JAES
Journal of Anatolian Environmental and Animal Sciences
(*Anadolu Çevre ve Hayvancılık Bilimleri Dergisi*)
DOI: https://doi.org/10.35229/jaes.1444548
Year: 9, No: 1, 2024 (119-126)
AÇEH
Yıl: 9, Sayı: 1, 2024 (119-126)
ARAŞTIRMA MAKALESİ
RESEARCH PAPER

Mite Species Exceeding the Economic Damage Threshold in the Tea Plantation Areas in Türkiye and Population Dynamics in the 2nd and 3rd Harvesting Periods [*]

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Received: *28.02.2023* ***Accepted:*** *19.03.2024* ***Puplished:*** *21.03.2024*
How to cite: **Yazıcı, F. & Akıner, M.M. (2024).** Mite species exceeding the economic damage threshold in the tea plantation areas in türkiye and population dynamics in the 2nd and 3rd harvesting periods. *J. Anatolian Env. and Anim. Sciences,* ***9***(1), 119-126. https://doi.org/10.35229/jaes.1444548
Atıf yapmak için: **Yazıcı, F. & Akıner, M.M. (2024).** Türkiye çay ekim alanlarında 2. ve 3. hasat döneminde ekonomik zarar eşiğini aşan akar türleri ve popülasyon dinamikleri. *Anadolu Çev. ve Hay. Dergisi*, ***9***(1), 119-126. https://doi.org/10.35229/jaes.1444548

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Abstract: The main goal of this study was to determine the mite species exceeding the economic damage threshold level during the 2nd and 3rd harvesting periods and population levels. This study was carried out in tea plantation areas in Artvin, Rize and Trabzon provinces from july to october in the second and third harvesting periods of 2023. Tea leaves were collected from the field by random sampling method by determining 3 districts from each province two times per month (Artvin: Sarp, Hopa Arhavi; Rize: Ardeşen, Çayeli, Derepazarı; Trabzon: Of, Sürmene 1, Sürmene 2). As a result of our study, it was determined that *Polyphagotarsonemus latus* (Acari: Tarsonemidae) (yellow tea mite), the most common species, exceeded the economic damage threshold in all months and in all locations. Especially in the samples collected from Sarp region in September, the number of mites per leaf was recorded as 116,73. *Brevipalpus phoenicis* (Prostigmata: Tenuipalpidae) (flat mite) was detected as a second most common species and found at exceeded EDT (economic damage threshold) in all months in the Sarp region. The same situation was observed in Çayelin in September. Both mite species that exceeded economic damage threshold (yellow tea mite and flat mite) were most frequently observed in september. *Tetranychus urticae*, *Tydeus californicus*, *Calacarus carinatus*, *Tuckerella* sp., mite species were found at some study points, and number of individuals did not exceed economic damage threshold except *Calacarus carinatus* Hopa region october samples.

Keywords: *Brevipalpus phoenicis*, *Polyphagotarsonemus latus*, population dynamics, acarina, tea.

Türkiye Çay Ekim Alanlarinda 2. ve 3. Hasat Döneminde Ekonomik Zarar Eşiğini Aşan Akar Türleri Ve Popülasyon Dinamikleri

Öz: Bu çalışmanın temel amacı, 2. ve 3. hasat dönemlerinde ekonomik zarar eşiğini aşan akar türlerini ve popülasyon düzeylerini belirlemektir. Bu çalışma Artvin, Rize ve Trabzon illerindeki çay ekim alanlarında 2023 yılının ikinci ve üçüncü hasat dönemlerinde temmuz-ekim ayları arasında gerçekleştirilmiştir. Çay yaprakları her ilden 3 nokta belirlenerek ayda iki kez (Artvin: Sarp, Hopa, Arhavi; Rize; Ardeşen, Çayeli, Derepazarı; Trabzon: Of, Sürmene 1, Sürmene 2) rastgele örnekleme yöntemiyle alandan toplanmıştır. Çalışma sonuçlarına göre *Polyphagotarsonemus latus* (Acari: Tarsonemidae)'un (sarı çay akarı) en yaygın tür olduğu gözlenmiştir. Türün tüm aylarda ve tüm lokasyonlarda ekonomik zarar eşiğini aştığı belirlenmiştir. Özellikle Eylül ayında Sarp bölgesinden toplanan örneklerde yaprak başına akar sayısı 116,73 olarak kaydedilmiştir. *Brevipalpus phoenicis* (Prostigmata: Tenuipalpidae) (yassı akar) ikinci en yaygın tür olarak tespit edilmiş ve Sarp bölgesinde tüm aylarda EZE'nin (ekonomik zarar eşiği) üzerinde bulunmuştur. Çayeli'nde ise aynı durum eylül ayında gözlenmiştir. Ekonomik zarar eşiğini aşan her iki akar türü de (sarı çay akarı ve yassı akar) en yoğun olarak eylül ayında gözlenmiştir. Hopa, Arhavi, Ardeşen ve Derepazarı'ndaki örnekleme noktalarında *Calacarus carinatus* türü gözlenmiş ve Hopa bölgesi için Ekim ayında ekonomik zarar eşiğini aştığı saptanmıştır. Bazı çalışma noktalarında *Tetranychus urticae*, *Tydeus californicus*, *Calacarus carinatus*, *Tuckerella* sp., akar türlerine rastlanmış olup, *Calacarus carinatus* Hopa bölgesi ekim ayı örnekleri dışında bu türlerin ekonomik zarar eşiğini aşmadığı gözlenmiştir.

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Anahtar kelimeler: *Brevipalpus phoenicis*, *Polyphagotarsonemus latus*, popülasyon dinamiği, akar, çay.

INTRODUCTION

Camellia sinensis (L.) O. Kuntze is a perennial plant grown in more than 50 countries between latitudes 43°N and 42°S (Barua 1989). According to the Food and Agriculture Organization 2021 data, Turkey ranks after China, India, Kenya and Srilanka in fresh tea production. It has a very high economic value for Türkiye, and yearly production is around 1 million 450 thousand tons on 82,247 hectares. Tea is producted in eastern blacksea area in Türkiye from Georgian border to Fatsa district of Ordu province. Tea is harvested almost every month in regions close to the equator line, while it decreases as you move towards colder climates. In Türkiye, tea is harvested three times a year; the first harvest begins in may and ends in mid-june. The second harvest begins in late june and ends in mid-august, while the third harvest begins in late august and ends in mid-october. Depending on climatic conditions, a fourth harvest may occur in some years.

There are many factors such as harmful mites, insects, various plant diseases, and soil degradation that reduce plant quality in the tea production areas. There are 1031 arthropod species known to interact with tea worldwide, and 3% of these species harm tea agriculture (Chen & Chen, 1989). These pest species cause high losses in tea production. Among these species, phytophagous mites are recognized as one of the most important pests reducing tea yield (Lehmann-Danzinger, 2000). According to a study conducted by Muraleedharan (1992), 12 mite species that damage tea were identified in China, India, Sri Lanka, Taiwan, Indonesia, Japan, Bangladesh and Malaysia. In another study covering Africa and Asia, *Brevipalpus phoenicis* (Geijskes), *Calcarus carinatus* (Green) (Eriophyidae), *Acaphylla theae* (Watt) (Eriophyidae) mite species were found in tea plantation areas (Muraleedharan, 1992; Rattan, 1992).

All phytophagous mites feed on plant sap and cause generally similar damage to the tea plant. They cause scarring, shriveling of the leaves as a result of feeding and brownish spots on the leaves. Since mites are very small in size, they are difficult to be detected until the plant shows signs of damage (Venzon et al., 2008). Yellow tea mite, which is one of the main target species of this study, causes general discoloration of the leaves and brownish spots (Figure 1).

The yellow tea mite (*Polyphagotarsonemus latus*), which spreads in tropical and subtropical regions, causes damage to many plant species (Monika et al., 2017; Gerson 1992; Beattie ve Gellatley 1983; Laffi, 1982; Nemestothy et al., 1982; Aubert et al., 1981). It is a common pest of more than 60 plant families in tropical and subtropical regions (Gerson, 1992; Peña & Bullock, 1994; De Coss-Romero & Peña, 1998; Can & Çobanoğlu, 2010). It was first detected on tea plants in Sri Lanka in 1890. According to the latest nomenclature, it was identified as *Polyphagotarsonemus latus* (Banks) (Trombidiformes: Tarsonemidae) (Gerson, 1992). It was detected for the first time in Türkiye in greenhouse plants in Antalya in 1995 (Uygun et al., 1995). The first record in tea plantation areas was in 2006 by Özman et al. (2006). The longevity of adults is about 4-5 days under optimum conditions (about 25°C and high relative humidity). Females prefer sheltered, small cavities in the fruit or leaves of the plant to lay eggs and attach to leaf surface. This species is multivoltine and able to breed throughout the year, approximately laying of 35 eggs per week in summer. This decreases during the winter months related to climate condition. The species not only affects the development of tea, but also causes serious damage to the shoots. White tea produces newly shoots which antioxidant rich part of tea plant. The damage signs are former discoloration, tanning of the lower surface of leaf and latter curling, breaking, wrinkling, and blister (Kamruzzaman et al., 2013) (Figure 1). Important phenolic compounds such as theaflavin, thearubigin content, and other parameters of the plants such as crude cellulose, water extract and dry matter content are affected by the *P. latus* damage. Çuhadar et al. (2019) determined that the phenolic compounds and some properties were out of the normal level. Tea quality reduces for the reasons listed above, and white tea production is affected more than the other tea products related to the newly shoots damage. Moreover, the yellow tea mite causes the damages to the leaf tissues of annual and perennial cultivated plants such as tomatoes, peppers, and lemon.

Mites can also spread some plant diseases related to the viruses. Many plant pests including Tetranychidae, Tarsonemidae, Tenuipalpidae and Eriophyoide families are polyphagous and vector plant diseases. Additionaly, mite species use the insects as a mechanical vector for transporting and spreading another areas (Palevsky et al., 2001). Childers and Rodrigues (2011), reported high rate of virus-borne diseases and yield loss for *Brevipalpus* genus because of their vectorial role.

Figure 1. A. Yellow tea mite damage; B. Flat spider mite damage.

Tenuipalpidae family members known as flat mites or false spider mites damage many agricultural crops (Escobar-Garcia & Ferragut, 2022). The flat mite lays its eggs on the leaf; along the mid vein and at the base of hairy parts (Das, 1965). Larvae, nymphs, and adults feed around the veins on the lower surface of the leaf. As a result of feeding, brown corky tissue forms on the back side of leaf (Das, 1965). The damage signs and shapes showed Figure 1.

Red spider mites (Acari: Tetranychidae) cause the greatest economic losses in agriculture. They have a high reproductive capacity and give many generations per year. They cause a high rate of damage in open field and greenhouse agriculture because of this. Babu and Muraleedharan (2010), reported that *Oligonychus coffeae* Nietner (Acarina: Tetranychidae), one of the Tetranychidae family members, caused serious damage on tea in Northeast India. *O. coffeae* adults and nymphs cause red brown spots on the upper parts of tea leaves. It has been reported to cause defoliation and 17%-46% crop loss in case the plant is heavily infested (Babu & Muraleedharan, 2010). Additionally, Lahai et al. (2003) indicated that the population density was very high, they could cause up to 100% yield loss for tuberous root of cassava. This study aimed to determine population levels for mite species on tea and situation of the density exceeding the economic damage threshold (EDT) during second and third harvesting period. Secondly, it is aimed to determine mite species in tea plantation areas.

MATERIAL AND METHOD

This study was conducted in two stages: Field and laboratory studies.

Area selection: Tea leaves were gathered from the provinces of Artvin, Rize, and Trabzon. Sampling points and coordinates are provided in Table 1. The selection of areas was based on randomness. Each selected area comprised a minimum of 10 different gardens, which were numbered for identification. From each area, random samples were collected from three of these gardens.

Collection and preservation of specimens: The collection took place over a four-month period from July to October 2023. Collection times were selected at the beginning and middle of each month. In total, collection occurred eight times, with approximately 30 leaves collected at each collection point. A total of 240 leaves were counted and evaluated for the study at each data collection point.

The collected leaves were transported to the laboratory in boxes and immediately examined under a stereo microscope. The number of mites on each leaf, both similar and different across samples, was recorded. Specimens were carefully removed from the leaves using a fine brush (size 00) and preserved in 2 ml of 70% ethanol in Eppendorf tubes. The data were analyzed using the IBM SPSS 22 statistical program and subjected to the Kruskal-Wallis test following a normality test.

***Identification of specimens*:** The tea leaves were examined under a stereo microscope to identify and count flat spider mites and yellow tea mites. Preserved samples were transferred to 90% lactic acid for the removal of internal organs.

Table 1. Collection points of the tea leaves.

Province	District	Coordinates	Altitude
Artvin	Sarp	41°31'03.8"N	41°33'02.9"E
	Hopa	41°23'09.1"N	41°24'58.5"E
	Arhavi	41°21'40.7"N	41°19'41.5"E
Rize	Ardeşen	41°10'59.9"N	40°58'54.2"E
	Çayeli	41°07'21.7"N	40°45'21.3"E
	Derepazarı	41°01'31.5"N	40°23'32.2"E
Trabzon	Of	40°56'17.3"N	40°16'18.5"E
	Sürmene 1	40°55'17.8"N	40°12'38.1"E
	Sürmene 2	40°54'46.9"N	40°10'01.4"E

Female individuals were prepared for morphological diagnosis of mites using Hoyer's solution (200 g chloral hydrate, 30 g crystalline gum arabic, 20 mL glycerol, and 50 mL distilled water) (Anderson, 1954). The preparation was incubated at 45°C for 4 weeks. According to Zhang (2003) and Vacante (2010), the diagnosis of flat mites can be made by examining the body size and various structures of mites using phase contrast microscopy, while the diagnosis of yellow tea mites was performed according to the methodology outlined by Ovando-Garay et al. (2022). Species were further verified by cross-referencing with a previous study conducted in 2022 (Diler et al., 2022).

During the field study, five tea producers in the region were asked three questions to determine tea production amounts and yield losses. The questions were as follows: How was your tea yield during the second harvesting period? How was your tea yield during the third harvesting period? Have any measures been taken against harmful organisms in tea production? The collected responses were analyzed using the IBM SPSS 22 program (IBM corp 2013).

RESULTS

The results of the current study showed that the mite population reached peak level in early September in all localities, following August which is the hottest month of the year. In september, an average of 116, 27 and 41 yellow tea mites per leaf was detected at the Sarp, Ardeşen and Sürmene-2 sampling points, respectively, in the third harvesting period (Figure 2). The leaf samples in these regions also showed a significant curling and color change in the tea leaf structure (Figure 3 A, C). The yellow tea mite is more densely present in fresh shoots part of the tea. It has been observed that the leaves where yellow tea mite is densely seen are extremely sensitive and break off from the branch upon contact. The yellow tea mite has exceeded the economic damage threshold (five mites) per leaf in all three provinces and localities (Figure 2).

Flat mite was detected in all locations except Of sampling point. The samples showed the sign of brown corky tissue forms on the back side of leaf (Figure 3 B, D). It was determined that the EDT was exceeded in all months in the Sarp region. Additionaly, the results obtained from Çayeli region showed that it exceeded the EDT level in September and was around this level in other months (Figure 4). In accordance with the results, both mite species that exceeded EDT (yellow tea mite and flat mite) were most frequently observed in September.

Tetranychus urticae, *Tydeus californicus*, *Calacarus carinatus*, *Neoseiulus californicus*, *Allothrombium* sp. and *Tuckerella* sp. species were found on the leaf samples during the study. The count results showed that the other mite species were less abundant than the yellow tea mite and flat spider mite but did not exceed the economic threshold value.

Tetranychus urticae was found at Hopa and Ardeşen sampling points at every month. *Tydeus californicus* was found at sampling points in Sarp, Hopa, Ardeşen, Çayeli and Of. *Calacarus carinatus* was found at sampling points in Hopa, Arhavi, Ardeşen and Derepazarı. *Tuckerella* sp. was found at sampling points in Sürmene-2, Hopa, and Ardeşen. *Allothrombium* sp. was found at sampling points in Arhavi and Ardeşen. *Neoseiulus californicus* was found at sampling points in Sarp, Hopa, and Çayeli.

Statistical analysis showed that our data set was not normally distributed. The differences between the means obtained by province, sampling point and months were compared using the Kruskall-Wallis test. Only two species densities related to the over densities of EDT were evaluated. The results showed no significant difference between provinces ($p>0.05$), but differences were observed between regions and months ($p<0.05$) for *P. latus* species. Secondly, there was a significant difference between provinces and regions for *B. phoencis* species ($p<0.05$), but not for months ($p>0.05$) (Table 2). For questionnaire, all the participants in Trabzon and Artvin region stated that there was a yield loss of almost 50%, while Rize participants stated that there was a decrease of almost 40%. When the results of the questionnaire were evaluated statistically, no significant difference ($p>0.05$) was found on the provinces, while the results of regions based on the yield loss showed that there was a significant difference ($p<0.05$). 20% of the growers reported that there were practices when asked whether there were any practices in the fields to control mites or other pests. But results showed no significant difference between the city and district (Table 2).

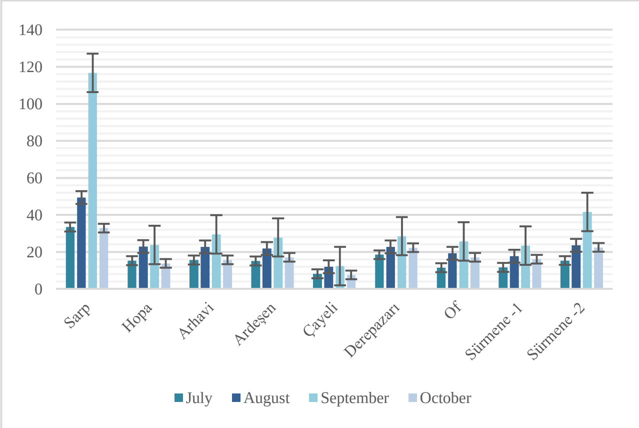

Figure 2. Population Dynamics of the 2nd and 3rd harvesting period of Yellow tea mite.

Figure 3. Tea leaves collected in September showed the following damage: (A) Leaf damage with yellow tea mite only, 118 individuals. (B) Leaf damage with flat spider mite only, 47 individuals. C) Damage to leaves with yellow tea mite only. (D) Damage to leaves with flat spider mites only.

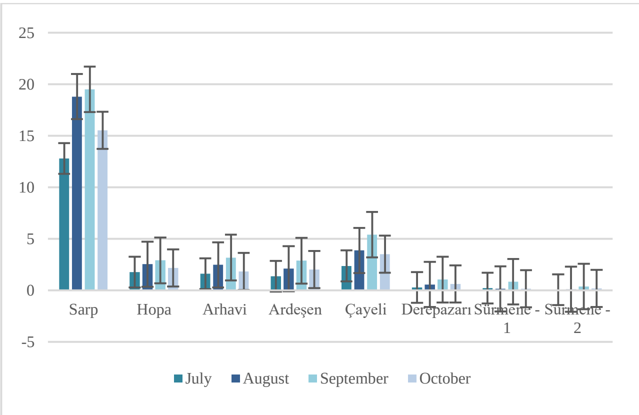

Figure 4. Population Dynamics of the 2nd and 3rd harvesting period of Flat spider mite.

Table 2. Statistical analysis results of the average number of species and questionnaire.

	B. phoencis		*P. latus*			City		District	
	χ2	*p*	χ2	*p*		χ2	*p*	χ2	*p*
City	24,135	0*	4,33	0,115	***Yield1***	0,609	0,738	9,775	0,281
District	28,384	0*	18,923	0,015*	***Yield2***	2,598	0,273	20,165	0,01*
Month	1,568	0,667	12,618	0,006*	***Application***	0	1	3,385	0,908

*indicates significant differences of 95% confidence level.

DISCUSSION

When examining pest studies related to tea in our country, notable research includes studies on *P. latus* and *Orosanga japonica* (Ak et al., 2013; Akyazı et al., 2019; Akıner et al., 2020; Akıner et al., 2021). Diler et al. (2022) identified eight mite species in tea plantation areas, while Çuhadar et al. (2023) reported on yield loss and physicochemical changes in fresh tea leaves associated with *P. latus* density. Akyazı et al. (2022; 2023) investigated the efficacy of extracts from *Prunus laurocerasus* L., *Nicotiana tabacum* L., and *Allium sativum* L. against the yellow tea mite, demonstrating varying degrees of effectiveness for control.

The study by Çuhadar et al. (2023) found that *P. latus* contamination did not affect tea yield in 2013, but that plants with at least 30 mites per leaf had lower yields compared to plots without mites in 2014. The study also highlights population increase during the second year of the study. Our study revealed that mite density was an average of 116 individuals per leaf, as shown in Figure 2. It was also determined structural changes of the leaves such as color differentiation, curling, and wrinkling were also observed on the leaves in these areas (Figure 3 A, C). In the study conducted by Diler et al. (2022) in Rize region, *P. latus* was found to be the most common mite species on tea plants with a rate of 49.7%. Apart from this study, no study investigating the effect of *P. latus* on tea yield was found in the study area. Although this study did not include *P. latus* effects on tea yield, samples from the field show a serious damage on tea leaves containing high dense yellow tea mite. In another study, Zhang et al. (2018) examined the changes in the physiological structure of tea and pointed out that the yield loss incraesed with *P. latus* density. Similarly, the yellow tea mite was determined as the most densely mite species and this implied yield loss may be related to the mite density in the study areas.

It was observed that the density of the *B. phoenicis* was above the EDT in Sarp and Çayeli regions. There are no studies on the effects of flat spider mite (*Brevipalpus phoenicis*) on tea plants and yield loss in Türkiye. In almost all Asian and African countries which are related to tea production, *B. phoenicis* is intensively observed in tea plantation areas and different degrees of yield loss (17% in India, 13% in Indonesia and 12% in Kenya) (Rattan, 1992) have been reported. Furthermore, Sudoi et al. (2001) reported 5%-22% yield loss related to *B. phoenicus* invasion in another study of Kenya. In our study, the species was observed to exceed the economic damage threshold in certain regions, and the changes in leaf color and shape are shown in Figures 1 and 3 B, D. This situation indicated the warning bell for Turkish tea production areas.

There is no record of the two-spotted red spider mite (*Tetranychus urticae*) on tea in Turkey and worldwide. Studies have reported that the red spider mite *O. coffeae*, which belongs to the same family as the two-spotted red spider mite *Tetranychus urticae*, causes yield loss ranging from 17% to 43% of tea (Das, 1959). Its presence has been known since the beginning of tea cultivation in the Assam region of northern India (Peal, 1986). *O. coffeae* was first reported in Turkey by Gökçe et al. (2020) on chestnut trees in the province of Aydın. Another mite species of the family Tetranychidae, *Tetranychus kanzawai*, is an important pest in China, Japan, the Philippines and Taiwan (Ho, 2000). Although the presence and distribution of the two spotted red mites was reported in the eastern Black Sea region on bean (*Phaseolus vulgaris*) plants even in the high altitude Ayder plateau, any study on the damage caused by *T. urticae* in tea has not been reported (Döker et al., 2014). This study is the first record of precense in tea plantation areas for this species. Although the number of the two-spotted red spider mite was found low number of the two areas, this species may expand its distribution in tea plantation areas and need to concern about the distribution pattern and future population situation.

Purple tea mite is known to cause serious yield losses in tea, especially in South India (Muraleedharan & Chandrasekharan, 1981). It (*C. carinatus*) was identified first time for tea plantations in Rize region by Diler et al. (2022). This study revealed the purple tea mite in new areas and in the Artvin and Trabzon region for the first time. While we found 12 individuals on some leaves at Arhavi sampling site, the average density of the species was found to be lower than the EDT.

Species belonging to the Tuckerellidae family was described in tea plantation areas by Diler et al. (2022). Tuckerellidae group is usually found in the fruit or woody part of the plant (Escobar-Garcia et al. 2022). In this study, the Tuckerellidae species was detected at sampling sites in Sürmene, Hopa and Ardeşen. *Tuckerella* sp. should be carefully monitored and controlled in both tea and citrus areas related to the damage potential citrus and tea crops. The most important point is that citrus trees are generally planted around tea plantations, and these two groups are target host status of the species.

In addition to the aforementioned pest mites, one ectoparasite, one predator, and others that are both parasites and predators were observed at the sampling sites. The first of these, *Allothrombium* sp. (Acari: Trombidioidea), is an ectoparasite of aphids as a larve after hatching. Its adults and deutonymphs are predators of many small arthropod species, especially spider mites and aphids (Zhang, 1998). It has no record in Rize and Artvin regions but has been found in soil samples in Trabzon

(Sevsay et al., 2016). This study indicated that this species is distributed at Arhavi and Ardeşen sampling points on tea leaves and revealed its first record of Rize and Artvin.

N. californicus, a predatory mite of the family Phytoseiidae, generally prefers tetranychid mites as food (Castagnoli et al., 1999, McMurtry and Croft, 1997). It has also been identified as a potential predator of *P. latus* (Pena and Osborne, 1996). This mite was detected on tea in Çayeli, Sarp and Hopa, and in Artvin for the first time.

Tydeus californicus (Banks.) (Acari: Tydeidae) is a phytophagous and also predatory, insect-parasitic mite. The species was detected in low numbers in at Sarp, Hopa, Ardeşen, Çayeli and Of sampling sites. Yellow tea mite and flat mite species were also found intensively in the leaves where *T. californicus* was detected. This mite species causes severe damage to grapes, pears and peaches in Italy, and is also known to damage citrus fruits and bean plants in Mediterranean countries (Ferreira & Carmona, 1994). Therefore, it is a need to concern about the distribution pattern and future population situation.

This study revealed that the yellow tea mite is present in all regions; while the flat spider mite has not yet spread as much as the yellow tea mite, it has the potential to do so rapidly. They cause significant quality decreases in tea, pose a serious threat to the citrus production, which is becoming increasingly valuable in the region. For above mentioned reasons and population levels during 2nd and 3rd tea harvesting period, it is essential to create monitoring study for these two species and other potential phytophagus mite species situations in tea plantation areas for taking a right and action about the EDT on time.

CONCLUSION

The population status of species in new areas and their spread are crucial factors, especially in the context of global climate change, as they can exert significant pressures on biodiversity and economically important species in the region. The presence of mites in high populations can lead to substantial yield losses, particularly in areas where citrus grows naturally without any additives. Therefore, monitoring the population levels of these species and taking action when they exceed the Economic Damage Threshold (EDT) is vital for the regional economy and household income.

Understanding the interaction levels between predator and parasitic mites with phytophagous mite species is essential for evaluating their potential as biological control agents in the future. Implementing various control methods, especially biological control strategies that avoid the use of insecticides, is crucial for promoting completely organic tea production, a goal championed by ÇAYKUR, the leading tea manufacturer. Roy et al. (2018) emphasize the importance of biological control not only for preserving the quality of tea but also for minimizing the unnecessary use of pesticides.

ACKNOWLEDGEMENTS

This study was supported by Recep tayyip Erdoğan University the Scientific Research Project Unit Grant Number FOA-2024-1527.

Disclosure statement

The authors declare that there are no conflicts of interest.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author Contribution

All authors contributed to the study's conception, design, experiments, analysis, and preparation of the manuscript. All authors read and approved the final manuscript.

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