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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Possible Negative Effects of the *Calacarus Carinatus* (Prostigmata: Eriophyidae) on the First Harvesting of Tea in Eastern Black Sea Area (Türkiye)

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Abstract: Tea (*Camellia sinensis* L.) is a perennial crop onrush by many arthropod pests. The eriophyid purple tea mite, *C. carinatus* damaged the fresh tea leaves and had a brownish discoloration and affected the tea flavor. It is also a major tea pest together with *Acaphylla theae* in India. This study focused on the population situations and chlorophyll content changes related to the *C. carinatus* infestations. A study was conducted over one year and collected tea leaves in 6 different tea plantation areas in the eastern Black Sea area. Individual count and chlorophyll content were performed the same day after collecting to avoid chlorophyll content changing and specimens dying during the preservation period. Study results showed that *C. carinatus* was found every season but the population started to increase in early February to reach a peak level at the end of March. It also showed that the population began to decrease in early April and finally remained at very low levels throughout the summer. During the high population density time chlorophyll content was adversely affected by the infestation levels. Density-dependent measurements also verify this situation according to the -density category chlorophyll content. Chlorophyll content of the 0, 0-5 individual category showed statistically significant differences from the other density categories. This work may help future tea production plan and their quality by focusing on pest management.

Keywords: *Calacarus carinatus*, population, chlorophyll content, first harvesting, tea.

Doğu Karadeniz Bölgesi (Türkiye)'nde İlk Çay Hasadı Üzerine *Calacarus carinatus* (Prostigmata: Eriphyidae)'un Olası Olumsuz Etkileri

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Öz: Çay (*Camellia sinensis* L.) birçok eklembacaklı zararlının saldırısına maruz kalan çok yıllık bir üründür. Eriophyid mor çay akarı, *C. carinatus* taze çay yapraklarına zarar vererek kahverengimsi bir renk bozulmasına neden olmakta ve çayın tadını etkilemektedir. Ayrıca, Hindistan'da *Acaphylla theae* ile birlikte önemli bir çay zararlısı durumundadır. Bu çalışma, *C. carinatus* istilalarıyla ilgili popülasyon durumlarına ve klorofil içeriği değişikliklerine odaklanmıştır. Çalışma bir yıl boyunca yürütülmüş ve Doğu Karadeniz Bölgesi'nde 6 farklı çay plantasyonundan çay yaprakları toplanmıştır. Klorofil içeriğinin değişmesini ve örneklerin koruma süresi boyunca ölmesini önlemek için örneklerin sayımı ve klorofil içeriği aynı gün içerisinde sonra gerçekleştirilmiştir. Çalışma sonuçları, *C. carinatus*'un her mevsim bulunduğunu, ancak popülasyonunun şubat ayının başlarında artmaya başladığını ve mart ayının sonunda zirveye ulaştığını göstermiştir. Ayrıca, sonuçlar popülasyonun nisan ayının başlarında azalmaya başladığını ve yaz boyunca çok düşük seviyelerde kaldığını göstermiştir. Yüksek popülasyon yoğunluğu zamanında klorofil içeriği istila seviyelerinden olumsuz etkilenmiştir. Yoğunluğa bağlı ölçümler de yedi yoğunluk kategorisi klorofil içeriğine göre bu durumu doğrulamaktadır. 0, 0-5 bireysel kategorinin klorofil içeriği diğer yoğunluk kategorilerine göre istatistiksel olarak anlamlı farklılıklar göstermiştir. Bu çalışma, zararlı yönetimine odaklanarak, çay üretim planına ve kalitesine olumsuz etkilerin önlenmesine yönelik gelecekte yapılacak çalışmalara yol gösterecektirr.

Anahtar kelimeler: *Calacarus carinatus*, populasyon, kolorofil miktarı, ilk hasat, çay.

INTRODUCTION

Phytophagous mites can extensively impact agricultural activity and natural ecosystems. Among these groups, eriophyid mite species have the highest potential to adversely affect agricultural practices. They are obligate plant feeders and show some symptoms that can confused with symptoms caused by viruses, deficiency of some plant nutrients, and physiological disorders. Eriophyidae family species usually have host specificity and can damage all parts of the plant except the root (Westphal & Manson, 1996). Members of this group can also transmit plant pathogens (Oldfield & Proeseler, 1996). Therefore, eriophyid mites ranked second most important group after tetranycid mites related to the yield losses of many economically most important plants. Working with the Eriophyoid mites on their effects on agriculture is a big defiance related to the small size and hidden life. They are widely distributed and found everywhere where their host plants cultivate areas and have a high host specificity (Oldfield, 1996; Skoracka et al., 2010). Environmental conditions variability, cultural practices, and some standards of the markets heavily affected to estimate of these groups' economic importance.

The genus Calacarus is one of the large economically important taxonomic groups in Eriophyoid mites. It consists of renowned pest species such as *Calacarus carinatus* (Green, 1890), *C. coffeae* (Keifer, 1960), *C. brionesae* (Keifer, 1963). This group members are seriously damaging different kinds of economically important crops such as tea, coffee, citrus, orange, and papaya (Lindquist & Amrine, 1996). This genus is connected with different tropical hosts and is reported mainly in tropical and subtropical areas in Asia, South Africa, the USA, and Brazil. Only two Calacarus species (*C. carinatus* and *C. pusillus*) are distributed in Europe (Pye, 2012; Pwkb, 2022). Mansilla et el. (2003) stated that *C. carinatus* is an invasive species in Europe together with *Acaphylla theae*. *C. carinatus* has been recorded in citrus plantation areas in Italy, Spain, Portugal, also reported Hungary, and Poland (Navajas et al., 2010). More than one hundred species of Eriophyoidea have been reported in Türkiye, just only one Calacarini species (*C. carinatus*) reported (Denizhan et al., 2015). It was first recorded in Giresun city on *C. sinensis* by Düzgüneş (1963). Moreover, five eriophyid mite species have been described in tea plantation areas globally, and only one species has been recorded in Türkiye tea plantation areas (*C. carinatus* (Green, 1890)).

Tea (*C. sinensis* L.) is produced in the eastern blacksea area from the Georgian border to the Fatsa district of Ordu province in Türkiye. The harvesting period covers five or six months period three times a year in Türkiye. Some years it collected 4 times related to the climatic conditions (Yazıcı & Akıner, 2024). It starts in early May and ends in early October. Tea is a perennial crop that is affected by many pests during the year. Among these pests, the eriophyid purple mite, *C. carinatus* leads to damage to the leaves that reduces the brightness and flavor of tea (Subaharan & Regupathy, 2006). The effect of *C. carinatus* on tea shows itself as a bronze coloration of the leaf after feeding. It has been reported that due to the intensive infestation of the species on the tea plant, the drying of tea leaves causes premature leaf fall (Shiao, 1976). It also is an important pest of tea in some parts of India and the population density of tea leaves was found high from January to April (Muraleedharan et al., 1994). Genetic and population studies showed that the species generalist of different varieties of tea in China and its passive spread is supported by frequent human commercial activities (Li et al., 2014). Limited studies about the important pest mite species and densities in tea plantation areas of Türkiye generally depend on yellow tea mite and biological control options (Diler et al., 2022; Akyazı et al., 2023; Çuhadar et al., 2023; Yazıcı & Akıner, 2024).

This study firstly aimed to determine population fluctuation during one year of the *C. carinatus* which second most important pest mite group member after tetranycid mites and secondly aimed their effects on chlorophyll content of the tea leaves related to the possible negative effects of the harvesting period.

MATERIAL AND METHOD

Area selection: Tea leaves were collected from three tea-growing provinces (Artvin, Rize, Trabzon) in the Eastern Black Sea Region (Figure 1). From these provinces, two sites were randomly selected between sea level and 75 m altitude. Artvin (Sarp, Hopa), Rize (Hamidiye, Derepazarı) Trabzon (Of, Sürmene) districts. Collection points consisted of at least three gardens.

Figure 1. Study area and collection points of the Eastern Black Sea area of Türkiye

Collection and preservation of specimens: The collection took place during one year from October 2023 to October 2024. Collection of the specimens was carried out twice a month during this period. In total, collection occurred twenty-four times, with more or less 30 leaf samples collected at each collection point. A total of 720 leaf results were evaluated for the study at each collection point. The

collected leaves were transported to the laboratory in boxes and immediately examined under a stereo microscope. The number of *Calacarus* spp. on each leaf was recorded. Samples were carefully removed from the leaves using a fine brush (size 00) and preserved in 2 ml 70% ethanol in Eppendorf tubes for morphological identification.

Identification of specimens: The tea leaves were examined under a stereo microscope to identify and count purple tea mites. Preserved samples were transferred to 90% lactic acid for the removal of internal organs. Mite specimens were cathed using a pin and slide-mounted with Keifer's Booster (Amrine & Manson, 1996) and the generic classification was made according to Amrine et al. (2003) and Han et al. (2015).

Chlorophyll contents during high densities of Calacarus carinatus: Chlorophyll contents were measured between three months (February-April) when the population started to increase and decrease. The reason for determining the measurement time between these dates is that the population exceeded the economic damage threshold in some collection areas. The chlorophyll content of each leaf was measured at five different points using a portable leaf chlorophyll meter (SPAD502, Konica Minolta, Inc., Japan). Measurements were taken from samples from the 4th leaves of tea shoots. Chlorophyll content was measured 6 times in total in the Sarp and Derepazarı regions with 30 4th leaves of tea shots. Average chlorophyll content was used for general evaluation. Chlorophyll content and count of the specimens correlation were evaluated according to the six-week results. The collected leaves were labeled separately and the chlorophyll levels were measured in the laboratory on the same day and the results were recorded. Furthermore, possible density-dependent changes in chlorophyll content were measured for these study areas. Tea shots are separated according to the different densities for these two areas. Seven different density ranges were used for this evaluation (75-60, 60-45, 45-30, 30-15, 15-5, 5-1, 0).

Analysis of the results: The IBM SPSS version 27 processed the results of weekly based chlorophyll content and density-dependent chlorophyll content. Chlorophyll data were analyzed by bivariate correlation weekly count and density-dependent chlorophyll data were analyzed by ANOVA. The means were separated by Tukey HSD post hoc test, with a p-value of 0,05 regard of statistically significant.

RESULTS

Visual differences of 100, 62, and 0 *C. carinatus* density of the lower surface of the tea leaf are shown in figure 2. The population density of the six localities during one year of the Eastern Black Sea area is given in figure 3. The low population densities generally recorded in 2024 from May to July under one person per leaf except Sarp in May and Hamidiye for the second part of June. The lowest count was in the Sürmene region (0 specimens per leaf). Populations started to increase in the first half of February and reached the peak level second half of March. The high population densities were found in March and April for all localities. The highest level of density was recorded for the Sarp region in March 2024 second half. Annual mean temperature and precipitation are given figure 4. Population peaks hold together with increase of temperature and decrease of precipitation.

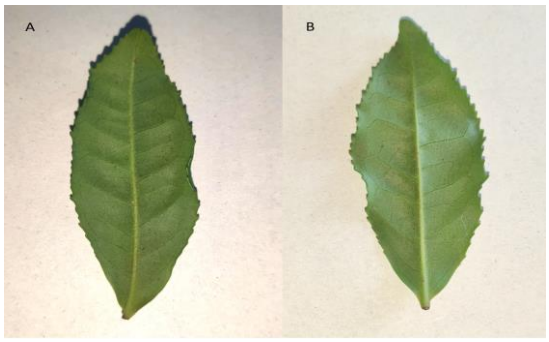

Figure 2. Appearance of the lower surface of the leaf according to the density of the specimens *((A) Leaf appearance by Calacarus carinatus mite (100 individuals) (B) Leaf damage by Calacarus carinatus mite(64 individuals)).*

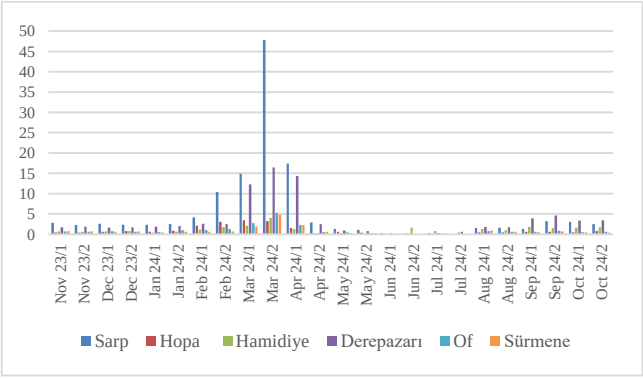

Figure 3. Annual population fluctuations of *Calacarus carinatus* in selected areas of the Eastern Black Sea area.

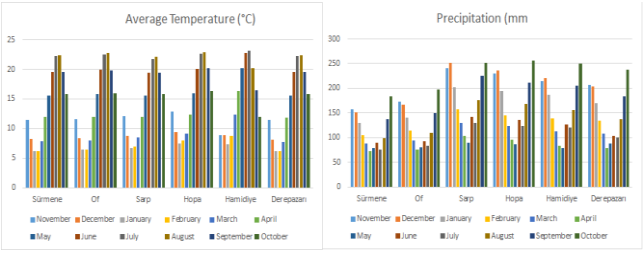

Figure 4. The mean temperature and precipitation of the study period in the study areas.

Three months comparison graphic of individual counts and chlorophyll content are given in figure 5. According to the results, a high degree of chlorophyll content indicated a low number of individuals on a leaf. The correlation of the six times counts specimens and chlorophyll content is statistically significant ($p<0,05$). The bivariate correlation coefficient of the mean count of the specimens and chlorophyll content was found -0,504.

Furthermore, density-dependent results of the seven categories showed a significant difference between groups (p<005) for the two study areas. The analysis of ANOVA and post hoc test based on mean values of the group result is given in Table 1. Boxplot graphs of the results based on the data mean are presented in figures 6 and 7 for Sarp and Derepazarı. It was found that a statistically significant difference between the seventh category and the other groups except between the sixth and seventh categories of Derepazarı. It was also found a statistically significant difference between the sixth category and the others (Table 1).

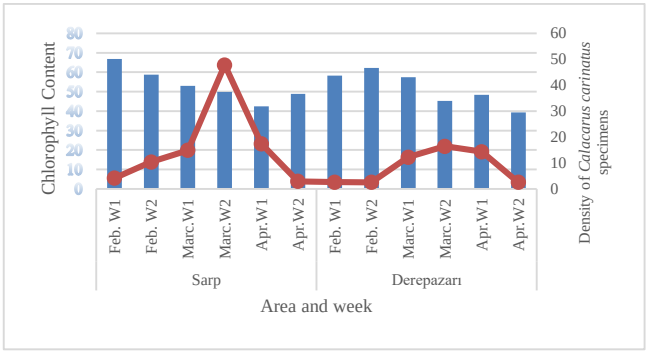

Figure 5. Six week based mean chlorophyl content and mean count of *Calacarus carinatus* comparison according to 30 leaves count and measurements.

Table 1. Analysis results of the chlorophly content and mean individual per leaf based on mean values.

			Sarp	df		f	sig	
	ANOVA			6		39,912	0,00*	
			Derepazarı	6		14,469	0,00*	
	Sarp	1	2	3	4	5	6	7
	1	1	0,068	0,993	1	1	0,02*	0,00*
	2			0,1*	0,091	0,123	0	0,00*
	3				0,983	0,964	0,015	0,00*
	4					1	0,001	0,00*
	5						0,001	0,00*
TUKEY HSD	6							0,00*
	Derepazarı	1	2	3	4	5	6	7
	1	1	0,932	0,971	0,977	0,888	0,00*	0,00*
	2			1	1	1	0,00*	0,00*
	3				0,997	1	0,001	0,00*
	4					1	0,00*	0,00*
	5						0,001	0,00*
	6							0,912

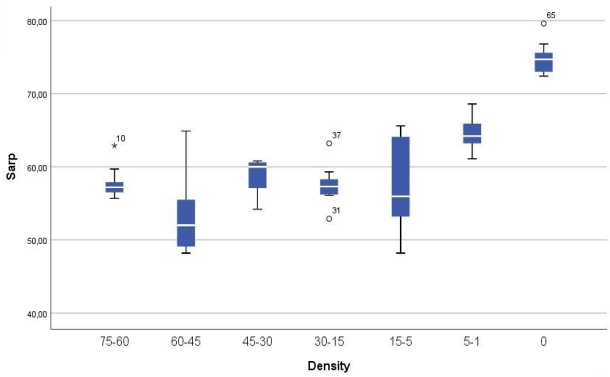

Figure 6. Mean chlorophy content of the leaves according to the density category of the *Calacarus carinatus* specimens from Sarp

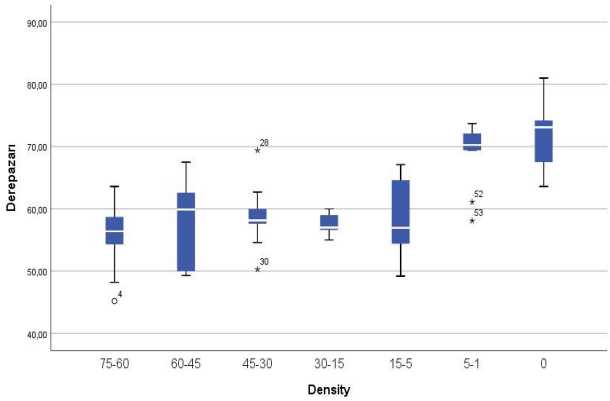

Figure 7. Mean chlorophy content of the leaves according to the density category of the *Calacarus carinatus* specimens from Derepazarı.

DISCUSSION

The purple tea mite *C. carinatus* is an important pest for tea cultivation and economically with *A. theae* in India and Southeast Asia (Channabasavanna, 1996). Both species are on the alien species list in Europe. Records related to the host plant range of *C. carinatus* are, mainly tea, *Viburnum opulus* L., and *Capsicum annuum* L. (Amrine & Stasny, 1994). However, no importance or status notification has been made for Türkiye in tea plantation areas or other areas.

Tea pest studies in Türkiye generally related to *P. latus* and *Orosanga japonica* (Akyazı et al., 2023; Akıner et al., 2020; Yazıcı & Akıner, 2024). The mite species survey study showed eight mite species in tea plantation areas and it just only a surveillance study for the tea plantation areas (Diler et al., 2022). Yazıcı and Akıner (2024), reported that commonly found species for tea plantation areas are *P. latus* and *Brevipalpus phoenicis*. They also found that *C. carinatus* during the survey time but did not imply high population density. Some studies about the mite species' effects on qualitative or quantitative effects reported some side effects of fresh tea production (Çuhadar et al., 2023; Yazıcı and Akıner 2024). In this aspect, Çuhadar et al. (2023) reported that adverse effects on tea related to the *P. latus* density and infestations. It was also found that plants with at least 30 *P. latus* mites per leaf had lower yields. Although the Calacarini genus is obligatory plant-feeding mites, they are not fully understood and are often neglected because of their

extremely small size (average body length, 200 µm) (Manson, 1984). Lee et al. (2014) stated this situation and found two new Acalphlla and *C. carinatus* species after a long survey in tea plantation areas. The same situation also prevailed in Turkiye.

Our study revealed that *C. carinatus* density is higher in early spring than in other seasons and also up the economic damage threshold (EDT). A survey of the year duration showed that *C. carinatus* effects on tea leaves as bronze coloration and intensive infestation for two study areas (Sarp, Derepazarı). Our results consisted of Shiao (1976) related to the bronze coloration and drying of tea leaves and premature leaf fall. We found the population higher season in February to April even if it is not above the economic damage threshold in all areas. These results were also consistent with Muraleedharan et al. (1994) results from some parts of India's *C. carinatus* populations on tea. *C. carinatus* is also a major pest in South India and also been reported that the Assam type of tea is more susceptible to purple mites (Kowsika, 2022). Our study also supported that the Sullivan et al. (2007). They reported that the *C. carinatus* is active during the winter time. They found a higher population level in April to May and a higher reduction in the summer time but our study showed that the population peaked in March and April and population levels gradually decreased end of April and May. Similarly, our results showed a low level of population during summertime.

Our survey during the year stated that the population peak is early spring and this period is important for the first harvesting time related to the area conditions. Chlorophyll content and individual density are related during the high population periods. This study showed that high individual density adversely affected chlorophyll content for the first time in Turkish tea plantation areas. Daud et al. (2012) another Calacarini species' chlorophyll levels changes related to the reduction of rubber three productivity. They reported leaf physiology changes related to the *Calacarus heveae* infestation on rubber trees. Although high relationship between mite infestation and its effects on tea leaves, the studies about this area are very limited. Al Mamun et al. (2016) studied to determine biochemical and physiological changes related to red spider mite infestation on tea leaves. But, they could not determine the gross chemical changes. Banerjee et al. (2019) indicated the relationship between mite infestation and chlorophyll, carotenoids, and xanthophylls. They reported that Darjeeling tea was damaged by the attack of a phytophagous mite and showed a reduction of chlorophyll, carotenoids, and xanthophylls with a rise of phenolic and alcoholic groups due to the mite infestation. They also reported that sugar and protein content were reduced with mite infestation. In this study, we only measured chlorophyll content relation with individual density per leaf during a high-density period. Density-dependent and independent measurements showed the same situation.

CONCLUSION

In conclusion, the extent *of C. carinatus* population dynamics and effects on chlorophyll content on tea leaves have been shown by one-year study efforts in tea plantation areas. Population peak time is important for tea growing before the first harvesting period and also a new shot for white tea production in April for the eastern Black Sea area. Study revealed that the reduction of chlorophyll content also for tea quality even if studies biochemical and physiological changes of the tea leaves have not been done. This work could promote the possibilities the enhancement in astern Black Sea area tea production and its quality by focusing on the pest management. Although there is no study about the pest control *of C. carinatus* or other mite species related to the tea plantation areas in Türkiye, maybe some initial precautions need to be taken before the first harvesting time such as biological control, and predatory species options.

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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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