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Original article (Orijinal araştırma)

Seasonal occurrence and prevalence of the invasive spider mite *Eutetranychus orientalis* (Klein, 1936) and the citrus red mite *Panonychus citri* (McGregor, 1916) (Prostigmata: Tetranychidae) in citrus-growing and recreational areas of Adana (Türkiye)[1]

Adana ili (Türkiye) turunçgil yetiştirilen ve rekreasyon alanlarında istilacı akar türü *Eutetranychus orientalis* (Klein, 1936) ve turunçgil kırmızı örümceği *Panonychus citri* (McGregor, 1916) (Prostigmata: Tetranychidae)'nin mevsimsel görülme sıklığı ve yaygınlığı

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Abstract

In this study, surveys were conducted every two or three weeks to evaluate the prevalence of the invasive spider mite *Eutetranychus orientalis* (Klein, 1936) (Prostigmata: Tetranychidae) and the citrus red mite *Panonychus citri* (McGregor, 1916) (Prostigmata: Tetranychidae), as well as their population developments in citrus and sour orange (*Citrus aurantium* L.) growing in recreational (non agricultural - residential) areas in Adana between 2019 and 2022. The host preference of *E. orientalis* varied among citrus species, with the pest predominantly found on lemons (*C. limon* (L.) Burm. f.) (62%), followed by oranges (*C. sinensis* (L.) Osbeck) (26%) and mandarins (*C. reticulata* Blanco) (12%), but no infestations were recorded on grapefruits (*C. paradisi* Macf.). Similarly, *P. citri* was most commonly observed on lemons (58%), followed by mandarins (19%), oranges (17%), and grapefruits (6%). The highest *E. orientalis* population densities were observed in December, while the pest was either absent or at low densities during the summer. Regardless of citrus species, *P. citri* did not establish noticeable populations in any of the orchards where *E. orientalis* was detected. On sour orange, *E. orientalis* showed a similar seasonal abundance to those observed in other citrus species, whereas *P. citri* was unable to establish a population. Likewise, the majority of *E. orientalis* preferred to feed and colonize on the adaxial side of the leaf in all citrus species. Predatory mite populations remained at low densities across all sampling sites and did not exhibit a consistent population pattern. Regarding the population developments of *E. orientalis*, the most frequent Phytoseiidae species were *Amblyseius swirskii* Athias-Henriot, 1962, *Euseius scutalis* (Athias-Henriot, 1958) and *Typhlodromus athiasae* Porath & Swirski, 1965 (Mesostigmata: Phytoseiidae).

Keywords: Citrus, *Eutetranychus orientalis*, *Panonychus citri*, population dynamics, seasonal abundance

Öz

Bu çalışmada, Adana ilinde turunçgil yetiştiriciliği yapılan bahçeler ve rekreasyon amaçlı turunç (*Citrus aurantium* L.) yetiştirilen alanlarda *Eutetranychus orientalis* (Klein, 1936) (Prostigmata: Tetranychidae) ve turunçgil kırmızı örümceği *Panonychus citri* (McGregor, 1916) (Prostigmata: Tetranychidae)'nin yaygınlığı ve popülasyon gelişmelerinin belirlenmesi için 2019 - 2022 yılları arasında iki–üç haftada bir alınan örnekler ile periyodik surveyler gerçekleştirilmiştir. *E. orientalis*'in konukçu tercihi turunçgil türlerine göre değişiklik göstermiş, zararlının bulaşıklığı en çok limonlarda (*C. limon* (L.) Burm. f.) (%62) saptanmış, bunu portakal (*C. sinensis* (L.) Osbeck) (%26) ve mandalina (*C. reticulata* Blanco) (%12) izlemiş; greyfurt (*C. paradisi* Macf.) bahçelerinde ise zararlıya rastlanmamıştır. Benzer şekilde, *P. citri* bulaşıklığı da en yüksek limonda (%58) gerçekleşmiş, bunu mandalina (%19), portakal (%17) ve greyfurt (%6) izlemiştir. *Eutetranychus orientalis* popülasyon yoğunlukları en yüksek Aralık ayında gözlenirken yaz aylarında zararlı popülasyonuna ya hiç rastlanmamış ya da düşük yoğunluklarda bulunmuştur. Turunçgil türlerinden bağımsız olarak *P. citri*, *E. orientalis* saptanan bahçelerin hiçbirinde yüksek popülasyonlar oluşturmamıştır. *Eutetranychus orientalis* turunçta diğer turunçgil türlerine benzer bir populasyon gelişmesi göstermiş, *P. citri* popülasyon oluşturamamıştır. Benzer şekilde tüm turunçgil türlerinde *E. orientalis* popülasyonunun çoğunluğu yaprak üst yüzeyinde beslenmeyi ve koloni oluşturmayı tercih etmiştir. Avcı akar popülasyonları tüm örnekleme alanlarında düşük yoğunluklarda kalarak tutarlı bir popülasyon gerlişmesi göstermemiştir. *Eutetranychus orientalis* popülasyon gelişmesinin izlendiği bahçelerde en sık görülen Phytoseiidae türleri *Amblyseius swirskii* Athias-Henriot, 1962, *Euseius scutalis* (Athias-Henriot, 1958) ve *Typhlodromus athiasae* Porath & Swirski, 1965 (Mesostigmata: Phytoseiidae) olmuştur.

Anahtar sözcükler: Turunçgil, *Eutetranychus orientalis*, *Panonychus citri*, popülasyon dinamiği, sezonsal bolluk

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Introduction

Citrus, *Citrus* spp. (Sapindalaes: Rutaceae) is one of the most widely cultivated and consumed fruit globally. Türkiye ranks eighth in global citrus production, with most of it concentrated in the eastern Mediterranean region, particularly around Adana (TEBGE, 2024; USDA, 2024). In addition to insect pests, numerous mite species have been documented in association with citrus across global citrus-growing regions. However, only a limited number of these species are recognized as causing significant economic damage (McMurtry, 1977; Vacante, 2010). Recently, several mite species that were once not considered economically significant have expanded their range due to factors such as extensive pesticide use, the pronounced effects of climate change, and the international movement of plant material (Yalçın et al., 2022). One such species, the citrus brown mite, *Eutetranychus orientalis* (Klein, 1936) (Prostigmata: Tetranychidae), has become a major invasive pest, posing a substantial threat to citrus production in over 40 countries (Migeon & Dorkeld, 2021).

Eutetranychus orientalis, a phytophagous mite, was first described in the Middle East by Klein in 1936 (Klein, 1936). Although its presence in Turkish citrus orchards was initially noted by Jeppson et al. (1975), detailed information about the pest remained scarce until Çobanoğlu & Can (2014) confirmed its establishment in Türkiye based on samples from citrus orchards in the Kumluca district of Antalya. Subsequent surveys across the Eastern Mediterranean have highlighted *E. orientalis* among the most prevalent mite species affecting citrus plantations. This species frequently coexists with various citrus pests, such as the citrus bud mite *Aceria sheldoni* (Ewing, 1937), rust mite *Phyllocoptruta oleivora* (Ashmead, 1879) (Prostigmata: Eriophyidae) and citrus red mite *Panonychus* citri (McGregor, 1916) (Prostigmata: Tetranychidae).

Although *E. orientalis* primarily infests citrus, it is capable of developing on a broad spectrum of host plant species, including soft and stone fruits, various forest trees, and ornamental plants (Dhooria, 2003; Yeşilayer & Çobanoğlu, 2010; Migeon & Dorkeld, 2014; Elhalawany, 2019; Amer, 2020). At high population densities, *E. orientalis* may also damage fruits and young shoots, leading to fruit drop. If control measures are not taken in a timely manner, this will eventually lead to plant death (Jeppson et al., 1975; Ferragut et al., 2013; El-Sharabasy, 2015). Vela et al. (2017) reported that the population of *E. orientalis* in Spain reached its highest density once a year, exclusively during the autumn season. Likewise, the pest population in orange, grapefruit, and lemon orchards peaked annually between August and September in Egypt (Halawa et al. 2020). In contrast, Chouikhi et al. (2022) found that in Tunisia, the population of *E. orientalis* showed four distinct peak periods each year, occurring in February, March, April, and May.

Although several methods are available for controlling *E. orientalis*, chemical control remains the most commonly employed strategy among citrus growers in Türkiye and the rest of the world (Halawa et al., 2014; Heikal et al., 2019). Among these methods, biological control holds significant potential as an environmentally sustainable and eco-friendly approach to mite management. Mites belonging to the Phytoseiidae family (Mesostigmata) are essential natural enemies contributing significantly to managing mite pest populations in agricultural and horticultural systems. Research has demonstrated that species such as *Amblyseius swirskii* Athias-Henriot, 1962 and *Euseius scutalis* (Athias-Henriot, 1958) can effectively manage *E. orientalis* under controlled conditions (Ali & Zaher, 2007; Momen & Abdel-Khalek, 2009; Nawar, 2017; Al-Azzazy & Alhewairini, 2020). Research on the field efficacy of these species in controlling *E. orientalis* remains scarce (Yalçın et al., 2023).

Panonychus citri is considered to be another major pest in citrus-growing regions worldwide, including the Eastern Mediterranean region of Türkiye (McMurtry, 1969; Jeppson et al., 1975). This species was first recorded in 1952 in Türkiye, but it was initially not considered a significant pest. However, recent outbreaks associated with ecosystem disturbances, often caused by the use of broad-spectrum pesticides that reduce natural enemy populations, have increased its importance as a primary pest (Düzgüneş, 1977; Kasap et al., 2009; Schmidt-Jeffris, 2023). The mite primarily infests citrus species such as lemons, oranges, grapefruits and mandarins, causing leaf bronzing during peak population periods on spring and autumn (Kasap, 2005). According to Furuhashi (1980), *P. citri* populations on citrus trees in Japan generally display a bimodal pattern, with population peaks occurring in June–July and October–November, while maintaining low densities during the midsummer and winter months. Similarly, Vela et al. (2017) observed that in Spain, the population of *P. citri* in citrus orchards reached its peak twice annually, specifically in June and September. *P. citri* population development is closely linked to temperature, with peaks in early summer and autumn during shoot growth and declines in mid-summer and winter (Jeppson et al., 1975; Zanardi et al., 2015).

Recent preliminary studies have indicated an increasing population density of *E. orientalis* in citrus- growing areas of the Eastern Mediterranean region of Türkiye. However, there is a lack of detailed information on the pest's prevalence on its primary host, citrus, as well as its species-specific distribution and seasonal occurrences in Türkiye. Therefore, this study aims to assess the prevalence of the pest in citrus within Adana province and its districts, analyze the infestation rates by citrus species, and to monitor the population development of three citrus species in four different areas with minimal to no pesticide application in comparison to the seasonal occurrence of *P. citri.*

Material and Methods

Prevalence of *Eutetranychus orientalis* and *Panonychus citri*

In this study, the prevalence of *E. orientalis* and *P. citri* on lemon, *Citrus limon* (L.) Osbeck; oranges, *Citrus sinensis* (L.) Osbeck; mandarins, *Citrus reticulata* Blanco and grapefruits, *Citrus paradisi* Macf. (Sapindales: Rutaceae) in various districts of Adana was assessed in relation to the infestation rates of these pests, with a primary focus on commercial citrus orchards. To achieve this aim, extensive surveys were conducted in the districts of Ceyhan, Sarıçam, Yüreğir, Karataş, Kozan, Seyhan, and Yumurtalık regions renowned for their substantial citrus production. The surveys were conducted between November 2019 and January 2022, during which a total of 190 citrus orchards were sampled, representing a broad range of citrus species regardless of variety. The highest number of samples was collected from Yüreğir district, with 80 orchards, followed by Seyhan, Kozan, Karataş, Ceyhan, Sarıçam, and Yumurtalık, based on the distribution of citrus orchards on each area. The total number of trees sampled was determined to represent at least 0.01% of the citrus trees in each district, following the methodology of Lazarov & Grigov (1961).

During sampling, leaves were randomly collected from citrus trees, with four specimens obtained from the outer canopy across different orientations and one from the inner canopy, resulting in five leaves per tree. Within each sampling unit (orchard), 100 leaf samples were collected from 20 trees. The samples were then stored in labeled polyethylene bags and transported to the laboratory using an ice box. The counts were conducted directly under stereo binocular microscope using a 6 cm² template, which included three marked 1 cm² sections on both the adaxial and abaxial leaf surfaces. During the counts, the egg and motile stages (larvae, protonymph, deutonymph, male and females) of *E. orientalis* and *P. citri*, as well as any predatory mites present, were recorded separately. The orchard was considered infested if any stage of *E. orientalis* or *P. citri* occurred in a sample. Additionally, the GPS coordinates of each sampled orchard were documented during the survey.

Seasonal occurrance of *Eutetranychus orientalis*, *Panonychus citri* and phytoseiid predatory mites

The seasonal occurrence of *E. orientalis* and *P. citri* was monitored in four different areas between November 2019 and January 2022. The first two studies conducted in an experimental citrus orchard at Çukurova University (Ç.Ü.), Adana. Monitoring focused on lemon (*Citrus limon* (L.) Burm cv. Interdonato) and orange (*C. sinensis* (L.) Osbeck cv. Yafa) species in this area. The third and fourth study sites consisted of sour oranges (*C. aurantium* L.) planted for recreational purposes in both Seyhan district of Adana and Ç.Ü campus areas, respectively. The studies prioritized areas where pesticides were either not used or applied sparingly. In this regard, only a single application of abamectin combined with petroleum oil was applied in May 2021 at the experimental orchard (Table 1).

The seasonal occurrance of both mite species on orange and lemon was monitored in 1 and 2 decare (da) of >20-year-old orchards with an area of 8 da, in Balcalı-Adana. Additionally, the population of the pests on sour orange was monitored on 20 trees in a 1 km-long row of trees in Seyhan district and Çukurova University campus area (Table 1). Based on the biology of *E. orientalis*, leaf samples were collected at 10-15 day intervals during the fall and winter months, when the pests were more abundant, and at 15-20 day intervals during the spring and summer months, when their presence was less frequent (Yalçın et al, 2022; Viola et al, 2023). A total of 100 leaf samples were taken from 20 trees on each of the sampling date in each orchard.

Table 1. Sampling sites information for monitoring the seasonal occurrence of *Eutetranychus orientalis* and *Panonychus citri*

Orchard	No. of trees	Vegetation	Coordination
Lemon (2 da) (>20 yr)	60	Single	37°01'39.2"N 35°21'43.0"E
Orange (1 da) (>20 yr)	30	Single	37°01'39.2"N 35°21'43.0"E
Sour orange (≈15 yr)	200 (km^{-1})	High vegetation	37°03'35.3"N 35°21'35.2"E
Sour orange (≈15 yr)	200 (km^{-1})	Road side	37°01'46.5"N 35°18'39.6"E

The sampling method and the number of samples taken were consistent with those used in the studies on the prevalence of *E. orientalis* and *P. citri*. The results are presented as the mean number of eggs and motile stages per 1 cm² on both sides of the leaves, including the adaxial and abaxial surfaces. During the counts, naturally ocurring predatory mites from the Phytoseiidae family, which were encountered and potentially associated with the pests, were preserved in 70% alcohol for identification purposes, as in the survey. Permanent preparations of the predatory mites were made using Hoyer's medium. The identification of species in both studies was based on Chant & McMurtry (2007) and Döker et al. (2016). Predatory mite densities are given per leaf due to their very low populations. In order to determine the statistical significance of the differences in mite population densities observed on the adaxial and abaxial leaf surfaces of all citrus species, the data were first subjected to homogeneity and normality tests. Subsequent analyses were performed with the non-parametric Mann-Whitney *U* test *(p*<0.05) (SPSS version 23).

Results

Prevalence of *Eutetranychus orientalis* and *Panonychus citri*

A comprehensive survey was conducted across 190 commercial citrus orchards in Adana province and its districts from 2019 to 2021. The results showed that *E. orientalis* was present in 38 (20%) orchards, *P. citri* in 65 (34.2%) orchards, and mixed infestations of both pests in 6 (3.15%) orchards. Additionally, 81 (42.63%) orchards were free from tetranychid mite infestations (Figure 1).

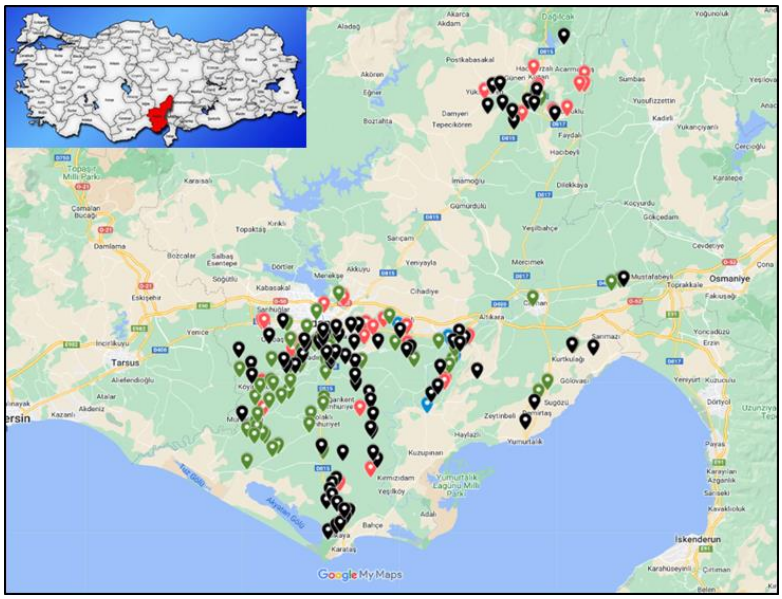

Figure 1. Distribution of *Eutetranychus orientalis* (red), *Panonychus citri* (green), both species coexisting (blue) and pest-free zones (black) in citrus orchards surveyed in Adana between 2019 and 2021.

Infestation rates by citrus species revealed that lemons had the highest infestation rate for *E.* orientalis. Out of the 65 lemon orchards surveyed, 17 were solely infested with *E. orientalis*, while 5 had mixed infestations with *P. citri*, resulting in a total of 22 affected orchards and an infestation rate of 33.84%. Oranges had the second-highest infestation rate, with 16 out of 51 orchards affected, 15 were infested solely with *E. orientalis*, and 1 exhibited mixed infestations. The infestation rate in oranges was 31.37%, nearly identical to that of lemons. In mandarins, *E. orientalis* was found in 6 out of the 69 (8.69%) sampled orchards. However, no biological stages of *E. orientalis* were observed in grapefruit orchards (Table 2).

The presence of *P. citri*, either alone or in combined with *E. orientalis*, was detected in 40 (61.53%) of the 65 lemon orchards surveyed. Oranges displayed the second-highest infestation rate, with 21 out of 51 orchards (41.17%) impacted. In mandarins, *P. citri* was present in 8 out of 69 orchards (11.59%). In contrast to *E. orientalis*, *P. citri* was observed in a single grapefruit orchard (Table 2).

The distribution of *E. orientalis* and *P. citri* infestations across various citrus species and districts exhibited significant regional variation. The highest infestation rates of *E. orientalis* were recorded in Yüreğir, Kozan, and Seyhan districts on lemons, oranges and mandarin, respectively. In contrast, *P. citri* infestations were most prevalent in Yüreğir district across all the three citrus species: lemons, oranges, and mandarins. Notably, *E. orientalis* was absent in grapefruit orchards, while *P. citri* was detected in only one orchard in Seyhan district (Table 2).

Table 2. Occurrence and infestation rates of *Eutetranychus orientalis* and *Panonychus citri* on various citrus species across districts of Adana Province

Citrus species	Total number of orchards (n*)	*E. orientalis* infested orchards (n)	*E. orientalis* infestation rate (%)	*P. citri* infested orchards	*P. citri* infestation rate (%)	Orchards infested with both species (n)	Orchards infested with both species (%)	Number of uninfested orchards (n)	Uninfested orchards (%)
Yüreğir (Districts)									
Lemon	31	8	25.8	17	54.8	4	12.9	2	6.4
Orange	16	3	18.7	9	56.2	-	-	4	25.0
Mandarin	30	2	6.6	6	20.0	-	-	22	73.3
Grapefruit	3	-	-	-	-	-	-	3	100
Total	80	13	16.2	32	40.0	4	5.0	31	38.7
Seyhan									
Lemon	10	-	-	9	90.0	-	-	1	10.0
Orange	12	3	25.0	6	50.0	-	-	3	25.0
Mandarin	15	3	20.0	1	6.6	-	-	11	73.3
Grapefruit	1	-	-	1	100	-	-	0	0.0
Total	38	6	15.7	17	44.7	-	-	15	39.4
Kozan									
Lemon	10	5	50.0	1	10.0	1	10.0	3	30.0
Orange	11	7	63.6	-	-	1	9.0	3	27.2
Mandarin	4	-	-	-	-	-	-	4	100
Grapefruit	1	-	-	-	-	-	-	1	100
Total	26	12	46.1	1	3.8	2	7.6	11	42.3
Karataş									
Lemon	9	2	22.2	5	55.5	-	-	2	22.2
Orange	3	-	-	-	-	-	-	3	100
Mandarin	10	-	-	1	10.0	-	-	9	90.0
Total	22	2	9.0	6	27.2	-	-	14	63.6
Ceyhan									
Lemon	2	1	50.0	1	50.0	-	-	0	0.0
Orange	5	1	20.0	4	80.0	-	-	0	0.0
Mandarin	7	-	-	-	-	-	-	7	100
Total	14	2	14.2	5	35.7	-	-	7	50.0
Sarıçam									
Lemon	2	1	50.0	1	50.0	-	-	0	0.0
Orange	2	1	50.0	1	50.0	-	-	0	0.0
Mandarin	1	1	100	-	-	-	-	0	0.0
Total	5	3	60.0	2	40.0	-	-	0	0.0
Yumurtalık									
Lemon	1	-	-	1	100	-	-	0	0.0
Orange	2	-	-	1	50.0	-	-	1	50.0
Mandarin	2	-	-	-	-	-	-	2	100
Total	5	-	-	2	40.0	-	-	3	60.0
Total	190	38	20	65	34.2	6	3.1	81	42.6

*n: number of surveyed orchards.

Seasonal occurrence of *Eutetranychus orientalis, Panonychus citri* and phytoseiid predatory mites

Seasonal occurrence on lemon

The seasonal abundance of *E. orientalis*, *P. citri*, and the phytoseiid predatory mites on lemon between 2019 and 2022, are presented in Figures 2a, b. The majority of the *E. orientalis* population preferred the adaxial side of leaf for feeding and colonization (Figure 2a). The mean total densities of *E. orientalis* on the abaxial and adaxial leaf surfaces across the entire sampling period were 2.31 and 0.39 all stages/cm², respectively and the difference was found to be statistically significant (Z=-2.936; $p<0.01$). In contrast, the same densities of *P. citri* on the abaxial and adaxial leaf surfaces were 0.05 and 0.12 all stages/cm², respectively, with no significant difference observed (Z=-0.741; $p>0.05$).

Eutetranychus orientalis was first observed in the first week of November in 2019. The pest population increased as ofthis date, with the highest density on the adaxial side of the leaf recorded on 15 December, showing a mean of 3.31 eggs and 0.83 motile stages/cm². Subsequently, the population density decreased to zero by March 2020 (Figure 2a). In 2021, the pest first began to establish a population on 11 October, reaching its peak in early January 2021 with a mean of 7.16 eggs and 2.73 motile stages/cm² on the adaxial side of the leaf. The last individuals were observed in March of the same year. The pest exhibited population development for the second time at the beginning of July 2021, achieving the highest density on November 1, 2021, with a mean of 6.08 eggs and 3.22 active stages/cm², after which it showed a decreasing trend (Figure 2a).

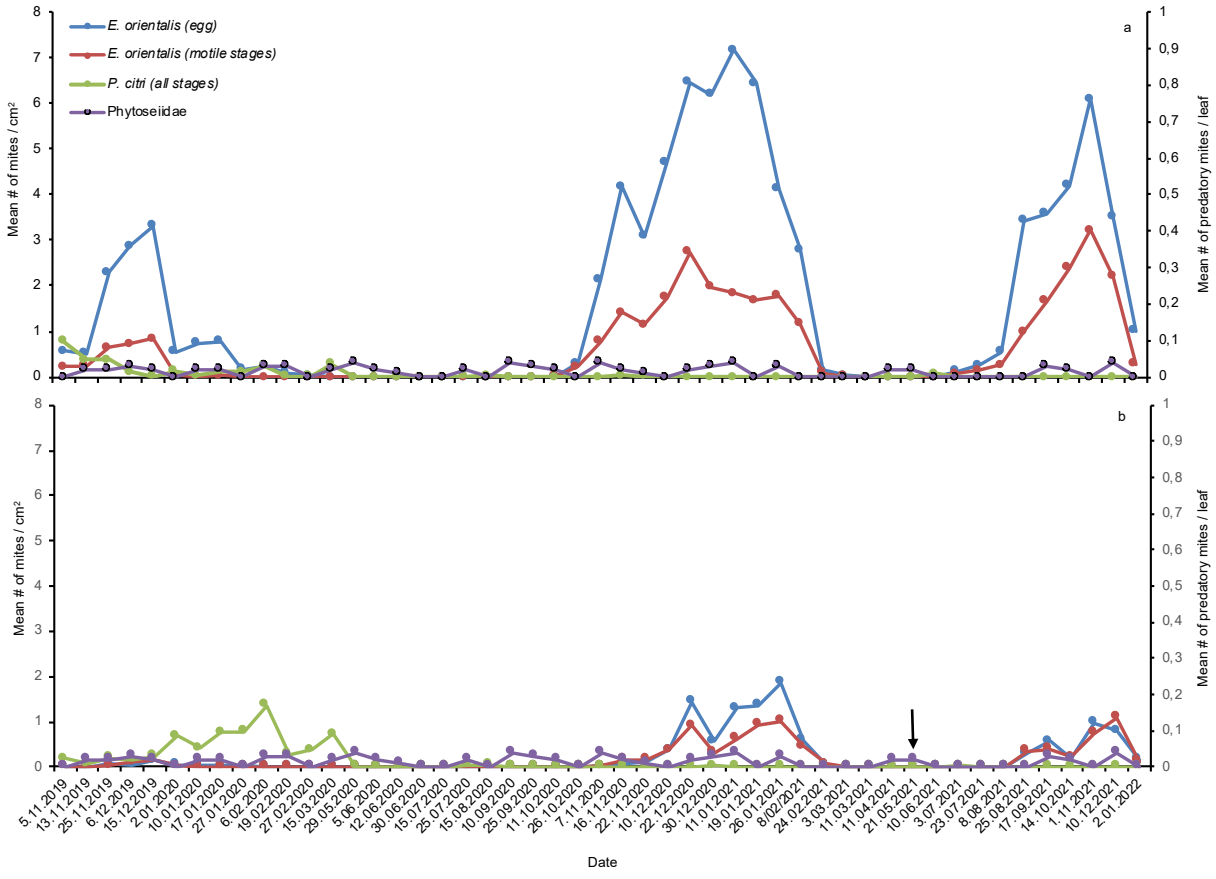

Figure 2. Seasonal occurrence of *Eutetrancyhus orientalis*, *Panonychus citri* and predatory mites on the adaxial (a) and abaxial (b) sides of leaf in lemon (*Citrus lemon* cv. Interdonato) in Adana (arrow: spraying).

The seasonal occurrence of *P. citri* was assessed concurrently with *E. orientalis*, which exhibited its highest density on 5 November 2019, recording 0.77 eggs and motile stages/cm² on the adaxial leaf surface. Following this peak, the population of *P. citri* remained at low levels until March 2020 (Figures 2a, b).

Eutetranychus orientalis exhibited significantly lower population development on the abaxial leaf surface compared to the adaxial side. The highest density on the abaxial side was recorded on 26 January 2021, with a mean of 1.87 eggs and 1.01 motile stages/cm² (Figure 2b). Subsequently, the pest's population remained consistently low, with a secondary peak observed in November 2021, with values of 0.97 eggs and 1.09 motile stages/cm² (Figure 2b). Throughout the sampling period, the total mean densities of phytoseiid predatory mites observed on both the abaxial and adaxial sides of lemon peaked at 0.04 individuals per leaf.

Seasonal occurrence on orange

As in lemon, the primary *E. orientalis* population on orange developed on the adaxial side of the leaves (Figures 3a, b). The mean total densities of *E. orientalis* on the abaxial and adaxial leaf surfaces across the entire sampling period were 1.15 and 0.14 all stages/cm², respectively, with this difference being statistically significant (Z=-2.727; p<0.01). In contrary, the mean total densities of *P. citri* on the same leaf surfaces were 0.007 and 0.006 all stages/cm², respectively, showing no statistically significant difference (Z=-0.281; p>0.05).

The highest population density of the pest, recorded at the beginning of sampling on November 13, 2019, was 3.47 eggs and 1.08 motile stages/cm². Following this peak, the population decreased to its lowest level in March 2020, before increasing again in October. It reached another peak of 3.1 eggs and 1.58 motile stages/ cm² on December 10, 2020. By March 2021, the population had dropped to zero but began to rise again in July. After peaking in December, the population declined once more (Figure 3a).

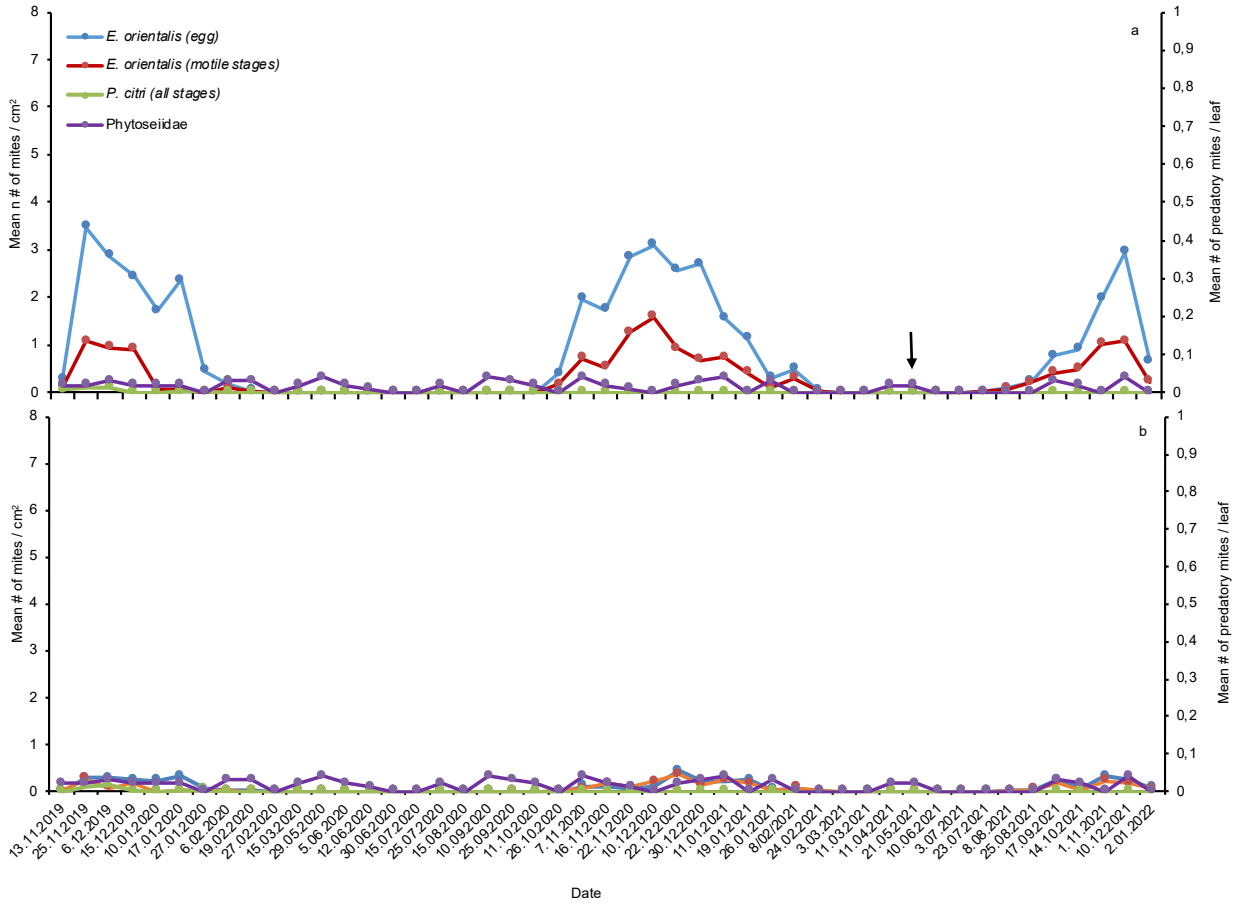

Figure 3. Seasonal occurrence of *Eutetrancyhus orientalis*, *Panonychus citri* and predatory mites on the adaxial (a) and abaxial (b) sides of leaf in orange (*Citrus sinensis* cv. Yafa) in Adana (arrow: spraying).

In contrast, the pest showed no significant population development on the abaxial side of the leaves; it remained at very low levels throughout the study (Figure 3b). Similarly, low populations of *P. citri* were observed on both citrus species and leaf surfaces (Figure 3a, b). During the sampling period, *Amblyseius swirskii* (Athias-Henriot) constituted 95% of the predatory mite species, while the remainder were *Tyhplodromus athiasae* Porath and Swirski (Mesostigmata: Phytoseiidae) (Figure 3a). In both citrus species, the populations of predatory mites remained low and did not exhibit stable development in response to pest density.

Seasonal occurrence on sour orange

Seasonal occurrence of *E. orientalis* and phytoseiid predatory mites on the adaxial and abaxial leaf surfaces of sour orange trees are presented in Figures 4a, b, in Seyhan, Adana. Similar to the lemon and orange, the density of *E. orientalis* determined on the abaxial side of the leaf was higher and statistically different from the adaxial side (Z=-3.595; p<0.001).

In this area, the pest population was detected from the first sampling date, reaching its highest density in mid-December, with an average of 2.82 eggs and 1.39 motile stages/cm² (Figure 4a). After this peak, the population density began to decrease, reaching its lowest level on February 10, 2020. The *E. orientalis* population was first recorded on the 1st of August in the same year, reaching another peak at the end of November, with 4.00 eggs and 2.17 motile stages/cm². Following these dates, the pest population began to decrease again, reaching zero by March 2021. The population resurged on May 21, 2021, and peaked on December 10, with 3.04 eggs and 1.41 motile stages/cm² on the adaxial leaf surface, before decreasing again (Figure 4a). On the abaxial leaf surface, the pest population remained significantly lower compared to the adaxial leaf surface (Figure 4b).

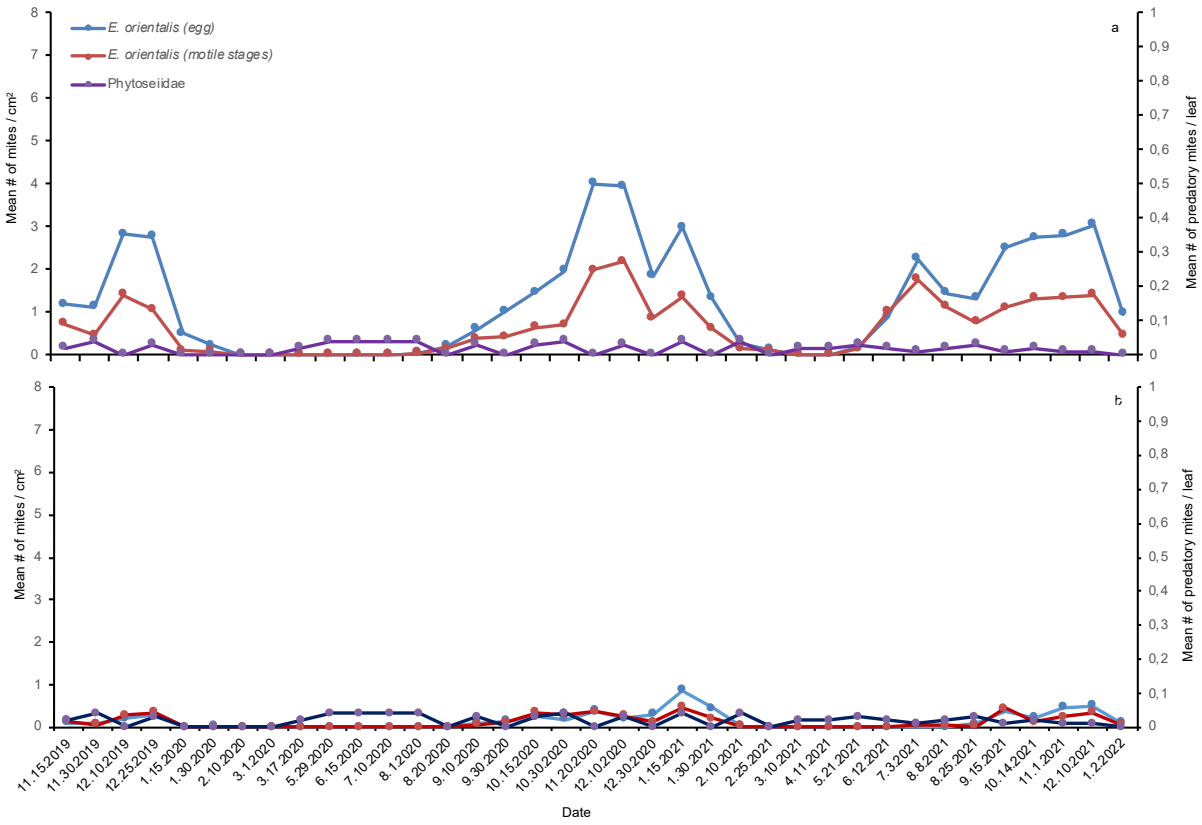

Figure 4. Seasonal occurrence of *Eutetrancyhus orientalis*, *Panonychus citri* and predatory mites on the adaxial (a) and abaxial (b) sides of leaf in sour orange (*Citrus aurantium*) in Seyhan, Adana.

Throughout the study, no biological stages of *P. citri* were observed in the samples. The predatory mite population persisted at a low level and did not increase in response to the increasing pest population (Figure 4a, b). Among the sampled phytoseiid predatory mite species, 57% were identified as *E. scutalis*, while 42% comprised *T. athiasae*, and the remaining portion consisted of *T. intercalaris* Livshitz & Kuznetsov (Figure 4a, b). Consistent with the densities recorded in lemons and oranges, the total density of phytoseiid predator mites across all samples varied between 0.01 and 0.04 per leaf for all stages.

Seasonal occurrence of *E. orientalis* on the adaxial and abaxial sides of the leaves of sour oranges in the Ç.Ü. campus area between 2019 and 2022 is shown in Figures 5a, b. On the first sampling date, the pest's density on the adaxial surface of the leaves was found to be 2.38 eggs and 1.01 motile stages/cm². Subsequently, the pest reached its highest density on December 10, with 3.76 eggs and 1.76 motile stages/cm² on the leaf surface. After this peak, the population began to decrease and had completely disappeared by early February 2020. *E. orientalis* re-emerged for the second time on August 20, 2020, reaching its peak on November 17, with a mean of 3.18 eggs and 1.75 motile stages/cm². After this date, the pest population began to decline again, maintaining low levels until March-April 2021 (Figure 5b). From May onwards, the population began to rise once more, reaching its highest density again in November 2021. On the abaxial leaf surface, the pest population remained significantly lower compared to the adaxial leaf surface (Figure 5b) ($Z=-3.634$; $p<0.001$). No eggs or motile stages of *P.* citri were observed on the orange at Balcalı campus during these surveys. The predatory mite population remained at very low levels ($p<0.05$ all stages/leaf).

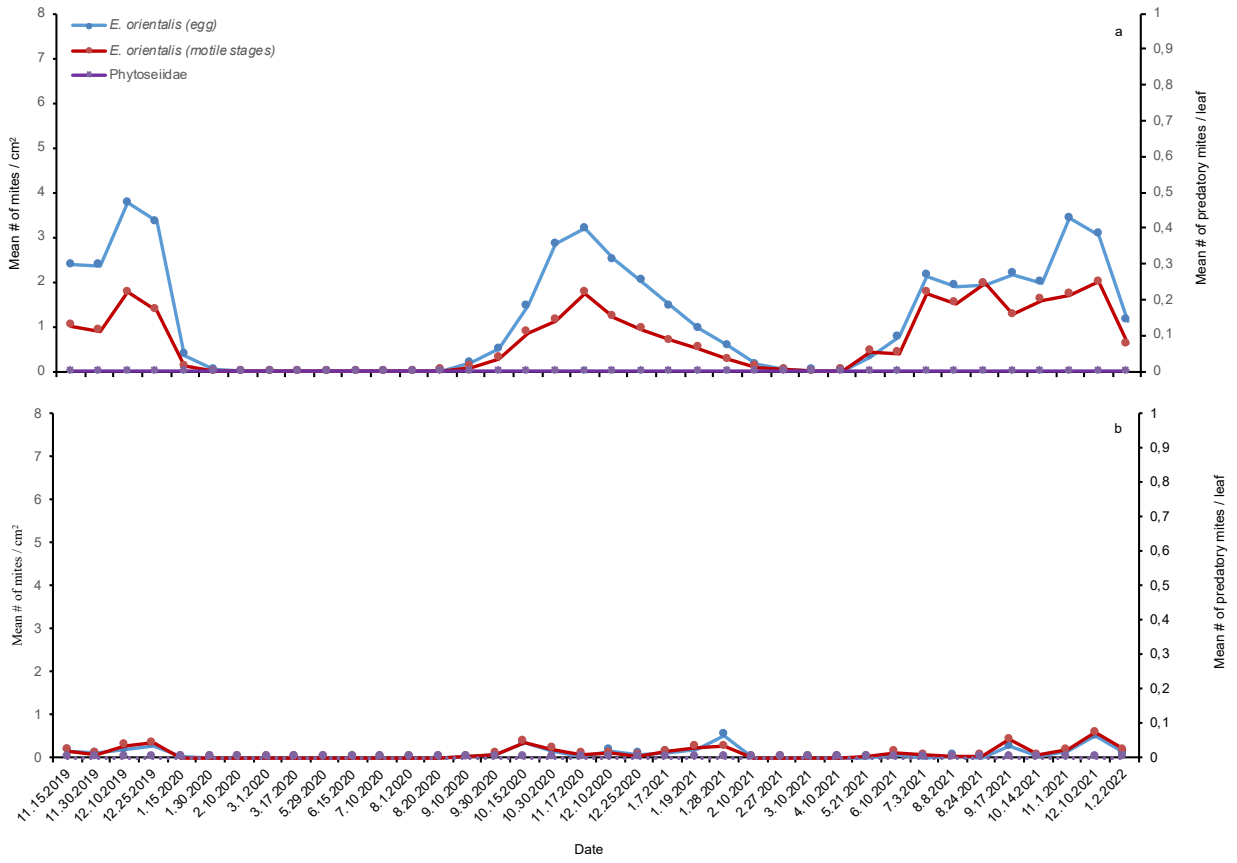

Figure 5. Seasonal occurrence of *Eutetrancyhus orientalis*, *Panonychus citri* and predatory mites on the adaxial (a) and abaxial (b) sides of leaf in sour orange (*Citrus aurantium*) in Ç.Ü. campus area, Adana.

Throughout the years of following the pest population development, the minimum and maximum temperatures were recorded at 6ºC and 37ºC, respectively, while the average humidity varied between 42% and 74%. The highest rainfall was recorded in December 2019, reaching 13 kg/m². The total rainfall varied between 1 and 7 kg/m² (Figure 6).

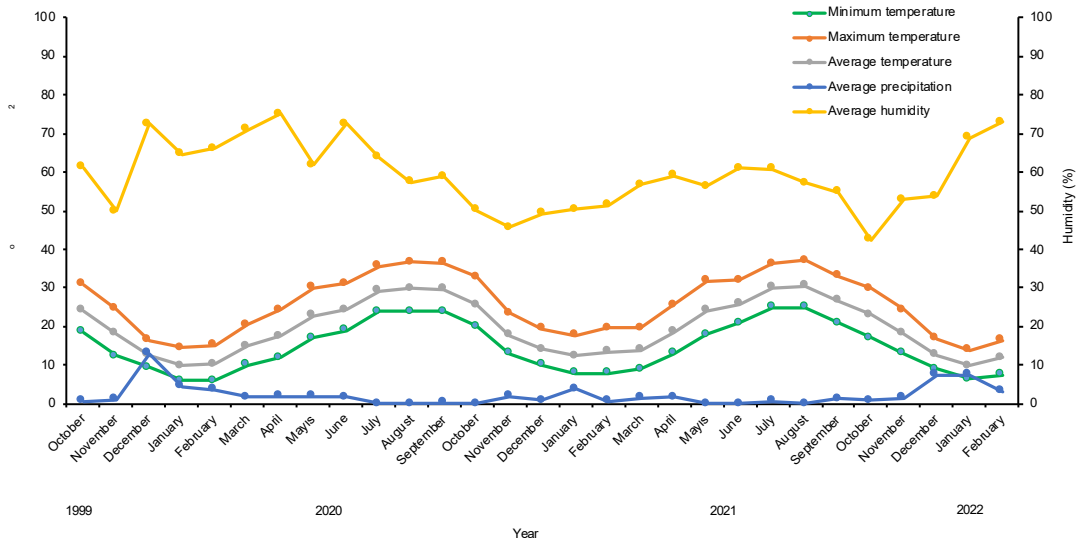

Figure 6. Meteorological data for Adana province during the 2019-2022 period.

Discussion

The presence of *E. orientalis* in Türkiye was first reported in the 1970s, with the first significant population density observed on citrus in 2014 (Jeppson et al., 1975; Çobanoğlu & Can, 2014). Currently, *E. orientalis* is among the most frequently found mites in citrus orchards of the Eastern Mediterranean region (Yalçın et al., 2022). No resistance to commonly used acaricides in the region has been observed on this pest (Akbay et al., 2024). In this context, potential factors contributing to the widespread presence of *E. orientalis* in the region include the impacts of long-term global climate change, as well as the negative effects of intensive pesticide use which may suppress natural enemies that could otherwise control citrus pest populations (Döker et al., 2021). Similarly, Ferragut et al. (2013) reported that *E. orientalis* rapidly became a major pest of citrus in Portugal shortly after its detection in 1999, and by 2001, it had formed dense populations in southern Spain. The pest has also been reported to reach remarkably high population densities in a short period in citrus in Sicily (Garzia et al., 2025). In addition, the capacity of *E. orientalis* to feed and reproduce on a range of host plants beyond citrus is likely a significant factor contributing to its widespread distribution (Beard, 2018; Garzia et al., 2025).

Surveys on lemon, orange, mandarin, and grapefruit orchards revealed that *E. orientalis* infestation rates and host plant preferences varied depending on the citrus species. In this study, *E. orientalis* was the most prevalent on lemon, followed by orange, and mandarin. No infestations were observed in grapefruit orchards. The host plant preference of *E. orientalis* among citrus species has been partially established in previous studies (Ledesma et al., 2011; Vela et al., 2017; Halawa et al., 2020; Chouikhi et al., 2022). These findings align with those of Ledesma et al. (2011), in which the highest infestation rate was on lemon, followed by orange, and the lowest on mandarin in Spain. Similarly, in another study conducted in Spain, *E. orientalis* was identified as the most prevalent tetranychid mite species on orange and lemon trees (Ferragut et al., 2013).

Morphological characteristics of leaves and secondary plant metabolites have significant effects on the feeding, development, and reproduction of phytophagous species. The quantity of tannic acids and the density of glandular structures in the host plant leaves have been found to positively influence mite population growth, while the thickness of the leaf cuticle has a negative impact on the development of certain *Eutetranychus* species (Mohamed, 1965). Overall, the biochemical properties of host plants significantly impact the population development of phytophagous mites. While oil content has been linked to the development duration of *Tetranychus urticae* Koch, 1836 (Prostigmata: Tetranychidae) no such correlation exists for carbohydrate and protein levels (Puspitarini et al., 2021). In contrast, the protein concentration in *C. limon* has been shown to positively influence the development of *E. orientalis* compared to other citrus species (Jyotika & Mandeep, 2003). Additionally,

secondary plant metabolites appear to have a negative effect on mite development (Luczynski et al., 1990; Jyotika & Mandeep, 2003). Yalçın et al. (2022) reported the net reproductive rate (r_m) of *E. orientalis* on lemon, orange, mandarin and grapefruit as 0.167, 0.163, 0.130 and 0.120 females/female/day, respectively. Therefore, it is plausible that the differences observed in the biological characteristics of *E. orientalis* across the three citrus species studied in this study may be attributed to the favorable contents of amino acids, proteins, carbohydrates, and oils found in lemon, which likely support the biological characteristics of the pest (Yalçın et al., 2022).

The seasonal occurrence of *P. citri* exhibited much abaxial density on lemon and orange compared to *E. orientalis*, and no individuals of *P. citri* were found on sour orange. Overall, when the *E. orientalis* population was low on lemon, the density of *P. citri* tended to increase. Rode et al. (2024) reported that *Panonychus ulmi* (Koch, 1836) which belongs to the same genus as *P. citri*, deposited significantly fewer eggs on leaves infested with *Aculus schlechtendali* (Nalepa, 1890) (Prostigmata: Eriophyidae) or *T. urticae*. This finding, alongside the higher population density of *E. orientalis* compared to *P. citri*, and the relatively rare occurrence of both pests coexisting in the same area, suggests the interspecific competition between *P. citri.* In addition, the preference of certain mite species for colonizing the abaxial or adaxial side of leaves is a multifaceted issue influenced by leaf surface characteristics, microhabitat conditions, and interactions with plant structures such as trichomes and domatia (Schmidt, 2014). Interactions between predatory and herbivorous mites also play a role in surface preference. Such behaviors suggest that mites actively choose leaf surfaces that balance environmental conditions and predator avoidance (Sudo & Masahiro, 2013).

In this study, *E. orientalis* populations reached the highest densities between November (mean temp. 18ºC) and January (mean temp. 10ºC), regardless of citrus species. The population declined in early spring and remained low throughout the summer. Similarly, Fathi (2018) reported that *E. orientalis* peaked in winter, especially when rainfall was low and temperatures exceeded seasonal averages in Morocco. In this study, the mean temperature did not fall below 10ºC, including in January, and rainfall was very low. Abdellah et al. (2021), also in Morocco, found two population peaks in the autumn, with low densities in the summer. Ledesma et al. (2011) observed the highest population densities between October and December in southern Spain. In Egypt, *E. orientalis* populations peaked in August and September, with significantly higher density on fruits than leaves (Halawa et al., 2020). Chouikhi et al. (2022) reported four population peaks for the pest in Tunisia between February and May. The results of this study indicate that the temporal patterns of *E. orientalis* population peaks differ from those previously reported for Tunisia and Egypt. These two countries exhibit comparable seasonal dynamics, characterized solely by dry and wet periods, in contrast to the more diverse climatic conditions observed in Turkey, Spain, and Morocco. The development of *E. orientalis* populations in Tunisia and Egypt primarily occurs outside the dry season, which may explain the observed discrepancies in population trends.

The *P. citri* population is generally found at a higher density on the abaxial side of lemon and orange leaves compared to *E. orientalis*, but at much lower densities overall, and no population development was observed on sour orange. Due to the very low population density, it could have not been possible to precisely determine the seasonal population development of the pest related to population density increases. Kasap (2009) reported that *P. citri* exhibited population peaks twice a year, in the spring and fall, depending on the new shoot production in citrus trees. These findings suggest that interspecific competition between these two pests warrants further investigation. Accordingly, Ledesma et al. (2011) reported that *E. orientalis* was the dominant species in lemon and orange orchards in Spain, while *P. citri* and *T. urticae* were present at low densities.

In light of these findings, further data collection is necessary to understand *E. orientalis* seasonal occurrence in detail with a particular concern on lemon, orange, and mandarin orchards. Furthermore, studies are required to determine the dominant species in the competition between *E. orientalis* and *P. citri* within infested orchards. Although preliminary results indicate that *A. swirskii* and *E. scutalis*, two predatory mites commonly found in the Eastern Mediterranean, exhibit predatory efficacy against the pest under controlled conditions, no positive association was detected between these predators and *E. orientalis* populations in untreated citrus orchards. Similarly, Gonzalez-Zamora et al. (2011) reported that *E. scutalis* and *E. stipulatus* showed no response to the population increase of *E. orientalis* in citrus orchards in Spain. Consequently, future studies should focus on evaluating the effectiveness of other potential natural predators, including various phytoseiid predatory mites and insect species, for pest control.

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