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Original article (Orijinal araştırma)

Spider mite predator *Feltiella acarisuga* (Vallot, 1827) (Diptera: Cecidomyiidae) in greenhouse strawberry cultivation in Antalya Province: recognition, population dynamics and parasitization by *Aphanogmus* sp.

Antalya İli örtüaltı çilek üretiminde kırmızı örümcek predatörü *Feltiella acarisuga* (Vallot, 1827) (Diptera: Cecidomyiidae): tanınması, popülasyon dinamikleri ve *Aphanogmus* sp. tarafından parazitlenmesi

Nurdan TOPAKCI[1*]

Abstract

Feltiella acarisuga (Vallot, 1827) (Diptera: Cecidomyiidae) is an effective and common beneficial species that feeds on many species of Tetranychid mites. Although it has been detected in Turkey, there are few studies on this predatory species. In this study, weekly leaf samples were taken to represent the growing area in the soilless strawberry greenhouse of Akdeniz University in 2020 and 2021. In leaf examinations, it was determined that *F. acarisuga* had an average egg size of 0.21 mm, young and mature larva of 0.26-1.51 mm, and a cocoon size of 2.01 mm. The average body length of male and female individuals was measured as 0.89 mm and 1.11 mm, respectively. It was determined that *F. acarisuga* can feed on all biological stages of *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae), as eggs, larvae, nymphs and adults were seen in the greenhouse in all seasons. *Feltiella acarisuga* is the most common natural enemy of *T. urticae*, with a maximum average of 0.38 larvae + cocoons/leaf in the greenhouse in the first year and 0.62 larvae + cocoons/leaf in the second year. In this study, a new species was detected, *Aphanogmus* sp., which was determined to be the parasitoid of *F. acarisuga* and different from its known congeners. The parasitization rate of *F. acarisuga* was found to be between 0 and 51.5%.

Keywords: *Feltiella acarisuga,* parasitoid, population dynamics, strawberry

Öz

Feltiella acarisuga (Vallot, 1827) (Diptera: Cecidomyiidae), Tetranychid akarların birçok türü ile beslenen etkili ve yaygın bir doğal düşman türüdür. Türkiye'de varlığı tespit edilmiş olmakla birlikte bu predatör tür ile ilgili olarak son derece kısıtlı çalışmalar bulunmaktadır. Bu çalışmada 2020 ve 2021 yıllarında, Akdeniz Üniversitesine ait topraksız çilek serasında üretim alanını temsilen haftalık yaprak örnekleri alınmıştır. Yaprak incelemelerinde, *F. acarisuga*'nın ortalama 0,21 mm yumurta, 0,26-1,51 mm genç ve olgun larva, 2,01 mm kokon büyüklüğüne sahip olduğu belirlenmiştir. Erkek ve dişi bireylerin vücut uzunluğu ise sırasıyla ortalama 0,89 mm ve 1,11 mm olarak ölçülmüştür. *Feltiella acarisuga*'nın, *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae)'nin yumurta, larva, nimf ve ergin olmak üzere tüm biyolojik evrelerinde beslenebildiği ve tüm sezon boyunca serada görülebildiği tespit edilmiştir. En yoğun olarak, ilk yıl serada ortalama 0.38 adet larva + kokon/yaprak, ikinci yıl ise 0,62 adet larva + kokon/yaprak tespit edilmiş olan *F. acarisuga*'nın, *T. urticae*'nin en yaygın doğal düşmanı olduğu belirlenmiştir. *Feltiella acarisuga*'nın parazitoiti olarak belirlenen ve bilinen türdeşlerinden farklı yeni bir tür olan *Aphanogmus* sp'nin tespit edildiği bu çalışmada, *F. acarisuga*'nın parazitlenme oranı %0-51,5 arasında bulunmuştur.

Anahtar sözcükler: *Feltiella acarisuga*, parazitoit, popülasyon dalgalanması, çilek

[1] Akdeniz University, Vocational School of Technical Sciences, Environmental Protection and Control Program, 07059, Antalya, Turkey
* Corresponding author (Sorumlu yazar) e-mail: ntopakci@akdeniz.edu.tr
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Introduction

Cecidomyiidae is among the families with the richest species in Diptera (Gagne, 2004). Gagne & Jaschhof (2014) listed 6203 species belonging to 736 genera worldwide. The Cecidomyiidae family, known as gall midges, also includes mycophagous, saprophagous and zoophagous species as well as phytophagous species that are plant pests (Skuhrava et al., 2010, 2014).

It has been reported that all known species of the genus *Feltiella* in the Cecidomyiidae family feed on tetranychid mites (Gagne, 2010). *Feltiella acarisuga* (Vallot, 1827) (Diptera: Cecidomyiidae) (syn. *Therodiplosis persicae* Kieffer, 1912) is a common species that can feed on many species of spider mites that cause economic damage to many host plants (Mo & Liu, 2007). It is an important species due to its efficiency and cosmopolitan distribution (Choi et al., 2021), and it is the most common predator of spider mites (Gillespie et al.,1997). It has been found that ~20°C and 90% RH are optimum conditions for *F. acarisuga*, which develop and reproduce at 15-27°C and 60-95% RH in greenhouses (Gillespie et al., 1998, 2000). The life history and life table parameters of *F. acarisuga* were determined using *Tetranychus cinnabarinus* (Boisduval, 1867) eggs under laboratory conditions (Mo & Liu, 2006). Xiao et al. (2011) reported that *F. acarisuga* is an excellent predator of both *Tetranychus urticae* Koch, 1836 (Acari: Tetranychidae) and *Oligonychus pratensis* (Banks, 1912) (Acari: Tetranychidae). Xiao et al. (2013) showed that *F. acarisuga* was highly effective on *T. urticae* eggs under laboratory conditions, while *Neoseiulus californicus* (McGregor, 1954) (Acari: Phytoseiidae) and *Amblyseius swirskii* (Anthias-Henriot, 1962) were moderately effective.

There are only a few studies on the Cecidomyiidae family or on *F. acarisuga* as a predator of spider mites in Turkey. In some of these studies, it is reported that a species of the Cecidomyiidae family is a predator of spider mites. For example, in the Antalya Province, a Cecidomyiid predator species, which could not be identified, was found in eggplant in addition to many natural enemies of spider mites (Soysal & Yayla, 1988). Çakmak (2002) detected an unidentified species from the Cecidomyiidae family in greenhouse strawberry fields in the Aydın Province and determined that the larvae of this species feed on *Tetranychus* species and locally put pressure on the leaves where the pest is dense. One of the few studies in which *F. acarisuga* was found in production areas at the species level was conducted in the Erzincan Province. In this study, besides many natural enemies of *T. urticae* in beans, *T. persicae* from Cecidomyiidae was identified as a specific mite predator, a new record for the fauna of Turkey (Aydemir & Toros, 1990). Bulut & Göçmen (2000) investigated pests and their natural enemies in greenhouse vegetable cultivation in the Antalya Province and identified *F. acarisuga* as a predatory species.

Although there are some studies on the natural enemies of spider mites, which are important pests in open and greenhouse cultivation, there is a lack of information on the predatory insect *F. acarisuga* in Turkey. Although the existence of this species has been reported in Turkey, detailed information has not been reported. Accordingly, the present study sought to determine the population dynamics, distinctive morphological features, parasitoid and parasitization rates of *F. acarisuga* on strawberry plants. The results of this study will provide useful information for researchers and biological control studies.

Materials and Methods

Study area and studies on *Feltiella acarisuga*

This study was conducted in the soilless research greenhouse of the Faculty of Agriculture of Akdeniz University in 2020 and 2021. A total of 110 cultivation pots (70 x 25 cm) were used, each containing cocopeat, and seven strawberry plants (cv. Festival) were planted in each pot in a growing area of 150 m^2. The ionic composition of the nutrient solution was as follows: 11.5 mM $NO3^-$, 1.5 mM $H2PO4^-$, 1.5 mM $SO4^{-2}$, 0.5 mM $NH4^+$, 3.5 mM K^+, 4.5 mM Ca^{+2}, and 1.5 mM Mg^{+2}. The EC and pH values of the nutrient solution were 1.5 dS/m and 6.0, respectively. The greenhouse was 5.5 m high, with a semi-circular roof

(without a heating system). Greenhouse controls were made on a weekly basis starting in November following planting, and the study continued until June. At least 50 leaf samples were taken to represent the greenhouse. The leaves were first placed in a paper bag and then in a polyethylene bag and brought to the laboratory in an icebox. Eggs, larvae and pupae of *F. acarisuga* as well as the feeding behavior of larvae on the pest were examined and viewed under a microscope. Adults emerged from larvae and pupae, which were placed into glass or plastic pots covered with gauze under laboratory conditions for examination. *Feltiella acarisuga* adults were preserved in 70% ethanol for species identification and labeled. In addition, due to their sensitive structure, female and male *F. acarisuga* were directly mounted in Hoyer's medium. Antenna, tarsus and genital parts of the samples were examined under a binocular microscope and photographed in their original form. The measurement values of at least three samples of the biological stages of *F. acarisuga* were obtained and used as an average. The morphological description of *F. acarisuga* was made according to Gagne (2018) and Abe et al. (2011), and the definitive species diagnosis was made by Dr. Marcela Skuhrava (CSc. Bítovská 1227/9 CZ-140 00 Praha 4 Czech Republic).

Population dynamics of *Feltiella acarisuga* and other natural enemies

The leaf samples were brought to the laboratory and kept in the refrigerator until they were examined. The larvae and cocoons of *F. acarisuga* on the leaves were examined under a stereo-microscope and counted. *Tetranychus urticae* and other natural enemies were counted. The larvae and cocoons of *F. acarisuga* and the adults, larvae and nymphs of other natural enemies were counted together and evaluated. To identify the spider mite species, the samples preserved in 70% ethanol were cleaned in lactophenol solution and prepared using Hoyer's medium (Henderson, 2001). The definitive diagnosis of spider mites was made by Edward A. Ueckermann (School of Environmental Sciences and Development, North-West University, South Africa). Despite the desire not to use pesticides in the growing area, spraying (240 g/l spiromesifen) was done twice in the first year against pests that exceeded the economic threshold (15 active individual/leaf) several times.

Parasitoid of *Feltiella acarisuga* and parasitization %

During the examination of leaf samples in the first year, parasitoid exit holes were found in the cocoons of *F. acarisuga*, and leaves with the larvae and cocoons were cultured in laboratory conditions. The adult parasitoids obtained were preserved in 70% ethanol and identified at the genus level by Dr. Kazunori Matsuo (Biosystematics Laboratory, Faculty of Social and Cultural Studies, Kyushu University, Motooka, Nishi-ku, Fukuoka 819-0395, Japan). When it was assumed that *F. acarisuga* was parasitized, leaf samples were taken in the second year of the study to determine the parasitization rate. Between April and June 2021, at least 20 leaves with *F. acarisuga* cocoons were collected weekly and cultured in laboratory conditions. Adults of *F. acarisuga* and parasitoid species emerging from the cultured leaves were counted, and the parasitization rate was calculated using the following formula:

Parasitization (%) = Number of adult parasitoids / (number of adult *F. acarisuga* + number of adult parasitoids) x 100

Results

Determination of *Feltiella acarisuga*

Feltiella acarisuga, which is seen in egg, larva and pupa stages on strawberry leaves, has also been found in adults flying around the plant from time to time. It has been observed that *F. acarisuga* lays its eggs on leaves with *T. urticae* eggs, especially on leaves with a high population of spider mites. Similarly, the egg size was found to be 0.21 mm on average. *Feltiella acarisuga* eggs can be easily distinguished from those of *T. urticae* under a microscope due to their thin and elongated structure (Figure 1a). At first, the newly hatched larvae were almost the same color as the eggs (whitish-yellow), and their color mostly darkened (yellow-pink-red) depending on feeding and in the following stages (Figure 1b-c).

Figure 1. a) Eggs of *Feltiella acarisuga* with *Tetranychus urticae* eggs; b-c) Larva of *Feltiella acarisuga*.

Both young and mature larvae of *F. acarisuga* feed on all biological stages of *T. urticae* indiscriminately (Figure 2a-b). In this study, young and mature larvae had a body length of 0.26-1.51 mm.

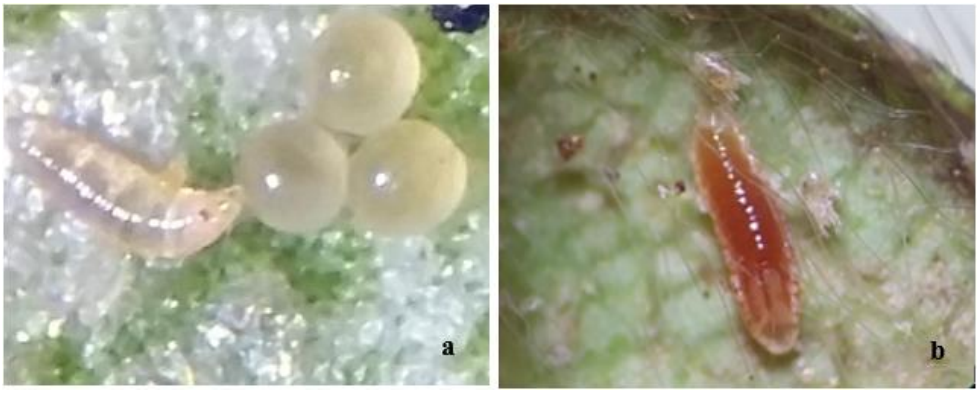

Figure 2. a) First instar larvae of *Feltiella acarisuga* feeding on *Tetranychus urticae* egg; b) mature larvae of *Feltiella acarisuga* feeding on *Tetranychus urticae*.

Feltiella acarisuga larvae, which feed on *T. urticae* eggs, larvae, nymphs and adults, did not differentiate between male and female.

Feltiella acarisuga forms cocoons and pupae mostly near the leaf veins (Figure 3a-b). Although rare, it is possible to encounter cocoons on any part of the leaf other than near the vein. In the study, the average cocoon length was 2.01 mm, while pupae size was found to be 1.35 mm on average. In the visual controls on strawberry leaves, the cocoons stood out as white small bumps and suggested the population density (Figure 3c). Cocoons and larvae could be seen widely among the *T. urticae* colony.

Figure 3. Pupa and cocoon of *Feltiella acarisuga* at the leaf vein margin. a-c) cocoon; b) pupa.

Adults of *F. acarisuga* with pinkish-brownish color have long legs. Males are distinguished from females by their thinner body structures and differences in antenna structures (Figure 4a-b). The antennae of males are longer than those of females, and the flagellomeres are completely different structurally, as shown in Figure 5 (a-b). In the study, the average body length of males and females were 0.89 and 1.11 mm, respectively.

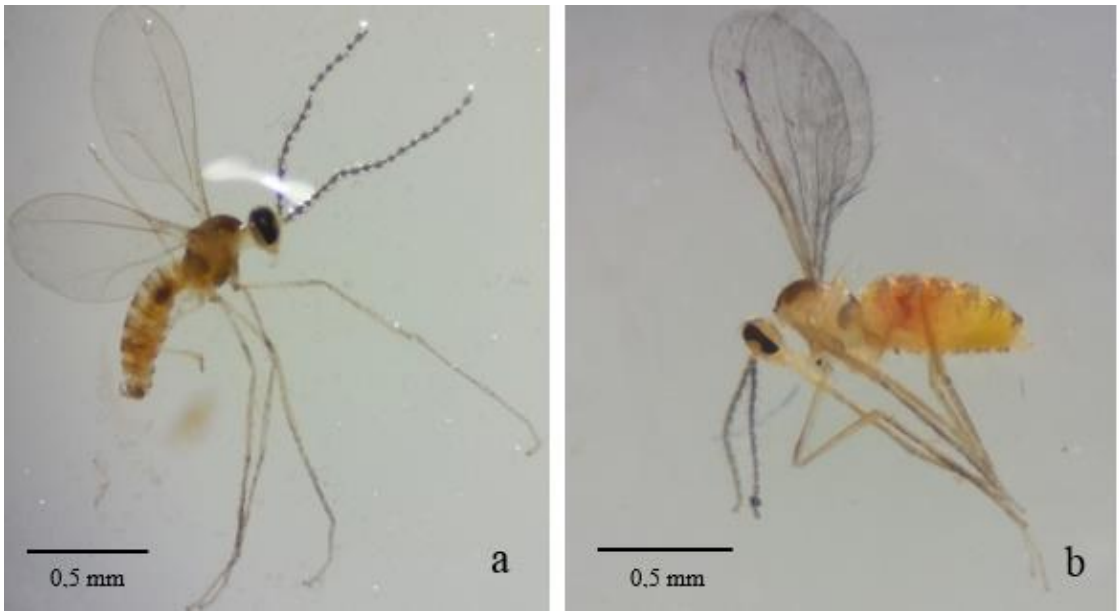

Figure 4. Adult of *Feltiella acarisuga* a) male; b) female.

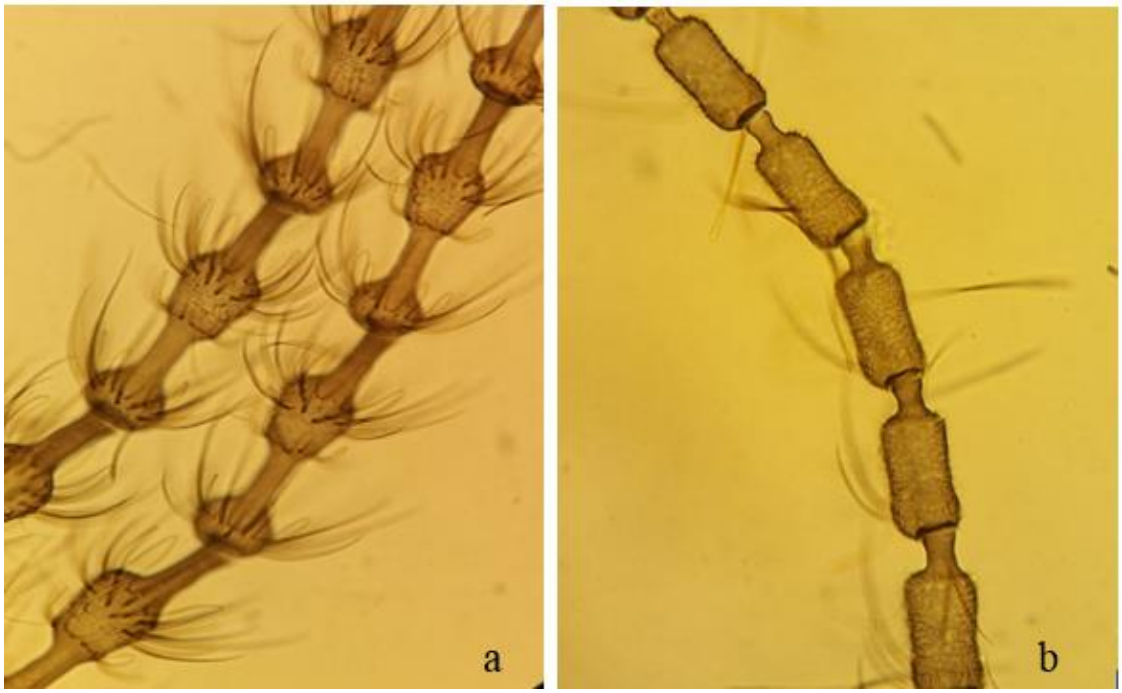

Figure 5. Antenna structure of *Feltiella acarisuga*: a) male flagellomeres; b) female flagellomeres.

The aedeagus was longer than the cerci and hypoproct in male specimens (Figure 6a), and the tarsal claws, which were simple in the middle and hind legs, were toothed in the forelegs (Figure 6b).

Figure 6. a) Male genitalia of *Feltiella acarisuga*: A: Aedegus, H: hypoproct, and C: cercus; and b) toothed tarsal claws on forelegs.

Population dynamics of *Feltiella acarisuga*

Feltiella acarisuga started to appear shortly after the appearance of *T. urticae* in the greenhouse and were found throughout the whole season. *Feltiella acarisuga* was present on the leaves as eggs, larvae and cocoons as long as the spider mites were present on the plant, and adults were also encountered occasionally during the sampling. In addition to *F. acarisuga*, which is the most common natural enemy of spider mites, *Stethorus gilvifrons (*Mulsant, 1850) (Coleoptera: Coccinellidae), *Scolothrips longicornis* Priesner, 1926 (Thysanoptera: Thripidae), *Orius* sp. (Hemiptera: Anthocoridae) and phytoseiids were determined as other natural enemies, respectively, according to their densities. The spider mites in the greenhouse were identified as *T. urticae*. In a study in 2018 in the same greenhouse, *Tetranychus solanacearum* Çobanoğlu & Ueckermann, 2015 (Acari: Tetranychidae) were detected (Topakci et al., 2021). This suggests the possibility of coexistence of both species or that *T. urticae*, which develops resistance to pesticides and has a wide host range, may be in a more dominant position than *T. solanacearum.*

In 2020, acaricide was applied twice when the *T. urticae* density averaged 25.2 and 29.4 per leaf (February and April). Despite this, the pest density was often above the economic threshold. *Feltiella acarisuga* started to appear from the third week after the start of greenhouse monitoring, and it was found almost throughout the entire season depending on the *T. urticae* population density. However, it was not effective in suppressing the pest. *Feltiella acarisuga* was most numerous (0.38 larvae + cocoons/leaf) on 18.05.2020 when the density of *T. urticae* was 18.2 per leaf (Figure 7). Twenty-nine *F. acarisuga* larvae and 164 cocoons were detected on the leaves, the highest number of natural enemies of *T. urticae*, and for the longest time during the season. Other natural enemies that were detected were *S. gilvifrons*, *S. longicornis* and phytoseiid species, with *S. longicornis* the second most common species. The highest number of *S. gilvifrons* was found on 2.06.2020, with 0.38 individuals/leaf, and the highest number of *S. longicornis* was 0.70 individuals/leaf on 08.06.2020. On 08.06.2020, the number of phytoseiid species was 0.02 individuals/leaf, but *Orius* was not found.

In 2021, *T. urticae* did not reach a population density as high as in 2020, and leaf drying was sometimes observed due to fungal infections. The pest population exceeded the economic threshold many times, and the density of the pest increased toward the end of the season. *Feltiella acarisuga* started to appear from the fifth week after the start of greenhouse monitoring and was detected throughout the entire season. It was observed that the beneficial species were more common in the greenhouse in 2021 compared to 2020 and reached greater numbers per leaf. The highest density of *F. acarisuga* was found on 20.05.2021, with 0.62 larvae + cocoons/leaf, and the density of *T. urticae* was 15.0 per leaf on that date (Figure 8). One

hundred and forty-eight larvae and 182 cocoons were found on the leaves sampled in the second year. Other natural enemies detected in the greenhouse were *S. gilvifrons*, *S. longicornis*, *Orius* and phytoseiid species, and these species were seen after 15.04.2021. After *F. acarisuga*, the second most common natural enemy species was *S. gilvifrons*, with the highest average number of 0.10 individuals/leaf on 27.05.2021. On 20.05.2021, there were 0.02 *Orius* individuals/leaf on average; on 2.06.2021 there were 0.08 *S. longicornis* individuals/leaf on average; and on 22.04.2021 there were 0.02 phytoseiid species individuals/leaf on average. *Orius* species, not found in 2020, were found in 2021.

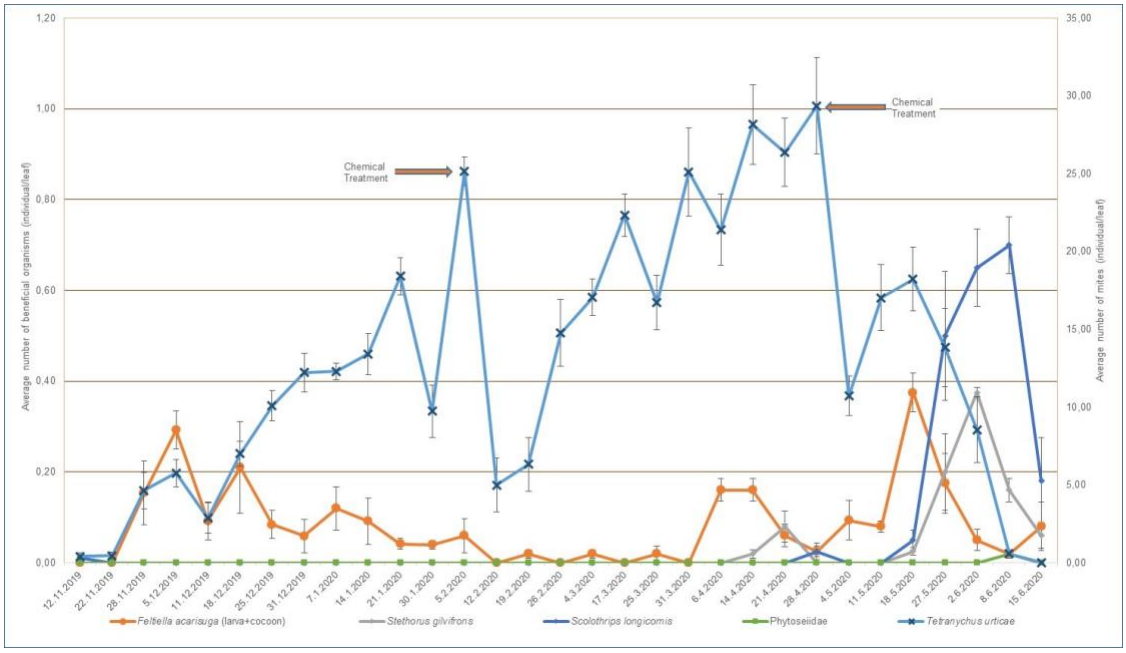

Figure 7. Population densities of *Tetranychus urticae* and beneficial organisms in 2020.

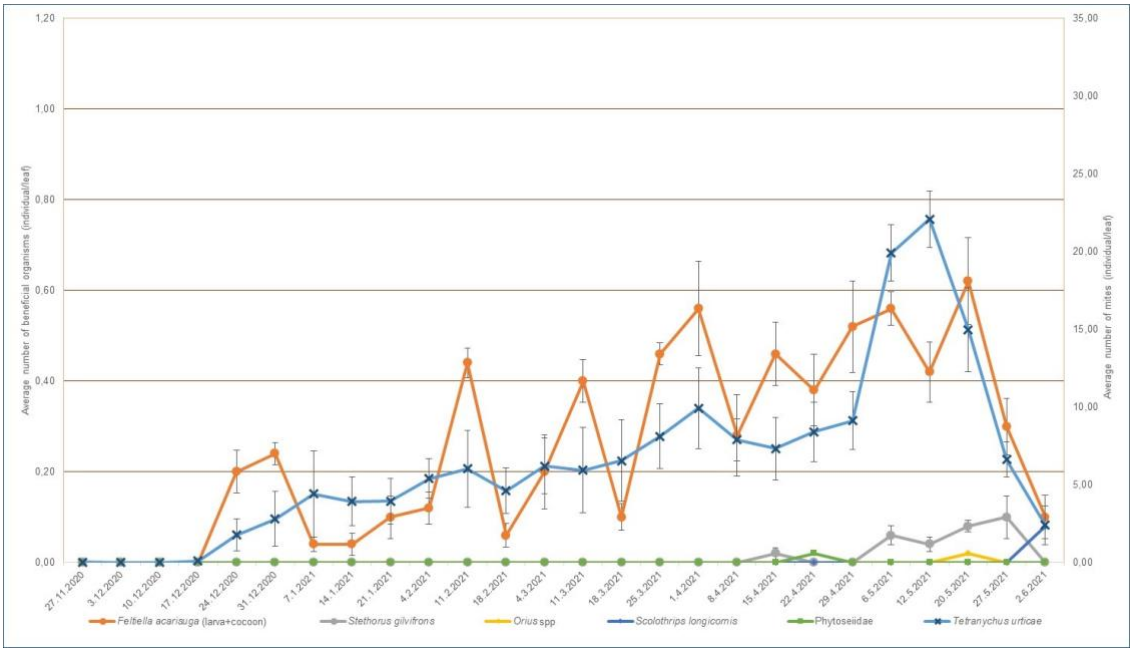

Figure 8. Population densities of *Tetranychus urticae* and beneficial organisms in 2021.

Parasitoid of *Feltiella acarisuga* and parasitization percentage

Characteristic parasitoid exit holes were observed in the cocoons examined under the microscope. The samples were cultured and it was determined that the holes were caused by a parasitoid exit. This species, a parasitoid of *F. acarisuga*, was thought to attack the host in the larval stage. Parasitized cocoons were partially distinguishable from non-parasitized cocoons due to their dark coloration (Figure 9a). The specimens that completed the prepupa (Figure 9b) and pupal stages (Figure 9c) in the cocoon and reached the adult stage (Figure 9d) were identified as belonging to the genus *Aphanogmus* (Hymenoptera: Ceraphronidae). The *Aphanogmus* sp. has different morphological characteristics from known congeners and has not yet been named (K. Matsuo, personal communication).

Figure 9. a) Parasitized *Feltiella acarisuga* cocoon; b) prepupa of *Aphanogmus* sp. with meconium; c) pupa of *Aphanogmus* sp. with meconium; d) adult of *Aphanogmus* sp.

Aphanogmus sp. was identified as the parasitoid of *F. acarisuga* for the first time in Turkey. The leaves with cocoons in the sampling between April and June 2021 were cultured in order to follow the emergence of adult parasitoids. *Aphanogmus* adults obtained from parasitized *F. acarisuga* cocoons were recorded, and data on the parasitization rate were obtained (Table 1). It was determined that the parasitization was higher in May, and the parasitization rate of *F. acarisuga* by *Aphanogmus* was found to be in the range of 0-51.5%.

Table 1. Parasitization rate of *Feltiella acarisuga* by *Aphanogmus* sp.

Date	*Feltiella acarisuga* adult	*Aphanogmus* adult	Parasitization rate (%)
01.04.2021	25	0	0
08.04.2021	14	0	0
15.04.2021	3	0	0
22.04.2021	15	1	6.25
29.04.2021	20	0	0
06.05.2021	27	2	6.89
12.05.2021	27	7	20.58
20.05.2021	16	17	51.51
27.05.2021	7	4	36.36
02.06.2021	5	5	50.00

Discussion

Spider mites are one of the most important pests affecting quality and yields in greenhouse strawberry cultivation. They increase their population in a very short time and cause severe damage to strawberries. *Tetranychus cinnabarinus* (Boisduval, 1867) (Acari: Tetranychidae) *T. urticae* and *Tetranychus turkestani* Ugarov & Nikolskii, 1937 (Acari: Tetranychidae) have been detected in greenhouse strawberry fields in Turkey, of which *T. cinnabarinus* is the most common (Çakmak, 2002). In another study conducted on the strawberry plant in 2018, *T. solanacearum* was identified (Topakcı et al., 2021).

In the current study, *F. acarisuga*, was present as long as *T. urticae* were present on the strawberry plant. It was found that *F. acarisuga*, whose egg, larva and pupa stages were examined on the leaves, could feed on all biological stages of *T. urticae*. It has been determined that the predator is also effective on adult spider mites, both females and males. Similarly, it has been reported that *F. acarisuga* larvae feed on all stages of spider mites (Zhang, 2003). It has been shown that *F. acarisuga* has no preference for male or female mites, killing females as well as males when both preys are present in equal numbers (Opit et al., 1997). It has been observed that *F. acarisuga*, which occasionally flies around strawberry plants, lays its eggs on leaves where the *T. urticae* population is dense. Xiao et al. (2011) reported that *F. acarisuga* flew 4.0-7.0 m in search of new prey in the greenhouse. Gillespie et al. (1998) noted that females tend to lay more eggs on leaves with more mites. Larvae can survive for several days in the absence of prey (Gillespie et al., 1998). Kawano (1969) reported that mature larvae have a body color ranging from pale orange to dark red depending on the prey species. Lee et al. (2004) reported that the larvae were cream-yellow-brown in color, 0.29 mm in size for the first instar larvae and 1.14 mm for the fourth instar. In the present study, the average body length of young and mature larvae was found to be 0.26-1.51 mm, which is consistent with these prior studies, and the colors of the larvae differed depending on feeding, but they were mostly a dark pinkish-reddish color.

Pupae in white cocoons and close to the leaf veins were observed commonly on the leaves. There were differences in the size of the cocoons. Zhang (2003) reported that this predator develops best in nutrient abundance, but in the case of food shortage the pupae can be smaller in size. Pupae are 1.1-1.47 mm in size and can be found in a white cocoon (Lee et al., 2004).

Fedotova & Kozlova (2019) found the body length of *F. acarisuga* to be 0.99-1.38 mm in females and 1.16-1.20 mm in males, and the antennae lengths were 0.61-0.77 and 1.69 mm, respectively. Lee et al. (2004) reported that adult males have a length of 1.11-1.33 mm and females 1.27-1.58 mm. In this study, the body measurements of male and female individuals were close to the ranges specified in the literature. Gagne (2018) highlighted the morphological characteristics of *F. acarisuga* in a diagnostic key. Abe et al. (2011) reported that *Feltiella* females could not be identified at the species level by morphological characteristics. In the present study, the morphological characteristics of *F. acarisuga* individuals were examined, and it was determined that the tarsal claws in males were toothed on the forelegs, simple in the middle and the hind legs and the aedeagus were much longer than the cerci and hypoproct. These results are consistent with the literature.

In this study, which looked for all the natural enemies of *T. urticae* in the strawberry greenhouse, the most prominent beneficial species was *F. acarisuga*. *F. acarisuga* started to appear 3-5 weeks after the start of the greenhouse controls and was found on the plants throughout the whole season. The number of *F. acarisuga* cocoons on the leaves was higher than the number of larvae, and 177 larvae and 346 cocoons were recorded over the two years. Other natural enemies of spider mites detected alongside *F. acarisuga* included *S. gilvifrons*, *S. longicornis*, *Orius* sp. and the unidentified phytoseiid species. It has been reported that *S. gilvifrons*, *S. longicornis* and cecidomyiid species, which are the natural enemies of spider mites on greenhouse strawberry plants in the Aydın Province, are unable to reach the population density needed to put pressure on spider mites with intensive spraying (Çakmak, 2002). Similarly, the most common beneficial species, *F. acarisuga*, was insufficient to completely suppress spider mites, despite the careful

application of pesticides. However, the number of mites *F. acarisuga* kills is high on leaves where pest density is high, indicating that *F. acarisuga* is successful when evaluated on a leaf basis. Similarly, Çakmak (2002) found that in greenhouse strawberry fields the larvae of an unidentified species of the Cecidomyiidae fed on *Tetranychus* species and exerted local pressure on the leaves where the pest was dense.

In this study, the number of *F. acarisuga* cocoons was higher than the number of larvae on the sampled leaves in both years. Although non-cocoon-forming pupae were detected at times, this situation was found to be negligible. The density of *F. acarisuga* was determined to be in the range of 0.01-0.62 larvae + cocoons/leaf. Çakmak (2002) reported a population density of cecidomyiids in the greenhouse as 0.01-0.27 larvae/leaflet. The higher number of predators cecidomyiids in the present study could be attributed to the combination of larvae and cocoon numbers. In addition, the cultivation conditions may have also been more effective, as the strawberry fields in which Çakmak (2002) conducted his study are covered after February.

Aphanogmus species are usually parasitoids of cecidomyiid flies (Evans et al., 2005). Gillespie et al. (1998) reported that the parasitoid *Aphanogmus floridanus* Ashmead, 1893 (Hymenoptera: Ceraphronidae) attacks the larvae of *F. acarisuga* and emerges from the cocoon. Oatman (1985) determined that *A. floridanus* on strawberries significantly affected the population of *Feltiella acarivora* (Felt, 1907) (Diptera: Cecidomyiidae), a predator of *T. urticae*, and parasitism ranged from 0 to 89.7%. Although there is a possibility that the parasitoid found in this study may be a different species, the evaluation of the parasitoid rate appears to provide sufficient information about the parasitization of *F. acarisuga*. Here, the parasitization ranged from 0% to over 50%, similar to the study of Oatman (1985). Gillespie et al. (1998) observed that parasitoids are most numerous in the summer months, and the decrease in parasitism in some periods may be due to diapause. Some *Aphanogmus* species have been reported to emerge from the pupa of *F. acarisuga* in other parts of the world, but not in Japan. It has been suggeest that the reason for this may be that another unidentified species, *F. acarisuga* and *F. acarivora*, also attacked *F. acarivora* when coexisting (Ganaha-Kikumura et al., 2012).

The *Aphanogmus* species, which was determined as a parasitoid of *F. acarisuga* in the present study, may be a factor affecting the successful control of spider mites. In addition, even individuals of *F. acarisuga* from natural populations that occasionally enter greenhouses can effectively reduce the pest density on cultivated plants (Sharaf, 1984). Commercially available as a biocontrol agent against tetranychid mites, *F. acarisuga* has a superior prey consumption rate to *Phytoseiulus persimilis* Athias-Henriot, 1957 (Acari: Phytoseiidae), an important and common spider mite predator (Opit et al., 1997). *Feltiella acarisuga* can naturally invade greenhouses, and its larvae can consume several times as many spider mites as *P. persimilis* per day. However, augmentative releases are required for spider mite control at high population densities (Gillespie et al., 1998). It has been found that a larva feeds on an average of 32.3 adult *Tetranychus* during the entire larval stage (Kawano, 1969). Larvae feed for 4-6 days depending on temperature and prey status, and they consume more than 150 eggs during their lifespan (Gillespie et al., 1998, Mo & Liu, 2006). Xiao e al. (2011) determined that the predation of *F. acarisuga* against *T. urticae* and *O. pratensis* ranged from 43.7 to 67.9% and 59.2 to 90.3%, respectively, under laboratory conditions. Xiao et al. (2013) showed that *F. acarisuga* is the most effective predator of *T. urticae* among three predator species, *N. californicus*, *A. swirskii* and *F. acarisuga*, and the daily predation by a larval *F. acarisuga* was 50 eggs per day. *Phytoseiulus persimilis* females were found to consume an average of 16.7 *T. cinnabarinus* eggs during their development at different temperatures (Kazak, 2006), while adult females consumed a maximum of 20.6 larvae and adult males a maximum of 3.25 larvae at different temperatures (Kazak, 2008).

Although the performance of *F. acarisuga* varies with temperature, all developmental stages can develop at 11.5-31.9°C (Choi et al., 2021). In the present study, the maximum daily temperatures in the greenhouse ranged from 18.5 to 32.9°C and the minimum daily temperature ranged from 7.2 to 26.6°C. It was found that greenhouses provide a suitable environment for *F. acarisuga.* In addition, it is thought that being careful about the use of pesticides in the greenhouse can facilitate the establishment of predator

species compared to commercial strawberry greenhouses where pesticides are commonly used. However, it is clear that the parasitism status of *F. acarisuga* should be considered. Matsuo et al. (2016) advised that the identification of *Aphanogmus* species is essential to evaluate their possible negative effects on the activity of *Feltiella* species. There is no commercial use of *F. acarisuga* for the biological control of spider mites in Turkey. However, as determined in this study, *F. acarisuga* can be found in strawberry greenhouses during the growing season.

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