remains under specific environmental conditions, such as confined or low-temperature environments, suggesting a previously unrecognised ecological plasticity. Its occasional association with carrion expands

the known functional scope of the species and highlights its potential relevance in forensic entomology, particularly for improving minimum post-mortem interval estimations when combined with more typical necrophagous insect assemblages (Magni et al., 2013).

Subfamily: Syrphinae

Genus: *Eupeodes* Osten-Sacken, 1877

***Eupeodes corollae* (Fabricius, 1794)**

Examined

Harran Plain, Şanlıurfa (N37° 00.802' E38° 58.830').

Distribution in Türkiye

This species has been recorded from several provinces in Türkiye, including Adana, Afyon, Aksaray, Ankara, Antalya, Bartın, Bolu, Burdur, Çankırı, Eskişehir (Sarıbıyık, 2014), Çanakkale, Diyarbakır, Edirne, Elazığ, Gaziantep, Hatay, İzmir, Kahramanmaraş, Kastamonu, Kilis, Manisa, Mersin, Muğla, Tekirdağ, and Osmaniye (Hayat and Tezcan, 2023). It has also been reported along the coastal belt of the Mediterranean Region (Özgür, 1986), in Ordu (Tozlu and Alaoğlu, 1994), Artvin, Erzurum, Erzincan, Iğdır, and Kars (Özbek et al., 1995), Niğde and Adana (Ulusoy et al., 1999), Erzurum (Tozlu et al., 2002), Kayseri (Karabıyık, 2005), Şanlıurfa (Yetkin, 2006), Kırıkkale, Mardin, Siirt, Adıyaman, Tokat, Aksaray, Konya, Kayseri, and the Marmara Region (Özkan and Çalışkan, 2011), as well as Edirne, Denizli, and Sivas (Toth, 2013).

Global distribution

The species is distributed in Iceland, Fennoscandia, and the Faroe Islands (Jensen, 2001); the Iberian Peninsula, the Mediterranean region, Madeira, the Canary Islands, and North Africa; South Africa, Mauritius, Ireland, many parts of Europe, the European regions of Russia, Siberia from the Ural Mountains to the Pacific coast, as well as Japan, China, and Formosa (Speight, 2020a).

Ecological role

Eupeodes corollae plays a key ecological role by providing both pollination and biological control services in natural and agricultural ecosystems. Adults frequently visit flowers for nectar and pollen, thereby acting as effective pollinators that enhance plant reproduction, seed set, and crop yield. In contrast, the larval stage functions as an active predator, feeding primarily on aphids and occasionally on small lepidopteran larvae, which contributes to the natural regulation of pest populations. Owing to its polyphagous feeding behavior, wide geographic distribution, and dual functional role, *E. corollae* is considered an important beneficial insect that supports ecosystem stability, biodiversity conservation, and sustainable pest management in agroecosystems (Jiang et al., 2023).

***Eupeodes luniger* (Meigen, 1822)**

Examined

Harran Plain, Şanlıurfa (N37° 00.802' E38° 58.830').

Distribution in Türkiye

Eupeodes luniger is a widely distributed hoverfly species in Türkiye, with records reported from various regions including Central Anatolia, the Aegean, the Mediterranean, the Marmara, and parts of the Black Sea region. Published faunistic studies indicate its presence in provinces such as Adana, Ankara, Bolu, Çanakkale, Çankırı, Denizli, Edirne, İzmir, Karabük, Kastamonu, Mersin, Muğla, and Van. The species is typically associated with open habitats, agricultural landscapes, orchards, and semi-natural areas, reflecting its ecological plasticity and strong dispersal ability. Although several Syrphidae surveys have been conducted in southeastern Türkiye, there are currently no published records confirming the occurrence of *E. luniger* in Şanlıurfa province. This absence may reflect insufficient sampling rather than true absence, given the species' migratory behavior and broad ecological tolerance. Further targeted surveys are therefore needed to clarify its distribution in southeastern Anatolia (Gözüaçık and Özgen, 2018).

Global distribution

Eupeodes luniger is a widely distributed Palearctic species, occurring from Fennoscandia southwards to the Iberian Peninsula, the Mediterranean region, Madeira, and North Africa. Its range extends west–east

from Ireland across most of Europe to the European parts of Russia and Asia Minor, including Türkiye. In northern and eastern Asia, the species is recorded from Siberia, spanning from the Ural Mountains to the Pacific coast, including the Kuril Islands, and further east to Japan, with additional records from northern India. *E. luniger* is a highly migratory hoverfly, and seasonal immigration from southern regions contributes substantially to population increases in many parts of Europe during the summer (Speight, 2020b).

Ecological role

Eupeodes luniger is an important ecological component of agricultural and semi-natural ecosystems due to its role in aphid population regulation. Its larvae are active aphidophagous predators that feed on a wide range of aphid species, including economically important pests such as Myzus persicae. Females lay eggs near aphid colonies, which increases larval survival and predation efficiency. By naturally suppressing aphid populations, *E. luniger* contributes to biological control without negatively affecting environmental balance. Additionally, adults visit flowers for nectar and pollen, supporting pollination services in agroecosystems (Jamali et al., 2018).

Genus: *Melanostoma* Schiner, 1860

***Melanostoma mellina* (Linnaeus, 1758)**

Examined

Harran Plain, Şanlıurfa (N36° 54.877' E38° 54.753').

Distribution in Türkiye

The species has been recorded across a wide range of regions in Türkiye, including Adana, Adıyaman, the coastal belt of the Mediterranean Region, Aksaray, Ankara, Antalya, Artvin, Aydın, Bolu, Çanakkale, Çankırı, the Çukurova Region, Denizli, Diyarbakır, the Eastern Mediterranean Region, Edirne, Erzincan, Erzurum, Eskişehir, Hatay, Iğdır, Isparta, İzmir, Kahramanmaraş, Karabük, Kars, Kastamonu, Kayseri, Konya, Mersin, Muğla, Niğde, Ordu, Sinop, Sivas, Şanlıurfa, Siirt, Tokat, and Zonguldak (Toth, 2013; Pehlivan and Atakan, 2014; Sarıbıyık, 2014; Gözüaçık and Özgen, 2018; Erbek, 2023).

Global distribution

The species has a broad Holarctic distribution, ranging from Iceland and Fennoscandia southwards to the Iberian Peninsula, the Mediterranean Basin, and North Africa. It is also widely distributed across much of Europe, extending eastwards from Ireland through European Russia, Siberia, and from the Ural Mountains to the Pacific coast. In North America, its range spans from Alaska to Quebec and southwards to Washington State (Speight, 2020a).

Ecological role

In Mediterranean ecosystems, this species plays an important ecological role primarily as a pollinator and as a contributor to ecosystem functioning in shrubland and maquis habitats, where hoverflies are often abundant. Adults visit a wide range of flowering plants, facilitating pollination and supporting plant reproduction, while their sensitivity to habitat structure and environmental quality makes them valuable bioindicators of ecosystem integrity. Through these functions, the species contributes to the maintenance of plant–insect interactions and overall biodiversity, particularly in semi-natural and heterogeneous landscapes, although its ecological role is increasingly threatened by anthropogenic pressures affecting Syrphidae diversity (Plume et al., 2025).

Genus: *Paragus* Latreille, 1804

***Paragus bicolor* (Fabricius, 1794)**

Examined

Harran Plain, Şanlıurfa (N36° 50.489' E39° 04.067').

Distribution in Türkiye

The species has been recorded from several provinces across Türkiye, including Aksaray, Ankara, Antalya, Bolu, Çankırı, Erzurum, Isparta, Konya, Kahramanmaraş, Kırşehir, Kastamonu, Kayseri, Muğla, Nevşehir, Niğde, Tokat, and Zonguldak (Sarıbıyık, 2014), as well as Şanlıurfa, Adıyaman, and Diyarbakır (Gözüaçık and Özgen, 2018), Adana (Pehlivan and Atakan, 2014), and Siirt (Erbek, 2023).

Global distribution

The species is widely distributed across Europe, North Africa, and northern Asia (Sack, 1932). It has been recorded in England (Coe,

1953), Hungary (Toth, 1982, 1984, 1985), Portugal, Spain, Italy, Bulgaria, Russia, Ukraine, Georgia, Azerbaijan, Armenia, Kazakhstan, Turkmenistan, and eastern and western Siberia (Peck, 1988), as well as in Iran (Sadeghi, 2003), southern Sweden, and Denmark; however, it is considered extinct in Belgium. Its range extends across the Mediterranean Basin and North Africa and, from France eastwards, through central and southern Europe to Mongolia and Afghanistan (Speight, 2020a).

Ecological role

The genus *Paragus* (Diptera: Syrphidae) plays a significant ecological role in both natural and agricultural ecosystems by contributing simultaneously to biological pest control and pollination services. As with many hover flies, adult *Paragus* species rely on floral resources such as nectar and pollen for energy, thereby participating in the pollination of a wide range of wild and cultivated plants. More importantly from an agroecological perspective, the larval stages of *Paragus* species are voracious predators of aphids and other soft-bodied insects, which are among the most damaging pests in agricultural and horticultural systems. Through this predator–prey interaction, *Paragus* larvae help regulate aphid populations, reduce plant damage, and limit the spread of aphid-transmitted plant viruses. By linking plants, herbivorous pests, and their natural enemies, *Paragus* species function as key components of tri-trophic interactions, enhancing ecosystem stability and supporting sustainable pest management. Their dual role as pollinators in the adult stage and predators in the larval stage highlights the ecological importance of *Paragus* as a multifunctional taxon capable of delivering multiple ecosystem services within a single life cycle (Singh, 2025).

Genus: *Sphaerophoria* Lepeletier & Serville, 1828

***Sphaerophoria rueppellii* (Wiedemann, 1830)**

Examined

Harran Plain, Şanlıurfa (N36° 51.643' E39° 00.424').

Distribution in Türkiye

The species has been recorded from numerous localities across Türkiye, including Adana, Ankara, Antalya, Bolu, Çanakkale, Çankırı, Hatay, Isparta, İzmir, Kastamonu, Konya, Kayseri, Mersin, Muğla, Osmaniye, Tokat, Zonguldak, and Aksaray, as well as the Çukurova and Marmara regions and Erzurum (Hayat, 1989). Additional records include Ordu (Tozlu and Alaoğlu, 1994), Tokat (Candemir and Kara, 2003), Kayseri (Karabıyık, 2005), Şanlıurfa (Yetkin, 2006), Kırıkkale (Düzgüneş et al., 1982), Adıyaman (Gözüaçık and Özgen, 2018), Siirt (Erbek, 2023), and Düzce (Toth, 2013).

Global distribution

The species is distributed from France across central and southern Europe, extending northwards to Sweden and Denmark and southwards through the Mediterranean region to North Africa. Its range also includes parts of Central and Western Asia, such as Mongolia, Iran, and Afghanistan, and it has additionally been recorded from the American continent (Speight, 2020a).

Ecological role

Sphaerophoria rueppellii plays an important ecological role in Mediterranean natural and agricultural ecosystems by contributing to both biological pest control and ecosystem stability. The larval stages of this species are effective predators of aphids and other soft-bodied Hemiptera, thereby helping to regulate pest populations that cause significant economic damage to crops. Through this predatory activity, *S. rueppellii* reduces the need for chemical insecticides and supports environmentally sustainable pest management strategies. As a native species within the Mediterranean region, its use in biological control minimizes ecological risks associated with non-native introductions, such as disruption of trophic interactions, competitive displacement, or invasive behavior. Adult *S. rueppellii* individuals feed on nectar and pollen and may contribute to pollination, linking plant resources with higher trophic levels. By integrating predation and, potentially, pollination within its life cycle, *S. rueppellii* functions as a key component of tri-

trophic interactions in agroecosystems and represents a valuable, ecologically safe biological control agent for sustainable agriculture (Lorite et al., 2025).

***Sphaerophoria scripta* (Linnaeus, 1758)**

Examined

Harran Plain, Şanlıurfa (N36° 57.782' E38° 59.189').

Distribution in Türkiye

The species has been recorded from a wide range of provinces across Türkiye, including Adana, Afyonkarahisar, Ankara, Antalya, Artvin, Bolu, Bursa, Çankırı, Eskişehir, Erzurum, Hatay, Isparta, İzmir, Kahramanmaraş, Konya, Karabük, Kastamonu, Kayseri, Mersin, Muğla, Osmaniye, Sinop, Trabzon, Tokat, Zonguldak, Aksaray, Adıyaman, Çanakkale, Nevşehir, Denizli, Sivas, İstanbul, Siirt, Bartın, Diyarbakır, Kırklareli, Şanlıurfa, Tekirdağ, Ordu, and Niğde. In addition, its presence has been reported from broader regions such as the Marmara Region and the Çukurova region (Özkan and Çalışkan, 2011; Sarıbıyık, 2014; Gözüaçık and Özgen, 2018; Toth, 2013; Kök and Kasap, 2021; Erbek, 2023).

Global distribution

This species exhibits a broad geographical distribution ranging from Fennoscandia to the Mediterranean region, including the Canary Islands, the Azores, and North Africa. Its range further extends to southwestern Greenland, Iceland, and Ireland. Additionally, it is widely distributed across Eurasia and along the Pacific coasts of Asia, with records from the Kashmir and Nepal regions. Toward the south, its distribution reaches the Oriental region, extending as far as Sri Lanka and Australia (Speight, 2020a).

Ecological role

Sphaerophoria scripta is a widespread and ecologically important syrphid species that contributes substantially to ecosystem functioning in agricultural and semi-natural landscapes. Its larvae are obligate predators of soft-bodied hemipteran pests, particularly aphids, and thus play a key role in the natural regulation of pest populations in a wide range of crops, including cereals, vegetables, and vineyards. Through this predatory activity, *S. scripta* supports biological control services and can contribute to reducing reliance on chemical insecticides. Adult flies feed on nectar and pollen and frequently visit flowering plants, providing complementary pollination services to both cultivated and wild flora, especially in field margins, inter-row vegetation, and semi-natural habitats. Owing to its relatively high dispersal capacity and adaptability to open and heterogeneous landscapes, *S. scripta* responds positively to landscape complexity, floral resource availability, and the presence of semi-natural habitats. Consequently, this species is often considered an indicator of functional landscape connectivity and ecological quality, highlighting its importance for sustainable agricultural systems and biodiversity-friendly vineyard management (Madureira et al., 2023). In a comprehensive study conducted by Yetkin (2006) throughout Şanlıurfa Province, a greater number of species, including some of those recorded in the present study, were reported. In that study, carried out in the Harran Plain, particularly in cotton-growing areas, *Eristalinus megacephalus* and *Eupeodes luniger* were reported as first records for Şanlıurfa Province.

3.2. DNA barcoding

DNA barcoding has emerged as a powerful and reliable tool for the rapid and accurate identification of insect species, particularly in contexts where expert taxonomists are unavailable and traditional morphological approaches are time-consuming or insufficient (Rupali et al., 2024). This molecular approach is especially valuable for the identification of immature life stages and for resolving taxonomic ambiguities among morphologically similar or cryptic species (Vuataz et al., 2024). Recent studies have demonstrated that DNA barcoding not only accelerates insect species discovery and biodiversity documentation but also enhances taxonomic resolution through well-curated reference libraries, enabling precise species delimitation across diverse insect groups (Yao et al., 2025). The sequence information of Syrphidae species collected from the cotton

agroecosystem of the Harran Plain is summarized in Table 2. For each specimen, the table includes the top species match obtained from BLAST analyses along with the corresponding similarity percentages, NCBI accession numbers of both the reference sequences and the sequences generated in this study, sampling codes, and sequence lengths (base pairs). In addition, taxonomic information at the family and subfamily levels is provided. These data were used to confirm species identification and to support subsequent phylogenetic analyses.

Table 2. Sequence information obtained from Syrphidae species collected from the cotton agroecosystem of the Harran Plain

Top species match	Similarity (%), Accession Number (NCBI)	Code in samplings/ Accession Number (NCBI)	Sequence length of samplings (base pairs)	Family	Subfamily
Eristalinus megacephalus	99.04, (OR960492.1)	PX919769	617	Syrphidae	Eristalinae
Eristalis tenax	99.66, (PV290322.1)	PX919768	561		
Syritta pipiens	99.82, (PP331807.1)	PX919764	596		
Eupeodes luniger	99.25, (ON421570.1)	PX919767	534		Syrphinae
Sphaerophoria scripta	99.17, (MW077837.1)	PX919765	372		
Sphaerophoria rueppellii	98.31, (PV875959.1)	PX919766	593		

DNA sequence data were successfully obtained for six of the ten species collected from cotton agroecosystems. Sequence data could not be generated for the remaining four species due to limited sample availability, low total genomic DNA quality, and clean-read errors encountered during the processing of outsourced sequencing services. The phylogenetic tree was constructed using the General Time Reversible (GTR) model. Bootstrap support values (1.000 replicates) are shown at the nodes, and branch lengths represent genetic distances inferred under the GTR model (Figure 2). Species are grouped according to their respective subfamilies, Syrphinae and Eristalinae. The Maximum Likelihood phylogenetic analysis based on the COI gene clearly resolved the species of the family Syrphidae into two well-supported clades corresponding to the subfamilies Eristalinae and Syrphinae. The topology of the tree is consistent with the current taxonomic classification of the family. Within the Eristalinae clade, *Eristalis tenax*, *Eristalinus megacephalus*, and *Syritta pipiens* clustered together, forming a monophyletic group supported by relatively high bootstrap values (81-88). In particular, the close phylogenetic relationship between *E. tenax* and *E. megacephalus* indicates a high level of genetic similarity in their COI sequences. The Syrphinae clade comprised *Eupeodes luniger*, *Sphaerophoria scripta*, and *Sphaerophoria rueppellii* and was also recovered as a monophyletic group. The sister-group relationship between *S. scripta* and *S. rueppellii* was strongly supported by a bootstrap value of 100, indicating a very close evolutionary relationship between these two species. The outgroup taxon, *Cephalops aeneus*, was clearly separated from the Syrphidae clade, confirming the correct rooting of the phylogenetic tree. The scale bar (0.02) indicates low to moderate genetic divergence among the analyzed taxa and supports the suitability of the COI gene as an effective molecular marker for species identification and phylogenetic inference within Syrphidae.

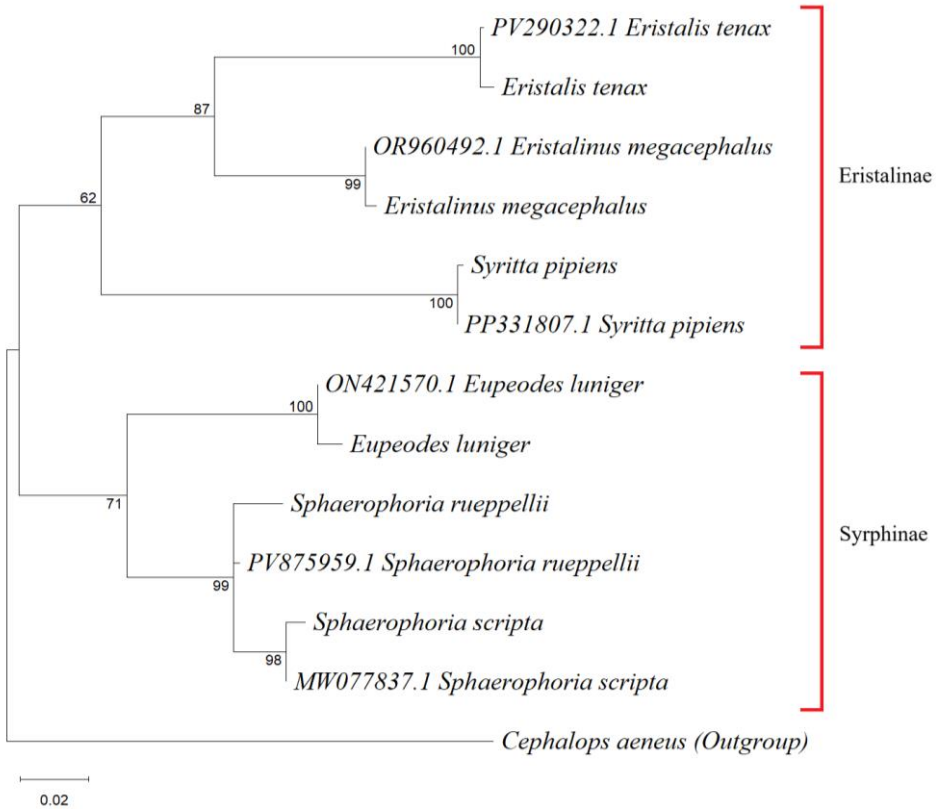

Figure 2. Maximum Likelihood (ML) phylogenetic tree based on COI gene sequences of Syrphidae species from the Harran Plain. Genetic distances were estimated using the General Time Reversible (GTR) model, and bootstrap values (1.000 replicates) are shown at the nodes. Reference sequences showing the highest similarity to the obtained sequences based on BLAST analyses were retrieved from GenBank and included in the phylogenetic analysis

4. Conclusions

This study provides an integrative assessment of Syrphidae diversity in cotton-growing areas of the Harran Plain based on morphological identification carried out by expert taxonomists and DNA barcoding. A total of 10 species belonging to 7 genera within two subfamilies were identified, highlighting the diversity of syrphid fauna associated with cotton agroecosystems in the region. Notably, *Eristalinus megacephalus* and *Eupeodes luniger* are reported as first records for Şanlıurfa Province, contributing new and valuable data to the regional Syrphidae fauna. The diversity of syrphid species observed in this study, which are recognized as both natural enemies and pollinators, suggests their potential ecological importance in cotton agroecosystems, particularly with respect to biological control and pollination services. These findings emphasize the value of integrative taxonomic approaches for documenting beneficial insect diversity and provide a baseline for future ecological and pest management studies in cotton production systems.

Funding

This study was supported by Van Yüzüncü Yıl University Scientific Research Projects Coordination Unit. Project number: FYL-2024-11285.

Ethical Committee Approval

This study did not involve human or animal subjects; therefore, ethical approval was not required.

Acknowledgment

The author thanks Assoc. Prof. Dr. Mustafa Cemal Çiftçi (Department of Plant Protection, Faculty of Agriculture, Siirt University) and Fatma Erbek (M.Sc.) for their valuable contributions to species identification.

References

Aktas, M., Saribiyik, S., 1996. Contribution to the Syrphidae fauna of Türkiye (Diptera: Syrphidae) II. Milesiinae. *Journal of the Institute of Science and Technology*, 9: 15-27.

Aydogdu, M.H., Karli, B., Parlakci, D.H., Sevinc, G., Eren, M.E., Kucuk, N., 2018. Economic analysis of agricultural water usage efficiency in the GAP-Harran plain: cotton production sampling, Sanliurfa-Türkiye. *International Journal of Advances in Agriculture Sciences*, 3(12): 12-19.

Azo'o Ela, M., Bissou Wangbara, B., Jordaens, K., 2022. Diversity of flower-visiting hoverflies (Diptera: Syrphidae) on ground cover vegetation from the market-gardening area of Meskine (Far-North Region, Cameroon). *African Journal of Ecology*, 60(1): 58-66.

Bilgen, A., 2018. Türkiye's southeastern anatolia project (GAP): a qualitative review of the literature. *British journal of Middle Eastern studies*, 47(4): 652-671.

Bischof, J., 1902. Engebnisse einer naturwissenschaftlichen Reise Zum Erdschios- Dagh (Kleinasten). Annales des k.k. *Naturhistorischen Hofmuseums*, 20: 1-9.

Candemir, D., Kara, K., 2003. Syrphidae (Diptera) fauna in Tokat provinces (Türkiye). *Turkiye Entomoloji Dergisi,* 27(2): 95-105.

Cetin, M., 2020. Agricultural water use. (Ed: Harmancioglu, N.B., Altinbilek, D.), World Water Resources. Springer, Cham.

Coe, R.L., 1953. Syrphidae handbooks for the identification of British Insects, *Royal Entomological Society*, 10(1): 1-98.

Courtney, G.W., Pape, T., Skevington, J.H., Sinclair, B.J., 2009. Biodiversity of Diptera. In: Insect Biodiversity: Science and Society. (Ed: Foottit R.G., Adler P.H.). Blackwell Publishing, Oxford.

Daccache, A., Ciurana, J.S., Rodriguez Diaz, J.A., Knox, J.W., 2014. Water and energy footprint of irrigated agriculture in the Mediterranean region. *Environmental Research Letters,* 9(12): 124014.

Davis, A.E., Deutsch, K.R., Torres, A.M., Mata Loya, M.J., Cody, L.V., Harte, E., Sossa, D., Munis, P.A., Ng, W.H., McArt, S.H., 2021. Eristalis flower flies can be mechanical vectors of the common trypanosome bee parasite, Crithidia bombi. *Scientific Reports*, 11(1): 15852.

Dousti, A.F., 2023. An updated checklist of Syrphidae (Diptera, Brachycera) from Iran, *Journal of Insect Biodiversity and Systematics*, 9(2): 207-264.

Düzgüneş, Z., Toros, S., Kılınçer, N., Kovancı, B., 1982. Ankara ilinde bulunan Aphidoidea türlerinin parazit ve predatörleri. T.C. Tarım ve Orman Bakanlığı Ziraai Mücadele ve Ziraai Karantina Genel Müdürlüğü, Ankara.

Dyola, U., Pandey, A., Sheikh, T., Subedi, P., Hassan, M.A., 2024. An updated checklist of the hoverflies of Nepal (Diptera: Syrphidae). *Journal of Insect Biodiversity and Systematics*, 10(3): 485-533.

Erbek, F., 2023. Siirt province Şirvan District Syrphidae family (Diptera) Fauna and Its Systematics. Ms Thesis, The Graduate School of Natural and Applied Sciences of Siirt University, Siirt.

Gözüaçık, C., Özgen, İ., 2018. Contribution to the Syrphidae (Diptera) fauna in the cereal fields of Souteasthern Anatolia, Türkiye. *Munis Entomology & Zoology*, 13: 522-526.

Hayat, R., 1989. Faunistic and systematic studies on Syrphidae (Diptera) species in the Erzurum region. Ms Thesis, The Graduate School of Natural and Applied Sciences of Ataturk University, Erzurum.

Hayat, R., Alaoglu, Ö. 1990. Fauna of Syrphidae (Diptera) in the vicinity of Erzurum (I), Syrphinae. *Türkiye Entomoloji Dergisi,* 14(3): 173-182.

Hayat, R., Tezcan, S., 2023. New locality records for some hoverflies (Diptera: Syrphidae) of Türkiye. *Munis Entomology & Zoology*, 18: 2078-2092.

Hebert, P.D.N., Cywinska, A., Ball, S.L., DeWaard, J.R., 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 270(1512): 313-321.

Hebert, P.D.N., Stoeckle, M.Y., Zemlak, T.S., Francis, C.M., 2004. Identification of birds through DNA barcodes. *PLoS biology*, 2(10): e312.

Jamali, R.A., Memom, N., Shah, M.A., Khan, K., Ansari, A., 2018. Prevalence of aphidophagous hoverflies (Syrphidae: Syrphinae) in relation to their prey, green aphids (*Myzus persicae*) on brassica (*Brassica rapa* oliefera) in Dadu. *JAPS: Journal of Animal & Plant Sciences*, 28(5): 1447-1456.

Jiang, S., Li, H., Wu, K., 2023. Predation and control effect of *Eupeodes corollae* Fabricius (Diptera: Syrphidae) on leguminous plant aphids. *Agronomy*, 13(7): 1739.

Joshi, S., Ballal, C.R., 2013. Syrphid predators for biological control of aphids. *Journal of Biological Control*, 27(3): 11-170.

Joshi, S.S., David, K.J., Sachin, K., 2023. Syrphid predators (Diptera: Brachycera). (Ed: Omkar, G.M.) In Insect Predators in Pest Managemen, CRC Press.

Karabıyık, N., 2005. Faunistic studies on the species of Syrphidae (Diptera) in Kayseri province. Ms Thesis, The Graduate School of Natural and Applied Sciences of Ataturk University, Erzurum.

Kök, Ş., Kasap, İ., 2021. Predatory Syrphids (Diptera: Syrphidae) of aphid pests on pome and stonefruit orchards in the Çanakkale. *Türkiye Biyolojik Mücadele Dergisi*, 12(2): 130-140.

Kumar, S., Stecher, G., Suleski, M., Sanderford, M., Sharma, S., Tamura, K., 2024. MEGA12: Molecular Evolutionary Genetic Analysis version 12 for adaptive and green computing. *Molecular Biology and Evolution*, 41(12): msae263.

Lorite, P., Rico-Porras, J.M., Palomeque, T., Marcos-García, M.Á., Cabral-de-Mello, D.C., Mora, P., 2025. Cytogenetic and Molecular Characterization of *Sphaerophoria rueppellii* (Diptera, Syrphidae). *Insects*, 16(6): 604.

Madureira, M., Rodrigues, I., Villa, M., Pereira, J.A., 2023. The surrounding landscape shapes the abundance of *Sphaerophoria scripta* and *Melanostoma mellinum* (Diptera: Syrphidae) in Portuguese vineyards. *Agricultural and Forest Entomology*, 25(2): 206-216.

Magni, P.A., Pérez-Bañón, C., Borrini, M., Dadour, I.R., 2013. *Syritta pipiens* (Diptera: Syrphidae), a new species associated with human cadavers. *Forensic Science International*, 231(1-3): 19-23.

Marcos-Garcia, M.A., Vujic, A, Mengual, X., 2007. Revision of the Iberian species of the genus *Merodon* (Diptera: Syrphidae). *European Journal of Entomology*, 104: 531–572.

Mengual, X., Mayer, C., Burt, T.O., Moran, K.M., Dietz, L., Nottebrock, G., Thomas, P., Andrew, D.Y., Marie, V., Brasseur, S.K., Scott, K., Claudia, E., Sander, B., Martin, H., Kurt, J., Gil, F.G.M., Gunilla, S., Wouter, S., Ralph, S.P., Jeffrey, H.S., Skevington, J.H., 2022. Systematics and evolution of predatory flower flies (Diptera: Syrphidae) based on exoncapture sequencing. *Systematic Entomology*, 48(2): 250-277.

Mengual, X., Stahls, G., Rojo, S., 2014. Phylogenetic relationships and taxonomic ranking of pipizine flower flies (Diptera: Syrphidae) with implications for the evolution of aphidophagy. *Cladistics*, 31(5): 491-508.

Özbek, H., Güçlü, S., Hayat, R., 1995. Kuzeydoğu tarım bölgesinde taş çekirdekli meyve agaçlarında bulunan fitofag ve predatör böcek türleri, *Turkish Journal of Agriculture and Forestry*, 20: 267-282.

Özgür, A.F., 1986. Akdeniz Bölgesi kıyı şeridi Syrphidae (Dipt.) faunası. II. Alt familya, Cheilosiinae, Spheginineae, Pelecocerinae, Milesiinae, Chrysotoxinae, Volucellinae. *Çukurova Üniversitesi Ziraat Fakültesi Dergisi*, 2(3): 67-81.

Özkan, M., Çalışkan, H., 2011. An investigation on Syrphinae fauna in Eskisehir (Diptera: Syrphidae). *Kastamonu Eğitim Dergisi*, 19(2): 601-608.

Peck, L.V., 1988. Family Syrpidae, Catalogue of Palaearctic Diptera. (Eds: Soos, A. Papp, L. Syrphidae-Conopidae, Entomological Society of America, Elsevier, Amsterdam.

Pehlivan S., Atakan E., 2014. Syrphidae (Diptera) species in Balcalı region of Adana (Türkiye). *Turkish Journal of Biological Control*, 5(1): 53-66.

Pérez-Bañón, C., Hurtado, P., García-Gras, E., Rojo, S., 2013. SEM studies on immature stages of the drone flies (Diptera, Syrphidae): *Eristalis similis* (Fallen, 1817) and *Eristalis tenax* (Linnaeus, 1758). *Microscopy Research and Technique*, 76(8): 853-861.

Plume, L., Maestracci, P.Y., Gibernau, M., 2025. Insight Into the Diversity of Flower-Visiting Hoverflies (Diptera: Syrphidae) in Shrubland Maquis Around Ajaccio (South-West Corsica, France). *Journal of Applied Entomology*, 149(6): 855-865.

Reemer, M., Renema, W., Van Steenis, W., Zeegers, T., Barendregt, A., Smit, J.T., Van Veen, M.P., Van Steenis, J., Van Der Leij, L.J.J.M., 2009. De Nederlandse zweefvliegen. Nederlandse Fauna 8. Nationaal Natuurhistorisch Museum Naturalis, Leiden.

Rupali, J.S., Madhuri, E.V., Reddy, G.R., Akhil, V.S., Ramya, N., Sagar, D., 2024. DNA Barcoding: Accelerating Insect Species Discovery and Biodiversity Documentation. *Journal of Advances in Biology & Biotechnology*, 27(7): 709-720.

Sack, P., 1932. Syrphidae In Lindler. *Die Fliegen der Palaeartis chen Region, Stuttgart*, 4(31): 451.

Sadeghi, H., 2003. A check list of granian hover flies (Diptera: Syrphidae), *II. International symposium on the syrphidae biodiversty and conservation*, Conference Proceedings Book, 16-19 June, Spain.

Sarıbıyık, S., 1998. Morphology, Ecology, Fauna and Systematics of Syrphidae Family for Ilgaz and Işık Mountains (Diptera: Syrphidae). PhD Thesis, The Graduate School of Natural and Applied Sciences of Ankara University, Ankara.

Sarıbıyık, S., 1999. Batı Karadeniz Bölgesi Syrphinae Faunası (Diptera: Syrphidae). *Kastamonu Egitim Dergisi*, 7(1): 185-194.

Sarıbıyık, S., 2014. Check list of Turkish flower flies (Diptera: Syrphidae), *Munis Entomology & Zoology*, 9(1): 570-585.

Sarıbıyık, S., Aktas, M., 1996. Contribution to the Syrphidae fauna of Türkiye (Diptera, Syrphidae) (I) Syrphinae. *Journal of the Institute of Science and Technology of Gazi University*, 9(1): 1-13.

Singh, G., Singh, N.P., Singh, R., 2014. Food plants of a major agricultural pest *Aphis gossypii* Glover (Homoptera: Aphididae) from India: an updated checklist. *Interntional Journalof Life Sciences Biotechnology & Pharma Research*, 3(2): 1-26.

Singh, R., 2024. Checklist of arthropod predators of the cotton aphid, Aphis (Aphis) gossypii Glover, 1877 (Insecta: Hemiptera: Aphididae), and their distribution in India. *Journal of Fauna Biodiversity*, 1(2): 20-68.

Singh, R., 2025. Tritrophic Associations of Aphidophagous Hover Flies *Melanostoma*, *Paragus* and *Sphaerophoria* Species (Syrphinae: Syrphidae: Diptera) in Different States and Territories of India. *International Journal on Biological Sciences*.16(1): 31-55.

Singh, R., Verma, A.K., Singh, G., 2023. Food Plant Catalogue of Indian Aphids (Homoptera: Aphididae). Asian Biological Research Foundation, Prayagraj, India; Nature Light Publications, Pune.

Smith, K.G.V., Vockeroth, J.R., 1980. Family Syrphidae. In: Catalogue of the Diptera of the Afrotropical Region. (Ed: Crosskey R.V.). British Museum, London, 488-510.

Soós, A., Papp, L., 1988. Catalogue of Palaearctic Diptera. Syrphidae–Conopidae. Akadémiai Kiadó, Budapest.

Speight, M.C.D., 2020a. StN key for the identification of the genera of European Syrphidae (Diptera) 2020. Syrph the Net, the database of European Syrphidae. Syrph the Net publications, Dublin.

Speight, M.C.D., 2020b. Species accounts of European Syrphidae, 2024. Syrph the Net, the database of European Syrphidae (Diptera). Syrph the Net publications, Dublin.

Ssymank, A., Nielsen, T.R., 2012. Hoverflies (Diptera, Syrphidae) from Kirgizia (regions Chuy, Naryn and Issyk- Kul) with description of two new species, *Platycheirus nigritarsis* sp.n. and *Platycheirus kirgizorum* sp.n. *Norwegian Journal of Entomology*, 59: 31–39.

Thompson, F.C., Rotheray, G., 1998. Family Syrphidae. In: Contributions to a Manual of Palaearctic Diptera (with special reference to flies of economic importance). (Eds: Papp L., Darvas B.). Higher Brachycera. Science Herald, Budapest.

Toth, S., 1982. A bakony termeszettudomanyi museum zengölegygyujtemenye (Diptera: Syrphidae) I. *Bakonyi termes, Museum, zirc*, 1: 139-154.

Toth, S., 1984. A bakony hegysegben folya zengölegy-kutatas (Diptera: Syrphidae). *Kilencedik bakony-kutato anket bakonyi termes. Museum, zirc*, 55: 66.

Toth, S., 1985. A barcsi borokas zengölegy faunaja (Diptera: Syrphidae), II. Duantuli dolgozatok termes, *Scrozat, Hungaria*, 5: 151-162.

Toth, S., 2013. Additional data to the hoverfly fauna of Türkiye (Diptera: Syrphidae), *Natura Somogyiensis*, 23: 239-254.

Tozlu, G., Alaoglu, O., 1994. Ordu ili mısır (*Zea mays* L.) ekim alanlarında bulunan fitofag ve predatör böcek türleri. *Türkiye Entomoloji Dergisi*, 18(1): 51-64.

Tozlu, G., Gültekin, L., Hayat, R., Güçlü, S., 2002. Erzurum'da lahanada zarar yapan böcek türlerinin doğal düsmanları üzerinde çalışmalar. *Türkiye 5. Biyolojik Mücadele Kongresi*, Kongre Bildiriler Kitabı, Erzurum, 4-7 September, 227-235.

Tuatay, N., Kalkandelen, A., Aysev, N., 1972. Nebat Koruma Müzesi Böcek Katalogu (1961-1971). T.C. Tarım Bakanlıgı Ziraai Mücadele ve Zirai Karantina Genel Müdürlügü Yayınları, Ankara.

Ulusoy, M.R., Vatansever, G., Uygun, N., 1999. The cherry pests, their natural enemies and observations on some important species in Ulukışla (Niğde) and Pozantı (Adana) province of Turkey. *Türkiye Entomoloji Dergisi*, 23(2): 111-121.

Uzun Yiğit, A., Demirözer, O., Hayat, R., Vujić, A., 2023. Entomophagous Syrphidae (Diptera) species and their distribution in Göller Yöresi (Türkiye). *Ege University Journal of Faculty of Agriculture*, 60(1): 141-154.

Van Steenis, J., Nedeljković, Z., Tot, T., Van der Ent, L.J., Mazanek, L., Sebic, A., Radenkovic, S., Vujić, A., 2019. New records of hoverflies (Diptera: Syrphidae) and the rediscovery of Primoceriodes regale Violovitsh for the fauna of Serbia. *Biologia Serbica*, 41: 94-103.

Van Veen, M.P., 2010. Hoverflies of Northwest Europe: identification keys to the Syrphidae. Knnv Publishing, Utrecht, The Netherlands.

Vuataz, L., Reding, J.P., Reding, A., Roesti, C., Stoffel, C., Vinçon, G., Gattolliat, J.L., 2024. A comprehensive DNA barcoding reference database for Plecoptera of Switzerland. *Scientific Reports*, 14(1): 6322.

Vujić, A., Likov, L., Radenković, S., 2021. Correct citations of the recently described species of genera *Merodon*, *Cheilosia* and *Paragus* (Diptera: Syrphidae). *Acta Entomologica Serbica*, 26(1): 67-70.

Vujić, A., Pérez-Bañón, C., Radenkovic, S., Stahls, G., Rojo, S., Petanidou, T., Simić, S., 2007. Two new species of the genus *Merodon* Meigen 1803 (Diptera: Syrphidae) from the island of Lesvos (Greece), in the Eastern Mediterranean. *Annales de la Société entomologique de France,* 43(3): 319-326

Vujic, A., Speight, M., Courcy Williams, M.E., Rojo, R., Stahls, G., Radenkovic, S., Likov, L., Milicic, M., Perez-Banon, C., Falk, S., Petanidou, T., 2020. Atlas of the Hoverflies of Greece (Diptera: Syrphidae). Leiden/Boston, Brill.

Yao, Y., Chen, J.Y., Gong, X.L., Li, C.H., Liu, Z., Lin, X.L., 2025. Species Delimitation and Cryptic Diversity in *Rheotanytarsus* Thienemann & Bause, 1913 (Diptera: Chironomidae) Based on DNA Barcoding. *Insects*, 16(4): 370.

Yetkin, C., 2006. Syrphidae (Diptera) Fauna of Şanlıurfa. Ms Thesis, The Graduate School of Natural and Applied Sciences of Harran University, Şanlıurfa.