Survey of the Ficus Whitefly, Singhiella simplex (Hemiptera: Aleyrodidae), and Its Natural Enemies in the Western Mediterranean Region of Turkey

Author: Yükselbaba, Utku

Source: Florida Entomologist, 106(1) : 22-28

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.106.0104

Survey of the Ficus whitefly, *Singhiella simplex* (Hemiptera: Aleyrodidae), and its natural enemies in the Western Mediterranean Region of Turkey

Utku Yükselbaba[1,*]

Abstract

In this study, the distribution of the Ficus whitefly, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), and its natural enemies in the Western Mediterranean Region of Turkey were investigated. For this purpose, the sampling was made from trees of *Ficus* spp. during Aug, Sep, and Oct when the pest population was at its peak in the various districts within the Antalya province in 2018 and 2019. In addition, the rate of natural parasitism in the sampling periods also was determined. To determine the dispersal and parasitoids of *S. simplex*, at least 100 branches were collected from *Ficus* trees in each district, the *Ficus* trees were checked visually for the determination of the predators. The results showed that Ficus whitefly is dispersed in all the districts within the Antalya province. *Encarsia protransvena* Viggiani (Hymenoptera: Aphelinidae) has been identified as the parasitoid of the Ficus whitefly in Antalya and its districts, wereas the highest natural parasitism rate was found to be 32.88% and 21.66% in Oct 2018 and 2019, respectively, across the sampling mo. *Chrysoperla mutata* (McLachlan) (Neuroptera: Chrysopidae), *Semidalis aleyrodiformis* (Stephens) (Neuroptera: Coniopterygidae), *Conwentzia psociformis* (Curtis) (Neuroptera: Coniopterygidae), *Conwentzia* sp. (Neuroptera: Coniopterygidae), *Oenopia conglobata* (L.) (Coleoptera: Coccinellidae), and *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) species were determined as the predators. The results obtained in the study may contribute to the control of *S. simplex* by using its natural enemies.

Key Words: natural parasitism; biological control; predator; parasitoid

Resumen

En este estudio, se investigó la distribución de la mosca blanca del ficus, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), y sus enemigos naturales en la región mediterránea occidental de Turquía. Para tal efecto, el muestreo se realizó a partir de árboles de *Ficus* spp. durante agosto, septiembre y octubre, cuando la población de plagas alcanzó su punto máximo en los diversos distritos de la provincia de Antalya en el 2018 y 2019. Además, también se determinó la tasa de parasitismo natural en los períodos de muestreo. Para determinar la dispersión y parasitoides de *S. simplex* se recolectaron al menos 100 ramas de árboles de *Ficus* en cada distrito, los árboles de *Ficus* fueron revisados visualmente para la determinación de los depredadores. Los resultados mostraron que la mosca blanca del ficus está dispersa en todos los distritos dentro de la provincia de Antalya. *Encarsia protransvena* Viggiani (Hymenoptera: Aphelinidae) ha sido identificada como el parasitoide de la mosca blanca del ficus en Antalya y sus distritos, donde se encontró que la tasa de parasitismo natural más alta del 32,88% y el 21,66% en octubre de 2018 y 2019, respectivamente. Se determinó *Chrysoperla mutata* (McLachlan) (Neuroptera: Chrysopidae), *Semidalis aleyrodiformis* (Stephens) (Neuroptera: Coniopterygidae), *Conwentzia psociformis* (Curtis) (Neuroptera: Coniopterygidae), *Conwentzia* sp., *Oenopia conglobata* (L.) (Coleoptera: Coccinellidae), y *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) como depredadores. Los resultados obtenidos en el estudio pueden contribuir al control de *S. simplex* mediante el uso de sus enemigos naturales.

Palabras Clave: parasitismo natural; control biológico; depredador; parasitoide

The Ficus whitefly, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), an Aleyrodidae species first described in India (Singh 1931), causes damage to *Ficus* spp. and was first reported in Turkey in 2016 on *Ficus microcarpa* L.f. (Moraceae) in Antalya (Yükselbaba et al. 2017). The Ficus whitefly is of Asia origin and has been detected in India, China, Myanmar, Puerto Rico, Jamaica, the Cayman Islands, Brazil, and Taiwan (Jesus et al. 2010; Vichiato et al. 2013; Ko et al. 2015; Ahmed et al. 2022). The Ficus whitefly was detected in Miami, Florida, USA, in 2007, Israel in 2011, Cyprus in 2014, and Italy in 2019 (Kondo & Evans 2012; Laudani et al. 2020). Adult and instar feed on leaves. Unlike many other whitefly species, instar stages appear on both sides of the leaf (Konda & Evans 2012; EPPO 2018). Adults are tiny, about 1 to 1.5 mm in length with a pale yellow body. Wings are white and waxy with 2 light gray bands, 1 in the middle and 1 like a stripe towards the top edge of the wing (Hodges 2007; Mannion 2010; Avery et al. 2011; Ahmed et al. 2022). A female can lay 46 eggs in its lifespan (Legaspi et al. 2011). Instar stages are usually flat, oval, and initially transparent. The pupa is oval, 1.3 mm in length and dark yellow to light green in color with red eyes (Hodges 2007; Mannion et al. 2010; Jesus et al. 2010). The adults fly very quickly when disturbed. While most of these flights are at close range, the wind can carry them to distant areas (Hodges 2007). Legaspi et al. (2011) reported that the total immature development time of *S. simplex* was 97.1 d at 15 °C and 25.2 d at 30 °C. According to Hodges (2007), *S. simplex* have at least 3 generations per yr like other *Singhiella* species in Florida.

As a result of the severe damage caused by the Ficus whitefly on the plant, yellowing and shedding of leaves and branch dieback usually occur before the death of the plant (Mannion 2010). Defoliation is the most obvious symptom of the *S. simplex* infestation (Mannion 2010; Avery et

[1]University of Akdeniz, Faculty of Agriculture, Department of Plant Protection, 07059 Antalya, Turkey; E-mail: uyukselbaba@akdeniz.edu.tr
*Corresponding author; E-mail: uyukselbaba@akdeniz.edu.tr

al. 2011; Ahmed et al. 2022). It was reported that severe infestations of *Ficus* trees by *S. simplex* caused intensive defoliation in Florida in Aug 2007 (Hodges 2007; Ahmed et al. 2017).

Various natural enemies have been observed in landscape areas that may play an important role in the long-term control of the Ficus whitefly (Ahmed et al. 2022). Awareness of these natural enemies is crucial in deciding on suitable pesticide applications which will not adversely affect them (Ahmed et al. 2022). Natural enemies of *S. simplex* have been reported from Florida, the US, and China (Hodges 2007; Mannion 2010; Ko et al. 2015; Lahey & Polaszek 2017; Ahmed et al. 2022).

The Ficus whitefly has been reported to cause serious damage to *Ficus* spp. in areas where the pest has dispersal (Ahmed et al. 2022), so it is necessary to monitor the geographical range of the pest and prevent its further dispersal. Ahmed et al. (2022) studied the behavior of the Ficus whitefly, the biology, and control measures in the US. Further studies on its biology, behavior, and control strategies are required to facilitate pest control in urban areas where the pest has dispersal. For the development of effective control strategies, it is important to have detailed information about the geographical distribution, damage potential, and biocontrol agents of the pest.

This study, therefore, sought to determine the geographical distribution and population status of *S. simplex*, as well as to determine the potential natural enemies that can be included in the IPM program in the Western Mediterranean Region of Turkey.

Material and Methods

DETERMINATION OF THE GEOGRAPHICAL DISTRIBUTION OF FICUS WHITEFLY, *SINGHIELLA SIMPLEX*

To determine the geographical distribution and population density of the Ficus whitefly, a study was conducted in Antalya city center and its districts, including: Kaş, Demre, Kumluca, Finike, Alanya, Manavgat, and Serik in the Western Mediterranean Region. Samplings were conducted in Aug, Sep, and Oct when the pest population was most intense in 2018 and 2019 (Manion 2010; Yükselbaba et al. 2018). The study was conducted in Antalya province and its adjoining districts in the Western Mediterranean Region of Turkey due to the conducive climatic conditions favoring the survival of *S. simplex* and the growth of *Ficus* species. The samples were coded according to the communities where they were collected with associated GPS coordinates (Table 1).

Sample units were chosen randomly at 5 places in each location and surveys were conducted on the trees that were most preferred by *S. simplex* as hosts. Twenty-five trees were chosen for the survey of *S. simplex* population in each location. On each tree, 4 branches were chosen randomly in all directions. Therefore, a total of 100 branches were sampled in each district.

In the samplings, branches of about 8 cm long with 5 to 7 leaves were collected. Each sample was placed into individual paper bags kept in plastic ice bags and brought back to the laboratory for analysis. The pre-adult stages of whiteflies on the branches were counted under a stereomicroscope (Nikon SMZ445, Tokyo, Japan) in order to determine the geographical distribution, presence, and density of *S. simplex*. Samplings were done once in the specified mo. Based on the presence in the branches, the density of the population was categorized into 6 grades (Table 2).

DETERMINATION OF THE PARASITOIDS OF FICUS WHITEFLY, *SINGHIELLA SIMPLEX*

The collected branches were kept in parasitoid emergence boxes (similiar to that of Goolsby et al. 2002) for 15 d in order to identify potential parasitoids of the Ficus whitefly. Parasitoids emerging in the glass tubes of the parasitoid emergence boxes were collected and placed in 80% ethanol and stored at −20 °C for morphological identification studies. Slide mounting of parasitoids was carried out according to the method specified in Polaszek et al. (2014). Identification of the parasitoids was conducted using the morphological characters and identification keys specified in Huang and Polaszek (1998). At least 10 individual parasitoids were slide mounted and identified from each location.

Table 1. Sampling locations for the determination of geographical distribution and natural enemies of *Singhiella simplex*.

Location	Location code	Coordinates
Antalya/Center	ANT	37.487500°N, 31.171666°E
Alanya	ALN	36.918888°N, 32.672777°E
Demre	DMR	36.412222°N, 30.648888°E
Finike	FNK	36.506111°N, 30.248611°E
Serik	SRK	37.532500°N, 31.161111°E
Gazipaşa	GZP	36.454444°N, 32.521388°E
Kaş	KAS	36.338888°N, 30.076666°E
Kumluca	KML	36.619444°N, 30.482777°E
Manavgat	MNV	37.317777°N, 31.735277°E

DETERMINATION OF THE NATURAL PARASITISM RATES

The parasitism rate was determined by counting the parasitized instar stages of *S. simplex* on the branches. Under the above-referenced stereomicroscope, parasitoid larvae and pupae in the instars also were counted separately. When using the parasitoid emergence box to determine the parasitism rate, the number of parasitoids and whiteflies obtained differed from the numbers on the branches. Therefore, the parasitism rate was determined by counting the parasitized and non-parasitized instars of the Ficus whitefly on the branches. Parasitism rate (%) was calculated according to Telli and Yiğit (2012) with the formula:

$$\text{Parasitism rate (\%)} = \frac{\text{(Parasitized whitefly instars)}}{\text{Total number of whitefly instars}} \times 100$$

DETERMINATION OF THE PREDATORS OF *SINGHIELLA SIMPLEX*

To determine the predators of the Ficus whitefly, the trees infected with *S. simplex* were examined first by the visual inspection method after waiting for a few minutes around the trees. Predators that were observed to be feeding on the Ficus whitefly stages were collected, after which they were separated and kept in Petri dishes. Petri dishes with predators were checked under the above-referenced stereomicroscope to confirm that the predator was feeding on the Ficus whitefly stages. Density of predators, both adults and larvae, were determined by recording them visually. Species identification of the predators were done by their experts. Species diversity of the predators of *S. simplex* in

Table 2. Standard evaluation procedure by presence in branches.

Number of branches observed	Prevelence category	Grade
0	Nil	1
1–20	Very low	2
21–40	Low	3
41–60	Moderate	4
61–80	High	5
81–100	Very high	6

the Western Mediterranean Region were estimated for each yr by the Shannon-Weiner index of Diversity (*H'*) (Shannon 1948) and Equitability divided by evenness (*E'*) (Pielou 1966). The higher the value of *H'*, the higher the diversity of species. The lower the value of *H'*, the lower the diversity. The *E'* index value ranges from 0 to l, with a value of 1 being the maximum possible evenness (Shannon 1948; Pielou 1966).

$$H' = -\sum_{i=1}^{s} Pi \ln pi$$

S = Total number of species
Pi = proportion of individuals of ith species in total sample
E′ = H′/lnS:
Equitability or evenness
H: Shanon's index
S = Total number of species

Results

GEOGRAPHICAL DISTRIBUTION OF FICUS WHITEFLY, *SINGHIELLA SIMPLEX*

In this study, the geographical distribution, population density, and natural enemies of *S. simplex* which have been recorded newly in Turkey were investigated in the Western Mediterranean Region. For this purpose, the samplings were carried out in Antalya Center, Alanya, Serik, Gazipaşa, Manavgat, Kumluca, Finike, Demre, and Kaş districts where the pest and its hosts were more intense in the mo of Aug, Sep, and Oct of 2018 and 2019 (Yükselbaba et al. 2018). From Tables 3 and 4, it is shown that *S. simplex* dispersed to all the districts within the Antalya province.

From Table 3, it is shown that the number of whiteflies per shoot was found to be lower in Aug compared to the other 2 mo in all the districts. In Kumluca, Manavgat, Gazipaşa, and Serik districts, the highest Ficus whitefly number per shoot was shown to be in Sep. In Antalya Center, Alanya, Demre, Finike, and Kaş districts, the highest Ficus whitefly number per shoot was shown to be in Oct.

According to the grade indicated in Table 2, a very high prevalence was detected in each district. In 10 of the branches collected from Demre and Kumluca districts, no immature stage of *S. simplex* was observed.

The highest number of whiteflies per shoot was recorded in Central Antalya, Finike, and Gazipaşa districts in Sep of 2019 (Table 4). In Serik and Manavgat districts, the highest number of whiteflies were detected in Aug, whereas it was detected in Oct in Kaş and Demre districts (Table 4). In 2019, the number of pests increased in all the districts and mo compared to the previous yr.

In addition, similar to the previous yr, it was determined that the pest had a very high prevalence in 2019 in the sampling areas. In 10 of the branches collected in Demre and Kumluca districts in 2019, no immature of *S. simplex* was observed.

PARASITOIDS OF FICUS WHITEFLY, *SINGHIELLA SIMPLEX*, AND NATURAL PARASITISM RATE

The result of the morphological analysis of the parasitoid samples showed *Encarsia protransvena* Viggiani (Hymenoptera: Aphelinidae)

Table 3. Results of *Singhiella simplex* and parasitoid samplings and parasitisim rate in 2018.

Location	Mo	Grade	*S. simplex* instar stages / shoot (Mean ± SE)	Larvae of parasitoid / shoot (Mean ± SE)	Pupae of parasitoid / shoot (Mean ± SE)	Natural parasitism rate (%)
ANT	Aug	6	10.70 ± 0.41	1.19 ± 0.07	0.86 ± 0.04	16.07
	Sep	6	25.89 ± 0.92	2.53 ± 0.11	3.48 ± 0.13	18.84
	Oct	6	28.68 ± 0.91	3.02 ± 0.12	3.99 ± 0.21	19.64
ALN	Aug	6	4.51 ± 0.36	0.17 ± 0.05	0.1 ± 0.03	5.64
	Sep	6	9.84 ± 0.73	0.44 ± 0.08	0.18 ± 0.05	5.92
	Oct	6	12.23 ± 0.77	1.51 ± 0.19	3.11 ± 0.42	27.41
DMR	Aug	6	5.46 ± 1.33	0.07 ± 0.07	0.07 ± 0.07	2.73
	Sep	6	15.47 ± 1.21	1.92 ± 0.35	2.94 ± 0.44	23.91
	Oct	6	19.6 ± 1.59	3.06 ± 0.38	6.12 ± 0.86	31.89
FNK	Aug	6	6.62 ± 0.84	0.00 ± 0.00	0.00 ± 0.00	0.00
	Sep	6	18.65 ± 1.03	1.73 ± 0.17	2.44 ± 0.39	18.27
	Oct	6	20.76 ± 1.3	2.77 ± 0.35	6.55 ± 1.03	30.99
SRK	Aug	6	11.13 ± 1.74	0.05 ± 0.02	0.04 ± 0.02	0.80
	Sep	6	30.51 ± 2.46	1.14 ± 0.24	0.56 ± 0.14	5.27
	Oct	6	17.61 ± 1.29	3.03 ± 0.33	3.23 ± 0.38	26.24
GZP	Aug	6	15 ± 1.42	0.49 ± 0.11	0.31 ± 0.06	5.06
	Sep	6	27.62 ± 2.29	1.55 ± 0.21	1.86 ± 0.28	11.01
	Oct	6	14.82 ± 1.14	2.8 ± 0.28	4.46 ± 0.41	32.88
KAS	Aug	6	3 ± 0.27	0.02 ± 0.01	0.00 ± 0.00	0.78
	Sep	6	15.5 ± 1.21	0.97 ± 0.16	0.97 ± 0.14	11.12
	Oct	6	15.66 ± 1.00	1.93 ± 0.28	2.37 ± 0.39	21.56
KML	Aug	6	3.63 ± 0.41	0.00 ± 0.00	0.00 ± 0.00	0.00
	Sep	6	24.86 ± 1.74	0.74 ± 0.13	1.34 ± 0.22	7.74
	Oct	6	16.49 ± 1.33	1.87 ± 0.24	4.02 ± 0.54	26.31
MNV	Aug	6	4.03 ± 0.45	0.02 ± 0.01	0.11 ± 0.03	3.125
	Sep	6	19.9 ± 1.44	0.26 ± 0.06	0.15 ± 0.07	2.05
	Oct	6	15.15 ± 0.95	0.91 ± 0.14	1.31 ± 0.24	12.81

Table 4. Results of *Singhiella simplex* and parasitoid samplings and parasitisim rate in 2019.

Location	Mo	Grade	*S. simplex* instar stages per shoot (Mean ± SE)	Larvae of parasitoid per shoot (Mean ± SE)	Pupae of parasitoid per shoot (Mean ± SE)	Natural parasitism rate (%)
ANT	Aug	6	23.8 ± 2.64	2.14 ± 0.16	1.48 ± 0.13	13.20
	Sep	6	32.64 ± 2.32	2.87 ± 0.24	1.74 ± 0.17	12.37
	Oct	6	30.75 ± 2.66	3.20 ± 0.28	3.42 ± 0.23	17.71
ALN	Aug	6	17.97 ± 1.47	0.6 ± 0.19	0.61 ± 0.18	6.31
	Sep	6	18.28 ± 0.98	0.47 ± 0.07	0.25 ± 0.06	3.86
	Oct	6	11.25 ± 0.86	0.81 ± 0.09	1.51 ± 0.19	13.92
DMR	Aug	6	3.17 ± 0.76	0.00 ± 0.00	0.00 ± 0.00	0.00
	Sep	6	9.81 ± 1.17	0.04 ± 0.03	0.00 ± 0.00	0.40
	Oct	6	25.79 ± 1.72	2.06 ± 0.21	1.71 ± 0.17	12.75
FNK	Aug	6	14.64 ± 1.62	0.46 ± 0.09	0.26 ± 0.07	4.68
	Sep	6	32.41 ± 1.97	2.75 ± 0.39	3.28 ± 0.42	15.68
	Oct	6	22.5 ± 1.68	1.49 ± 0.19	2.28 ± 0.28	14.35
SRK	Aug	6	29.56 ± 2.38	0.02 ± 0.02	0.00 ± 0.00	0.06
	Sep	6	21.76 ± 2.04	2.74 ± 0.33	2.78 ± 0.33	20.23
	Oct	6	22.49 ± 1.67	3 ± 0.29	3.22 ± 0.29	21.66
GZP	Aug	6	14.81 ± 1.23	0.18 ± 0.06	0.06 ± 0.03	1.59
	Sep	6	38.62 ± 2.44	2.48 ± 0.26	3.79 ± 0.44	13.96
	Oct	6	31.98 ± 2.61	3.04 ± 0.36	2.98 ± 0.35	15.84
KAS	Aug	6	15.06 ± 1.23	0.9 ± 0.18	0.71 ± 0.17	9.65
	Sep	6	25.69 ± 1.83	0.89 ± 0.15	0.73 ± 0.13	5.93
	Oct	6	26.64 ± 1.86	3.29 ± 0.34	2.2 ± 0.22	17.08
KML	Aug	6	11.7 ± 1.43	0.04 ± 0.03	0.01 ± 0.01	0.42
	Sep	6	27.31 ± 2.49	0.05 ± 0.02	0.15 ± 0.06	0.72
	Oct	6	13.12 ± 1.3	1.73 ± 0.27	1.24 ± 0.21	16.44
MNV	Aug	6	31.5 ± 1.77	0.17 ± 0.07	0.13 ± 0.04	0.94
	Sep	6	26 ± 1.62	0.3 ± 0.06	0.08 ± 0.03	1.44
	Oct	6	31.03 ± 1.71	2.15 ± 0.27	1.69 ± 0.25	11.01

as the only parasitoid species of the pest. The numbers of *E. protransvena* larvae and pupae detected in shoot counts and natural parasitism rates are given in Tables 3 and 4.

From Table 3, it is shown that the lowest number of parasitoids was detected in Aug, whereas the highest number was observed in Oct in 2018. While natural parasitism rates ranged from 0% to 16.07% in Aug, the highest natural parasitism rate was found in Oct. The natural parasitism rate was detected between 12.81% and 32.88% in Oct. The result from Table 4 showed that natural parasitism rates were between 0% and 13.20% in Aug. In Sep, the natural parasitism rates were found to be between 0.4% and 20.23%. Similar to the previous yr, the highest rates of natural parasitism were observed in Oct, except in the Finike district. In Oct, the lowest parasitism rate was observed in Manavgat with 11.01%, and the highest in Serik with 21.66% (Table 4).

PREDATORS OF FICUS WHITEFLY, *SINGHIELLA SIMPLEX*

Chrysoperla mutata (McLachlan) (Neuroptera: Chrysopidae), *Semidalis aleyrodiformis* (Stephens) (Neuroptera: Coniopterygidae), *Conwentzia psociformis* (Curtis) (Neuroptera: Coniopterygidae), *Conwentzia* sp. (Neuroptera: Coniopterygidae), *Oenopia conglobata* (L.) (Coleoptera: Coccinellidae), and *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae) were determined to be predators of the Ficus whitefly in this study. Abundance of the predators according to the sampling locations and periods were given in Tables 5 and 6. *H′* and *E′* values of the diversity index of predators of *S. simplex* in the Western Mediterranean Region were determined to be 1.55 and 0.28 in 2018, respectively. In 2019, the *H′* and *E′* values were estimated at 1.41 and 0.24, respectively.

Discussion

In this study, the geographical distribution, abundance, and natural enemies of Ficus whitefly have been determined. The result of the study showed that *S. simplex* is common in all the locations within Antalya province and its districts in the Western Mediterranean Region. While the lowest population of *S. simplex* was determined as 90% in the Demre and Kumluca districts, it was found to be 100% in other districts and Central Antalya. In the Kumluca and Demre districts, it was observed that the branches in which *S. simplex* was not detected were the branches collected from the *Ficus* trees found on the main road edges. The reason for this may be that the whiteflies were affected by the exhaust fumes of vehicles. Another reason may be distance, as reported by Ahmed et al. (2022). They observed that an infestation started on one side of the road and moved on the same side along the hedge for over a yr. Ahmed et al. (2022) stated that the Ficus whitefly is unable to fly long distances, and its dispersal can be interrupted when there is a sufficient distance between trees. It was observed that there was an increase in Ficus whitefly population in the second yr of sampling. The increase in Ficus whitefly population in 2019 caused intense defoliation of *Ficus* trees. Due to the increasing damage by *S. simplex*, especially in the Kumluca and Demre districts, chemical management and pruning of *Ficus* trees were applied to control the pest by local municipalities (personal communication). However, despite the management, an increase in the Ficus whitefly abundance per shoot was observed in these 2 districts and others (Table 4). While the lowest population was determined in Aug in all districts, the highest Ficus whitefly population was recorded in Sep and Oct (Tables 3 and 4). Simi-

Table 5. Density of the predators of *Singhiella simplex* in 2018.

		ANT			ALN			DMR			FNK			SRK			GZP			KAŞ			KML			MNV		
Sampling species		A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O
C. mutata	Larva	–	1	1	–	1	2	1	2	2	1	3	3	1	2	3	1	1	2	1	2	3	–	2	5	–	2	3
	Adult	–	1	1	1	–	2	1	1	3	1	3	2	–	1	2	1	–	2	1	3	3	1	3	4	1	2	2
Conwentzia sp.	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	1	1	–	–	–	2	3	4	1	2	5	–	–	–	–	–	–	1	2	2	–	–	–	–	–	–
S. aleyrodiformis	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	–	–	1	3	4	–	–	–	–	–	–	1	1	2	–	–	–	–	–	–	1	1	4	2	3	4
C. psociformis	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	2	–	–	–	–	–	–	–	–	–
O. conglabata	Larva	1	1	1	–	–	1	–	–	–	–	1	–	–	–	1	1	–	–	1	–	1	–	–	–	1	1	2
	Adult	–	1	2	1	1	–	–	–	2	–	–	1	1	–	1	1	–	1	–	–	–	1	1	2	–	1	3
S. parcesetosum	Larva	–	–	–	1	3	4	–	–	–	–	–	–	–	2	3	–	1	2	–	–	–	–	–	–	2	4	2
	Adult	–	–	–	1	2	3	–	–	–	–	–	–	1	1	4	1	1	3	–	–	–	–	–	–	1	3	10

A = Aug; S = Sep; O = Oct

Table 6. Density of the predators of *Singhiella simplex* in 2019.

		ANT			ALN			DMR			FNK			SRK			GZP			KAŞ			KML			MNV		
Sampling species		A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O	A	S	O
C. mutata	Larva	–	1	–	–	3	3	–	1	2	–	1	3	–	2	3	1	2	3	–	3	1	1	1	2	1	3	1
	Adult	1	1	1	1	1	3	1	1	2	1	–	2	1	1	1	2	2	1	1	1	3	–	1	2	1	1	3
Conwentzia sp.	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	1	2	–	–	–	1	2	3	1	1	2	–	–	–	–	–	–	1	1	2	–	–	–	–	–	–
S. aleyrodiformis	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	–	–	1	2	2	–	–	–	–	–	–	1	2	2	–	–	–	–	–	–	2	4	12	2	5	8
C. psociformis	Larva	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Adult	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	3	–	–	–	–	–	–	–	–	–
O. conglabata	Larva	1	2	2	2	–	–	–	–	1	–	1	1	–	–	1	–	1	3	–	–	1	1	1	1	–	–	–
	Adult	–	2	2	–	–	–	1	1	1	–	–	–	–	2	2	2	1	2	–	1	–	–	–	1	–	–	4
S. parcesetosum	Larva	–	–	1	1	3	2	–	–	–	–	–	–	2	1	4	1	4	20	–	–	–	–	–	–	1	8	37
	Adult	–	1	1	1	1	1	–	–	–	–	–	–	1	3	3	1	3	21	–	–	–	–	–	–	3	6	30

A = Aug; S = Sep; O = Oct

lar to our study, Mannion (2010) reported in a study on the population fluctuation of *S. simplex* that the whitefly population increased in Aug, reached the highest number in Sep and Oct. Mannion (2010) stated that the first leaf shedding started in the last d of Aug and increased in other mo. In a similar development, Yükselbaba et al. (2018) also determined the population dynamics of the pest with yellow sticky trap in Antalya between 2017 to 2018. In their study, they reported the first appearance of *S. simplex* adults on sticky traps in early Apr and reached the highest numbers of 1,035 and 643 in Aug and Sep, respectively. Parallel with our findings, Ahmed et al. (2022) found that *the S. simplex* population started to increase in Apr, remained high until Oct, and then decreased.

To determine the parasitoids of the Ficus whitefly, morphological characters were examined, and it was observed that all parasitoids collected from the central area and districts of Antalya had the same diagnostic characters. *Encarsia protransvena* was determined as the only parasitoid species of the *S. simplex* in the Western Mediterranean Region. Hodges (2007) has reported the *S. simplex* for the first time in Florida and *Encarsia tricolor* Förster (Hymenoptera: Aphelinidae) as the parasitoid of the Ficus whitefly. Avery et al. (2011) speculated that the parasitoid detected in *S. simplex* larvae was *E. protransvena*. Myartseva et al. (2014) indicated that *E. protransvena* and *Encarsia hispida* De Santis (Hymenoptera: Aphelinidae) are parasitoids of *S. simplex* in Mexico. Ko et al. (2015) stated that there may be a possible native parasitoid species that would be a good candidate in the classical biological control of *S. simplex*, and this could be *Encarsia singhiellae* Shih & Polaszek (Hymenoptera: Aphelinidae), which they identified as a new species in their study. Ahmed et al. (2017) reported 3 parasitoid species of *S. simplex* in their research conducted between 2014 to 2016 in Florida, namely *Amitus bennetti* Viggiani & Evans (Hymenoptera: Platygasteridae), *Baeoentedon balios* Wang, Huang & Polaszek (Hymenoptera: Eulophidae), and *E. protransvena*. Lahey and Polaszek (2017) reported *S. simplex* as the second confirmed host for parasitoid *B. balios*. When the literature above is examined, 5 parasitoids of *S. simplex* have been reported from different parts of the world. In our study, *E. protransvena* was detected as the only parasitoid of Ficus whitefly in the Western Mediterranean Region. Ulusoy and Ülgentürk (2003) reported *E. protransvena* as the parasitoid of *Dialeurodes citri* Ashmead (Hemiptera: Aleyrodidae) and *Tetraleurodes neemani* Bink-Moenen in Bink-Moenen & Gerling (Hemiptera: Aleyrodidae) in Turkey. Huang and Polaszek (1998) reported the distribution of *E. protransvena* in various parts of the world that include Guangzhou, Taiwan, Puerto Rico, Spain, and the US (Florida, Georgia, and Hawaii). They reported *Bemisia tabaci* (Gennadius), *D. citri*, *Dialeurodes citrifolii* (Morgan), *Dialeurodes kirkaldyi* (Kotinsky), and *Trialeurodes packardi* Morrill (all Hemiptera: Aleyrodidae) from the Aleyrodidae family as hosts of *E. protransvena*.

In the present study *C. mutata*, *S. aleyrodiformis*, *C. psociformis*, and *Conwentzia* sp. in the order Neuroptera, and *O. conglobata* and *S. parcesetosum* in the order Coleptera were determined to be the predators of *S. simplex*. The generally observed natural enemies are *Harmonia axyridis* (Pallas), *Olla-v-nigrum* (Mulsant), *Exochomus childreni* Mulsant, *Chilocorus nigritus* (Fabricius), *Curinus coeruleus* (Mulsant) (all Coleoptera: Coccinellidae), and Neuroptera *Chrysopa* spp. (Mannion 2010). Avery et al. (2011) observed adult ladybird beetles *C. coeruleus*, *H. axyridis*, eggs and larvae of the green lacewing, *Chrysopa* spp., as predators of *S. simplex.* Ahmed et al. (2022) reported *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), *C. nigritus*, *C. coeruleus*, *H. axyridis*, *O. v-nigrum*, *Brachiacantha dentipes* (Fabricius), *Coelophora inaequalis* (Fabricius), *Delphastus pallidus* (LeConte), *Egius platycephalus* Mulsant, *E. childreni* Mulsant (all Coleoptera: Coccinellidae) species as predators of *S. simplex*. In this study, predator abundance was observed at its highest in Oct among the mo studied. According to the results of the *H′* and *E′* values, the diversity index of predators was considered low in the Western Mediterranean Region for both yr of the study period. The fact that the abundance of natural enemies is low and it differs among the districts may be the reason for the relatively low *H′* and *E′* values. The low density of natural enemies may be because natural enemies already are adapting to different hosts. The observed predator density was lower than that of parasitoid *E. protransvena*. Telli and Yiğit (2012) reported *Clitostethus arcuatus* Risso, *Cryptoleamus montrouzieri* Mulsant, *Chilocorus bipustulatus* L., *S. parcesetosum* (all Coleoptera: Coccinellidae), *Conwentzia* sp., and *C. carnea* as the predators of *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae) in Turkey. In the same study, they indicated *Cunaxa potchensis* Den Heyer (Acari: Cunaxidae), *C. arcuatus*, *C. bipustulatus*, *Conwentzia* sp., and *C. carnea* as the predators of *Paraleyrodes minei* Iaccarino (Hemiptera: Aleyrodidae).

In this study, the highest natural parasitism rates recorded in Oct of 2018 and 2019 were 32.88% and 21.65%, respectively, across the sampling mo. In 2019, compared to the previous yr, a decrease was observed in natural parasitism rates, especially in Oct in all the districts. One of the principal reasons for the proportional decrease in the natural parasitism rate was due to the increase in the Ficus whitefly populations. The second reason could be due to chemical control of *S. simplex* and mosquitoes that indirectly might have affected the parasitoid population. Supporting our judgment, Ahmed et al. (2022) reported that foliar application of contact insecticides may affect the resident natural enemies of *S. simplex*. They also stated that applying systemic insecticide by soil drenching could minimize the chemical impact on resident natural enemies of *S. simplex*. The third reason may be due to routine pruning in the landscaped areas. Municipalities usually do the pruning in the early summer mo (personal communication) and there is a possibility of the adult Ficus whitefly flying away to lay their eggs on other leaves and reproduce there. The possibility of the parasitoid finding the whitefly instar decreases and, therefore, the parasitoid population may be more affected. Avery et al. (2011) reported in their study that 10% death was caused by parasitization of *Encarsia* species, and 90% death was due to natural causes such as entomopathogenic fungi and predators, but they stated that these findings should be confirmed with a more comprehensive study. Telli and Yiğit (2012) determined the natural parasitism rates of *A. floccosus* and *P. Minei* in a study conducted in Hatay (Turkey) between 2005 to 2006. The result of their study showed that *A. floccosus* was suppressed by the species specific parasitoid, *Cales noacki* Howard (Hymenoptera: Aphelinidae), and the natural parasitism rate was found to be 88.71% in Erzin and 70.27% in Samandag in Oct. In the same study, they reported the natural parasitism rate of *P. minei* by *E. hispida* to be 25.60% in Oct and the highest of 38.73% in Jun.

In the light of these data, it has been observed that the dispersal ability of *S. simplex* is high. It was observed that the population of Ficus whitefly increased as of the end of Aug and the population of natural enemies increased in parallel. Improving the effectiveness of its natural enemies, especially parasitoids, and taking protective measures such as partial pruning, using selective insecticides will make a serious contribution to the management of the Ficus whitefly. Studies to determine the seasonal relationship between the Ficus whitefly and parasitoid, the biology and the parasitism capacity of the parasitoid on *S. simplex* will contribute to the development of more effective control methods in urban environments for control of *S. simplex*. In addition, applications of entomopathogenic fungi and continued research in this direction will be useful.

Acknowledgments

The author extends his appreciation to Nedim Uygun (retired academician, Adana, Turkey) for identification of Coccinellidae species, to Sziráki György (Hungarian Natural History Museum, Department of Zoology, Budapest, Hungary) for identification of Coniopterygidae species, to Ferenc Szentkirályı (Plant Protection Institute, Hungarian Academy of Sciences, Budapest, Hungary) for identification of Chrysopidae species.

Funding

The author is grateful for funding through The Scientific and Technological Research Council of Turkey (TUBITAK) under Project Number 118O558.

References Cited

Ahmed MZ, Hernandez YV, Francis A, Evans G, Rohrig E, Osborne L, Mannion C. 2017. Balios Eulophid *Baeoentedon balios* Wang, Huang & Polaszek (Insecta: Hymenoptera: Eulophidae). UF IFAS Extension publication #EENY 696. https://edis.ifas.ufl.edu/pdffiles/IN/IN116900.pdf (last accessed 22 Oct 2022).

Ahmed MZ, McKenzie CL, Revynthi AR, Evans GA, Mannion C, Osborne L. 2022. Pest status, survey of natural enemies and a management plan for the whitefly *Singhiella simplex* (Hemiptera: Aleyrodidae) in the United States. Journal of Integrated Pest Management 11: 1–14.

Avery PB, Mannion C, Powell CA, McKenzie CL, Osborne LS. 2011. Natural enemies managing the invasion of the fig whitefly, *Singhiella simplex* (Hemiptera: Aleyrodidae), infesting a *Ficus benjamina* hedge. Florida Entomologist 94: 696–698.

EPPO – European and Mediterranean Plant Protection Organization. 2018. Mini data sheet on *Singhiella simplex* (Hemiptera : Aleyrodidae) Ficus whitefly. https://gd.eppo.int/taxon/SINLSI/documents (last accessed 22 Oct 2022).

Goolsby AJ, Kırk AA, Meyerdirk ED. 2002. Seasonal phenology and natural enemies of *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae) in Australia. Florida Entomologist 85: 494–498.

Hodges G. 2007. The fig whitefly, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae): a new exotic whitefly found on *Ficus* species in south Florida. Pest Alert DACS-P-01642. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, Florida, USA. https://hcplc.bibliocommons.com/v2/record/S142C627951 (last accessed 22 Oct 2022).

Huang J, Polaszek A. 1998. A revision of the Chinese species of *Encarsia* Förster (Hymenoptera: Aphelinidae): parasitoids of whiteflies, scale insects and aphids (Hemiptera: Aleyrodidae, Diaspididae, Aphidoidea). Journal of Natural History 32: 1825–1966.

Jesus LFM, Trindade TD, Ferreira Jr AJ, Racca Filho F, Lima AF. 2010. Registro de uma especie exotica demosca-branca-do-ficus (Hemiptera: Aleyrodidae) e sua disseminacao no Brasil. *In* Abtracts of the XXIII Congresso Brasileiro de Entomologia, 26–30 Sep 2010. Natal, Rio Grande do Norte, Brazil.

Ko CC, Shih YT, Schmidt S, Polaszek A. 2015. A new species of *Encarsia* (Hymenoptera: Aphelinidae) developing on ficus whitefly *Singhiella simplex* (Hemiptera: Aleyrodidae) in China and Taiwan. Journal of Hymenoptera Research 46: 85–90.

Kondo T, Evans G. 2012. *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), a new aleyrodid invasive species for Colombia. Boletín del Museo de Entomología de la Universidad del Valle 13: 31–33.

Lahey ZJ, Polaszek A. 2017. *Baeoentedon balios* (Hymenoptera: Eulophidae): a parasitoid of ficus whitefly, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), new to the United States. International Journal of Pest Management 63: 349–351.

Laudani F, Giunti G, Zimbalatti G, Campolo O, Palmeri V. 2020. *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), a new aleyrodid species for Italy causing damage on *Ficus.* EPPO Bulletin 50: 268–270.

Legaspi JS, Mannion C, Amalin D, Legaspi Jr BC. 2011. Life table analysis and development of *Singhiella simplex* (Hemiptera: Aleyrodidae) under different constant temperatures. Annals of the Entomological Society of America 104: 451–458.

Mannion C. 2010. Ficus whitefly management in the landscape. https://fufc.org/downloads/ficus_whitefly_2010.pdf (last accessed 22 Oct 2022).

Myartseva NS, González-Julián P, Ruíz-Cancino E, Coronado-Blanco CMJ, Muñoz-Viveros LA. 2014. Parasitoides de la mosquita blanca *Singhiella simplex* (Singh, 1931) en México (Hymenoptera: Chalcidoidea: Aphelinidae). Entomología Mexicana 1: 1113–1117.

Pielou EC. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131–144.

Polaszek A, Ayshford T, Yahya BE, Fusu L. 2014. *Wallaceaphytis*: an unusual new genus of parasitoid wasp (Hymenoptera: Aphelinidae) from Borneo. Journal of Natural History 48: 1111–1123.

Shannon CE. 1948. A mathematical theory of communication. The Bell System Technical Journal 27: 379–423.

Singh K. 1931. A contribution towards our knowledge of the Aleyrodidae (whitefies) of India. Memoirs of the Department of Agriculture in India 12: 1–98.

Telli Ö, Yiğit A. 2012. Natural enemies of citrus woolly whitefly, *Aleurothrixus floccosus* (Maskell) and nesting whitefly, *Paraleyrodes minei* Iaccarino (Hemiptera: Aleyrodidae) in Hatay Province, Turkey. Turkish Journal of Entomology 36: 147–154.

Ulusoy MR, Ülgentürk S. 2003. The natural enemies of whiteflies (Hemiptera: Aleyrodidae) in southern Anatolia. Zoology in the Middle East 28: 119–124.

Vichiato MRM, Vichiato M, Silva P, Couto C, Pereira L, Lima M, Pradoö E. 2013. Defoliation and progressive death of branches on *Ficus microcarpa* L. trees ın the city of Belo Horizonte, Minas Gerais State, Brazil. REVSBAU, Piracicaba, São Paulo 8: 17–27.

Yükselbaba U, Kırmızıoğlu MH, Göçmen H. 2018. Population dynamics of ficus whitefly *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae) in Antalya, p. 41 *In* Başpınar H [Ed.], VII Turkish Plant Protection Congress, 14–17 Nov 2018, Muğla, Turkey.

Yükselbaba U, Topakcı N, Göçmen H. 2017. A new record of Turkey Aleyrodidae fauna, ficus whitefly *Singhiella simplex* (Singh) (Hemiptera:Aleyrodidae). Phytoparasitica 45: 715–717.