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Determination of Population Dynamics of Cicadellidae (Hemiptera) Species and Their Relationship with Climatic Parameters in Organic Cotton Fields in Hatay Province, Türkiye

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ABSTRACT
In this study, population dynamics of leafhopper (Hemiptera: Cicadellidae) species in organic cotton-growing areas of Hatay province were investigated along with their associations with climatic parameters. Weekly sampling using a sweep net (100 sweep net/parcel) identified nine species within the Cicadellidae family. Among these, *Asymmetrasca decedens* (Paoli) and *Empoasca decipiens* (Paoli) displayed high population densities throughout the entire vegetation period of cotton, while *Zyginidia sohrab* (Zatchvakin), *Psammotettix striatus* (Linnaeus), *Orosius orientalis* (Matsumura), *Anaceratagallia laevis* (Ribaut), and *Anaceratagallia sinuata* (Mulsant & Rey) were present in both vegetative and reproductive phases of cotton, with *Z. sohrab* reaching significant population levels. *Cicadulina bipunctella* (Matsumura) and *Balclutha hebe* (Kirkaldy) were found only during the reproductive phase, yet they achieved considerably high populations. Correlation and regression analyses have shown a moderate to high level of positive correlation between the population development of five leafhopper species and various temperature (°C) parameters ($r=0.578-0.790$, $p<0.05$). Additionally, a high level of positive correlation has been observed between the population development of *O. orientalis* and maximum humidity (%) ($r=0.732$, $p=0.003$), and a middle level of negative correlation between *P. striatus* and minimum temperature ($r=0.650$, $p=0.011$). These findings indicate that leafhopper species exhibit variations in population presence and densities throughout the cotton vegetation periods, and certain climatic parameters may influence the population development of leafhoppers. The findings from this study may assist in developing more cost-effective and efficient pest management strategies to timely detect and suppress pest leafhopper species in cotton cultivation areas.

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Hatay İlindeki Organik Pamuk Tarlalarında Cicadellidae (Hemiptera) Türlerinin Popülasyon Dinamikleri ve İklim Parametreleri ile İlişkilerinin Belirlenmesi

ÖZET
Bu çalışmada, Hatay ilinde organik pamuk yetiştirilen alanlardaki yaprakpiresi (Hemiptera: Cicadellidae) türlerinin popülasyon dinamikleri ve iklim parametreleriyle olan ilişkileri araştırılmıştır. Atrap ile yapılan haftalık örneklemeler (100 atrap/parsel) sonucunda Cicadellidae familyasına bağlı dokuz tür belirlenmiş ve bunlar arasında *Asymmetrasca decedens* (Paoli) and *Empoasca decipiens* (Paoli)'in popülasyon yoğunluğunun pamuğun tüm vejetasyon dönemi boyunca yüksek seyrettiği, *Zyginidia sohrab* (Zatchvakin), *Psammotettix striatus* (Linnaeus), *Orosius orientalis* (Matsumura), *Anaceratagallia laevis* (Ribaut) ve *Anaceratagallia sinuata* (Mulsant & Rey)'nın pamuğun her iki vejetasyon aşamasında varlık gösterdiği ve *Z. sohrab*'ın popülasyon yoğunluğunun önemli seviyelere ulaştığı görülmüştür. *Cicadulina bipunctella* (Matsumura) ve *Balclutha hebe*

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(Kirkaldy)'nin pamuğun yalnızca generatif döneminde varlık gösterdiği ancak önemli ölçüde yüksek popülasyonlara ulaştığı belirlenmiştir. Korelasyon ve regresyon analizleri, beş yaprakpiresi türünün popülasyon gelişimi ile farklı sıcaklık (°C) parametreleri arasında orta ya da yüksek düzeyde pozitif korelasyon olduğunu (r=0.578-0.790, p<0.05), buna ek olarak *O. orientalis*'in popülasyon gelişimi ile maksimum nem (%) arasında yüksek düzeyde pozitif korelasyon olduğunu (r=0.732, p=0.003) ve *P. striatus* ile minimum sıcaklık arasında orta düzeyde negatif korelasyon olduğunu (r=0.650, p=0.011) göstermiştir. Bu sonuçlar yaprakpiresi türlerinin, popülasyon varlıklarının ve yoğunluklarının, pamuğun vejetasyon dönemleri içerisinde farklılık gösterdiğini ve bazı iklim parametrelerinin yaprakpirelerinin popülasyon gelişimi üzerinde etkili olabileceğini göstermiştir. Çalışmadan elde edilen bulgular, pamuk yetiştirilen alanlarda bulunan zararlı yaprakpiresi türlerinin varlıklarını zamanında tespit etmek ve bunların popülasyonlarını baskı altına alabilmek için daha ekonomik ve etkili zararlı yönetim stratejileri geliştirilmesine yardımcı olabilir.

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.), a pivotal member of the Malvaceae family, is a crucial fiber crop cultivated in approximately 100 countries across temperate and tropical regions (Ozyigit & Gozukirmizi, 2009; Datta et al., 2020; USDA, 2020).

Cotton holds significant economic value, offering wide-ranging applications, contributing to value creation, and providing employment opportunities in producer countries (Majumdar et al., 2019; Rehman et al., 2019). As a versatile raw material, cotton supports various sectors: its fibers are essential to the textile industry, while its seeds are valuable for both oil and feed industries. Additionally, its byproducts, such as lint, are used in paper manufacturing (Ozyigit, 2009; Munir et al., 2020). The oil derived from cottonseed is also finding increasing use as a feedstock in biodiesel production, serving as an alternative to petroleum-based fuels (Sharma et al., 2020; Sundar & Udayakumar, 2020).

In the 2021/22 season, Türkiye achieved a significant standing in the global cotton market, ranking third in the world for cotton yield per harvested hectare at 1,930 kilograms (kgs/ha). This performance also placed Türkiye seventh in global cotton production and fourth in global cotton consumption (ICAC, 2022). The country produced 1.017.500 tons of fiber cotton in an area of 5.7 million decares, which was the result of processing 2.75 million tons of seed cotton in 2022. Most notably, 85.5% of Türkiye's cotton production in 2022 was concentrated in six provinces: Adana accounted for 40%, Şanlıurfa 14%, Diyarbakır 12%, Aydın 9%, Hatay 7%, and İzmir 5% (TÜİK, 2022).

The Cicadellidae family is the largest within the Hemiptera order, encompassing over 40 subfamilies and more than 20,000 described species (Abdollahi et al., 2015; Demirel & Erbey, 2022; Tanyeri & Zeybekoğlu, 2022). These insects can feed on almost all vascular plants and are known to cause significant damage to crops. Most species, commonly referred to as leafhoppers, subsist on the phloem of plants, which can lead to both direct and indirect damage (Dietrich, 2013; Bayhan & Ölmez Bayhan, 2022). In Hatay province, species belonging to the Cicadellidae family are particularly harmful to cotton cultivation areas, with especially severe effects noted in hairless and broad-leaved cotton varieties (Delvare, 1996; Özgür et al., 1988; Bayhan & Ölmez Bayhan, 2022). Leafhoppers infest cotton fields from the emergence of seedlings and continue throughout the vegetation period. Severe infestations cause mottling on the leaves, are harmful to the development of seedlings in the early stages, and result in delayed growth, as well as reduced quality and quantity of the yield (Room & Wardhaugh, 1977; Forrester & Wilson, 1988). Studies and records indicate the presence of 476 Cicadellidae species in Türkiye (Demir, 2006a, 2006b, 2006c; Karavin et al., 2011; Uğur & Bayhan, 2023).

Within the cotton plantations of Türkiye, a complex consisting of the leafhopper species *Asymmetrasca decedens* (Paoli) and *Empoasca decipiens* (Paoli) has been encountered, with both species inflicting considerable damage to the crops. Notably, *A. decedens* emerges as the dominant species in a variety of regional contexts (Başpınar, 1994; Göçmen et al., 1996;

Efil & Güçlü, 2004; Durusoy, 2005; Uğur & Bayhan, 2023). The cotton plant has been reported to be among the host plants for *Orosius orientalis* (Matsumura), a species commonly observed in certain cotton-growing regions within Türkiye, as evidenced by various studies (Efil & Güçlü, 2004; Mart & Sunulu, 2011; CABI, 2021). Additionally, *O. orientalis* holds economic significance in the country due to its role as a vector for the sesame phyllody phytoplasma disease (Sertkaya et al., 2007). It has been reported that *Psammotettix striatus* (Linnaeus) is a significant pest in Türkiye, affecting major crops such as maize and wheat (Mutlu et al., 2008), and attains substantial populations in cotton-growing areas (Mart & Sunulu, 2011). Additionally, this species has been identified as a vector for the wheat blue dwarf (WBD) phytoplasma disease (An et al., 1991). *Zyginidia sohrab* (Zachvatkin) has been recognized as a principal pest of maize in Türkiye, with reports indicating that its population density has reached serious levels in recent years (Atmaca et al., 2021). It is known that *Cicadulina bipunctella* (Matsumura) is a vector for Maize Stripe Virus (MSpV) (Kaya & Başpınar, 2019). Considering the capability of virus-carrying species to migrate long distances at night (Ossiannilsson, 1978), research on this family is of considerable significance.

Various studies have been conducted on leafhoppers in cotton production areas in Türkiye (Özgür et al., 1988; Başpınar et al., 1996; Göçmen et al., 1996; Efil et al., 1999; Atakan et al., 2004; Efil & Güçlü, 2004; Demirel & Yildirim, 2008; Atakan, 2009; Mart & Sunulu, 2011; Dündar et al., 2012; Uğur & Bayhan, 2023), however, these studies are not sufficient to determine the presence and densities of leafhopper populations at different developmental stages of cotton. Additionally, a study elucidating the relationship between the population dynamics of leafhopper species and climatic parameters has not yet been conducted in Türkiye.

Therefore, this study aimed to determine the population dynamics of Cicadellidae species in organic cotton fields in Hatay province and to investigate the correlations between their population development and various climatic parameters.

MATERIAL and METHOD

Study Site

The study focused on an organic cotton field consisting of six parcels where *Gossypium hirsutum* L. was planted with 75 cm inter-row spacing (Table 1). The field is located in the 'Demirköprü' district of Hatay province (36°14'14"N, 36°20'21"E; 92 m elevation). The cotton variety called 'Lazer' was used for organic cotton production in the field, and it is a hairless, medium-tall, early cotton variety (ProGen, 2024). No chemical insecticide application was performed throughout the entire vegetation period of the cotton.

Table 1. The size of the parcels belonging to the field where the study was conducted (in daa) and locality information.
Çizelge 1. Çalışmanın yürütüldüğü tarlaya ait parsellerin büyüklük (daa) ve lokalite bilgileri

Parcels	Size (decares)	Coordinates
A	68	36°14'12"N 36°19'59"E
B	127	36°14'14"N 36°20'21"E
C	161	36°14'06"N 36°20'23"E
D	74	36°13'56"N 36°20'25"E
E	131	36°14'03"N 36°20'42"E
F	89	36°14'20"N 36°20'49"E

Sampling Method

Field sampling was conducted weekly in June, July, August, and September, specifically on the dates 24 June, 1, 7, 15, 22, 29 July, 6, 12, 19, 26 August, 2, and 9 September 2022. Sampling focused on the middle and lower leaves of the cotton plant, utilizing a 45-cm diameter sweep net to collect leafhopper samples. The sweeping process was synchronized with a walking pace, with each step corresponding to one meter and one sweeping motion. To prevent the escape of captured insects, the net was swiftly twisted at a 180° angle at the end of each arc and at the beginning of the subsequent step.

Each sweep sample consisted of 100 step-sweeps, and separate sampling was conducted for each of the six parcels within the field. Throughout the entire vegetation period of the cotton, samples were collected weekly and carefully labeled with information including the region, parcel, sampling number, date of collection, collector's name, and the field owner's name. The collected samples were then transported to the Entomology laboratory at Hatay Mustafa Kemal University and stored at -18°C.

Upon retrieval, frozen samples were delicately separated from soil and vegetation residues using a fine-tipped brush. These samples were examined under a stereo microscope and morphologically separated. However, due to the inability to distinguish between the species *A. decedens* and *E. decipiens* based on morphological characteristics, these two species have been considered as a single species complex. Adult cicadellids were counted among the examined samples, while nymphs, due to their extremely low numbers and inability to be identified, were not evaluated.

Species codes were assigned to the morphologically separated adult samples, which were then placed in 1.5 ml Eppendorf tubes containing 70% alcohol. Each tube was labeled with the species code, date of collection, and the parcel code from which it was collected. The tubes were stored at 4 °C until the preparation process.

Identification of Insect Samples

Genital preparations were made using male individuals of the samples obtained (Kaya & Başpınar, 2019). For the preparation process, the abdomens of male individuals were dissected and heated to boiling point in 10% KOH solution. The solution was boiled and allowed to cool to room temperature (25°C). The material in the cooled solution was placed in a coverslip containing glycerol and the genitalia were separated from the abdomen using a needle under a stereo microscope. Species identification was made by examining the genitalia separated from the abdomen under the same microscope, and the identified samples were placed in a 1.5 ml Eppendorf tube to be evaluated in the study and preserved.

Meteorological Data

The weekly meteorological data for climate parameters were provided by the Hatay Meteorological Directorate (Anonymous, 2022).

Statistical Analysis

In this study, the statistical analysis involved calculating the means and standard errors of data collected from field samples of leafhopper species in 2022 using Excel. These data were subsequently visually presented in conjunction with climate parameters. To elucidate the relationship between population development and climate parameters, Pearson correlation and linear regression analyses were performed utilizing IBM SPSS Statistics (Version 27) software (SPSS, 2020).

RESULTS and DISCUSSION

The Identified Leafhopper Species

In the study, 9 different species from 3 subfamilies within the Cicadellidae family have been identified and are presented in Table 2. Weekly sampling from these parcels yielded a total count of individual leafhoppers for each parcel, with species categorized under their corresponding subfamilies. Notably, the combined count of *A. decedens* and *E. decipiens* represented the most significant population within the Typhlocybinae subfamily, amassing a combined total of 60,620 individuals across all parcels. This suggests a robust presence of these species in the sampled area and potentially indicates their impact on the organic cotton ecosystem. *Zyginidia sohrab*, another member of the Typhlocybinae subfamily, registered the next highest population with 2,271 individuals collected, reinforcing its status as a common resident within the agricultural habitat.

Table 2. Cicadellidae species identified, and total sample numbers obtained from field samplings in Hatay province, 2022

Çizelge 2. Hatay ilinde 2022 yılında yapılan tarla örneklemelerinde belirlenen Cicadellidae türleri ve elde edilen toplam örnek sayıları

Subfamilies	Number of samples collected						
Species	Parcels						Total
	A	B	C	D	E	F	
Deltocephalinae							
Psammotettix striatus (Linnaeus)	71	36	39	53	39	39	277
Circulifer haematoceps (Mulsant & Rey)	5	4	4	6	3	3	25
Orosius orientalis (Matsumura)	29	32	21	30	34	32	178
Cicadulina bipunctella (Matsumura)	181	138	103	155	108	115	800
Balclutha hebe (Kirkaldy)	62	74	91	79	76	75	457
Agalliinae							
Anaceratagallia laevis (Ribaut)	14	13	16	20	11	9	83
Anaceratagallia sinuata (Mulsant&Rey)	33	43	41	43	33	34	227
Typhlocybinae							
Asymmetrasca decedens (Paoli) + *Empoasca decipiens* (Paoli)	8140	16388	12251	7540	6139	10162	60620
Zyginidia sohrab (Zatchvakin)	408	400	478	410	285	290	2271

Species of the Deltocephalinae subfamily also showcased in notable numbers, with *C. bipunctella* amassing the highest count of 800 individuals, followed by *Balclutha hebe* (Kirkaldy) with 457 individuals, and *P. striatus* with 277 individuals, further underscoring the diversity and prevalence of leafhopper species in this particular farming environment. The counts for *Circulifer haematoceps*

(Mulsant & Rey) and *O. orientalis* were lower in comparison but still notable with 25 and 178 individuals, respectively. Within the Agalliinae subfamily, *Anaceratagallia sinuata* (Mulsant & Rey) was more abundant than *A. laevis* (Ribaut), with respective totals of 227 and 83 individuals, pointing to the varied population distributions among the parcels

Population Dynamics of Leafhoppers

Figure 1 illustrates the weekly seasonal population dynamics of *A. decedens* + *E. decipiens* from June 24th to September 9th, 2022. Upon examination of the data, it is evident that the population remained high throughout the entire vegetation period of cotton. A continuous increase in population density was observed starting from June 24th, with the peak for the vegetative phase being reached on July 22nd, recorded at 1206.33±188.28. The transition into the reproductive phase was marked by a decline on July 29th, which was followed promptly by a sharp rise, reaching the highest population peak of the reproductive phase on August 6th, recorded at 1268.83±485.77. This was then followed by a significant drop on August 26th, after which the population fluctuated and recorded the lowest density during the reproductive phase at 510.17±81.00.

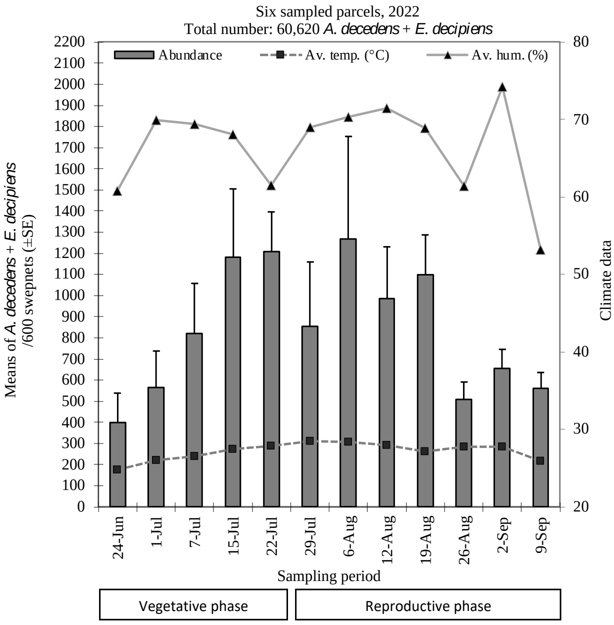

Figure 1. The weekly seasonal population dynamics of *Asymmetrasca decedens* + *Empoasca decipiens* on organic cotton

Şekil 1. Organik pamuk üzerindeki Asymmetrasca decedens + Empoasca decipiens'in haftalık mevsimsel popülasyon dinamikleri

Figure 2 illustrates the weekly seasonal population dynamics of *Z. sohrab* from June 24th to September 9th, 2022. Upon analysis of the data, it was found that no individuals of *Z. sohrab* were detected during the first two weeks of the cotton plant's vegetative growth phase. As the vegetative phase advanced, the population began to be observed from the third week (2.00±0.73), and the number of individuals increased rapidly, reaching a peak during the second week of the reproductive phase on August 6th (69.67±9.37). This peak was followed by a sharp decline to the lowest observed population size in the reproductive phase by August 19th (25.83±3.22), then the population sharply increased again the following week (51.83±9.74) and continued to show a fluctuating and elevated trend in the subsequent weeks.

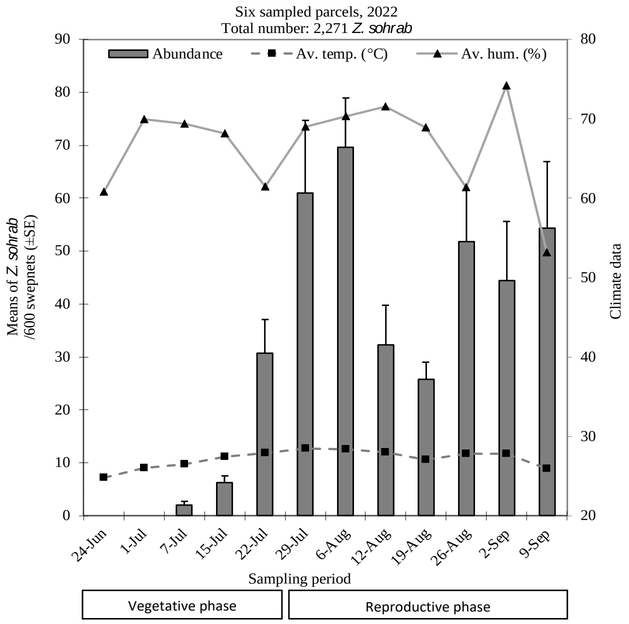

Figure 2. The weekly seasonal population dynamics of *Zyginidia sohrab* on organic cotton

Şekil 2. Organik pamuk üzerindeki Zyginidia sohrab'ın haftalık mevsimsel popülasyon dinamikleri

Figure 3 illustrates the weekly seasonal population dynamics of *C. bipunctella* from June 24th to September 9th, 2022. The data review reveals that during the vegetative phase of the cotton plant, no leafhopper individuals were detected. Population emergence, however, was first documented in the reproductive phase beginning from the second week (August 6th), with an average of 2.50 ± 0.67 individuals. Subsequent weeks saw a gradual increase in population numbers, culminating in a peak at 58.00±9.62 individuals by September 9th.

Figure 4 illustrates the weekly seasonal population dynamics of *B. hebe* from June 24th to September 9th, 2022. Analysis of the data reveals that during the vegetative phase of the cotton plant, no individuals of this species were detected. With the commencement of the cotton plant's reproductive phase on August 6th, population presence was first recorded (0.50±0.34) and subsequently, a sharp and sustained increase in population numbers was observed, culminating in the peak level on September 9th (27.00±4.36).

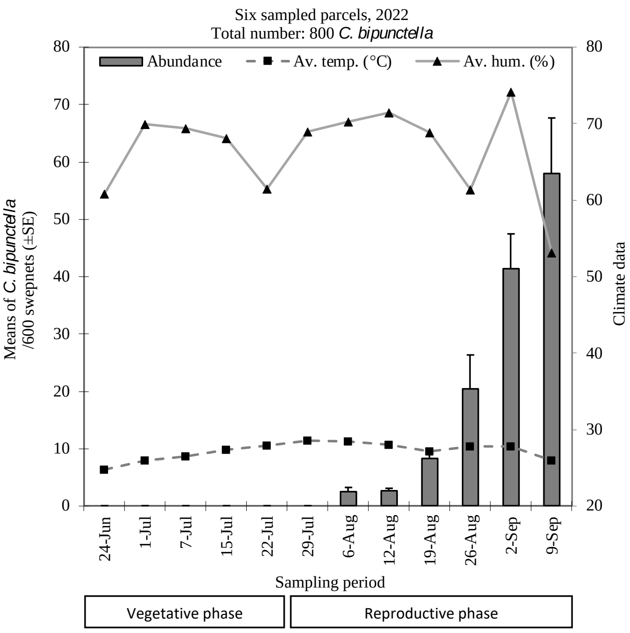

Figure 3. The weekly seasonal population dynamics of *Cicadulina bipunctella* on organic cotton

Şekil 3. Organik pamuk üzerindeki Cicadulina bipunctella'nın haftalık mevsimsel popülasyon dinamikleri

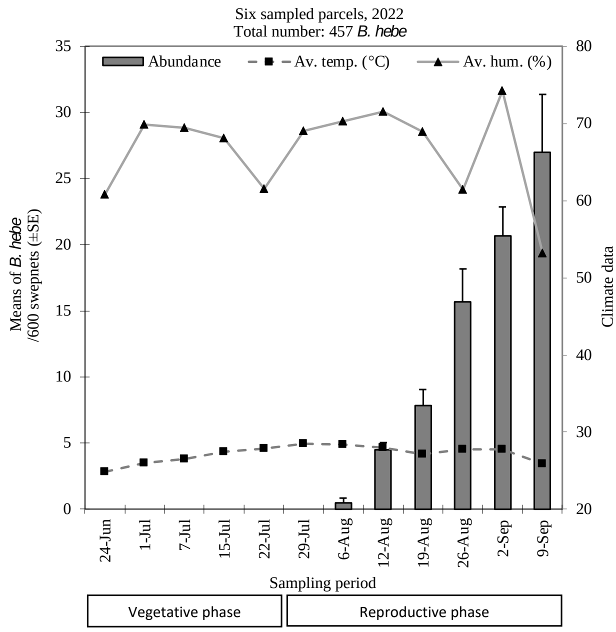

Figure 4. The weekly seasonal population dynamics of *Balclutha hebe* on organic cotton

Şekil 4. Organik pamuk üzerindeki Balclutha hebe'nin haftalık mevsimsel popülasyon dinamikleri

Figure 5 illustrates the weekly seasonal population dynamics of *P. striatus* from June 24th to September 9th, 2022. Analysis of the data reveals that the population density exhibited a fluctuating trend throughout the developmental period of the cotton plant. Observations of initial individuals commenced on June 24th during the vegetative phase, with the population showing a steady increase in the ensuing weeks and reaching a peak in the vegetative phase marked by a high of 4.33±0.80 on both July 1st and 7th. Transitioning into the reproductive phase, the population underwent a decline, thereafter, fluctuating significantly during this phase, and ultimately attaining the highest recorded level on September 9th at 14.17±2.10.

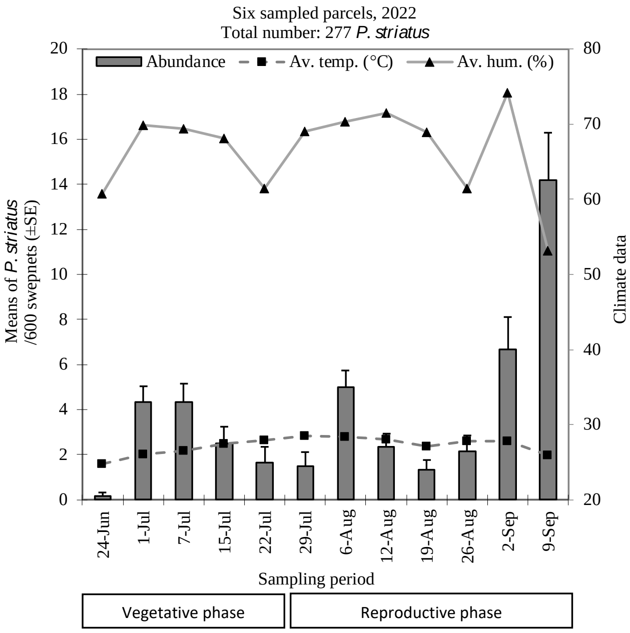

Figure 5. The weekly seasonal population dynamics of *Psammotettix striatus* on organic cotton

Şekil 5. Organik pamuk üzerindeki Psammotettix striatus'un haftalık mevsimsel popülasyon dinamikleri

Figure 6 illustrates the weekly seasonal population dynamics of *O. orientalis* from June 24th to September 9th, 2022. Upon examining the data, the population density is observed to have generally maintained a low level throughout the cotton plant's vegetative phase. The emergence of the first individuals was noted on July 1st (1.00±0.37), with the peak count during this phase recorded on July 15th (3.00±0.58), and the phase concluding with a relatively low population (1.17±0.31). Although the population levels were low during the vegetative phase, a significant increase was evident in the first week of the cotton plant's reproductive phase (July 29th), with the population reaching its maximum (9.33±0.92). The population experienced a sharp decline by August 6th (3.00±0.52), and in the subsequent weeks, it displayed a higher and more variable pattern compared to the vegetative phase.

Figure 7 illustrates the weekly seasonal population dynamics of *C. haematoceps* from June 24th to September 9th, 2022. Upon examining the data, it is observed that the population density remained low during both cotton plant's phenological phases, with an initial presence of individuals on June 24th

(1.33±0.42). No observations were made the following week. A minor presence re-emerged on July 7th (0.67±0.21) and increased slightly by July 15th (1.33±0.33). The population then decreased to zero by July 22nd. As the cotton plant entered the reproductive phase, a very modest increase in population was recorded on July 29th (0.83±0.31). However, from the beginning of August, the population density dropped to zero and remained at this level throughout the reproductive phase.

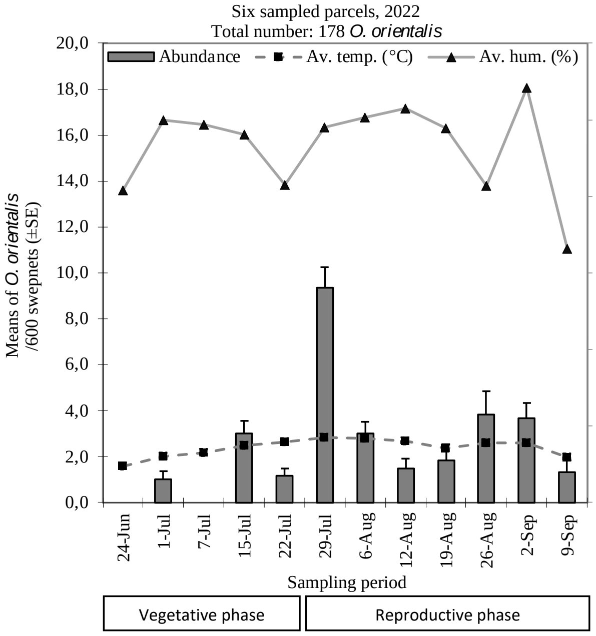

Figure 6. The weekly seasonal population dynamics of *Orosius orientalis* on organic cotton

Şekil 6. Organik pamuk üzerindeki Orosius orientalis'in haftalık mevsimsel popülasyon dinamikleri

Figure 8 illustrates the weekly seasonal population dynamics of *A. laevis* from June 24th to September 9th, 2022. Upon examining the data, it is observed that the population density throughout the monitoring period exhibited a fluctuating and low trend. In the first week of the vegetative phase (June 24th), no individuals were recorded, but the first sightings were noted on July 1st (1.50±0.43), which stood as the highest population level during the vegetative phase. In the subsequent weeks, there was a decrease observed on July 7th (0.50±0.22), a partial increase on July 15th (0.67±0.33), and a drop to zero by July 22nd, concluding the vegetative phase. With the start of the reproductive phase on July 29th, there was a significant increase in population density (3.67±0.76), peaking on August 12th (4.17±0.70). Following this, the population began to decline, dropping to zero on September 2nd and 9th.

Figure 9 illustrates the weekly seasonal population dynamics of *A. sinuata* from June 24th to September 9th, 2022. The data analysis indicates that no individuals were present in the first week. Population density became prominent on July 1st (6.50±0.85), marking the highest average recorded during the vegetative phase.

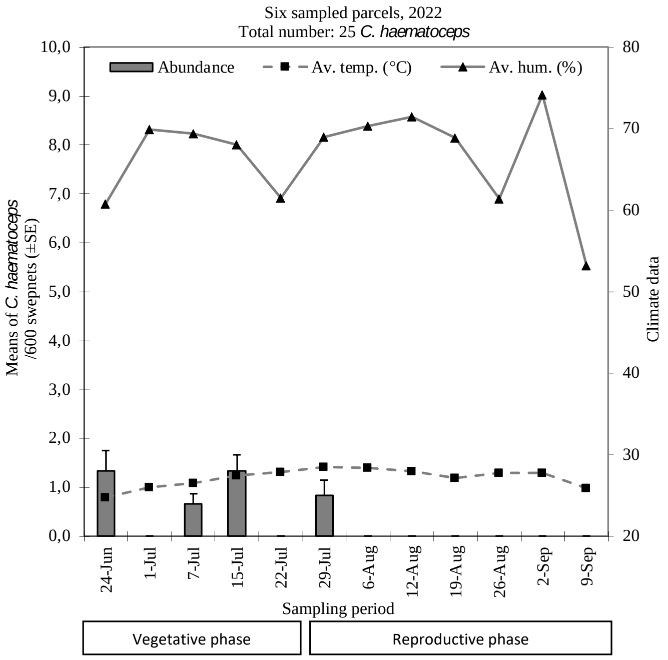

Figure 7. The weekly seasonal population dynamics of *Circulifer haematoceps* on organic cotton

Şekil 7. Organik pamuk üzerindeki Circulifer haematoceps 'in haftalık mevsimsel popülasyon dinamikleri

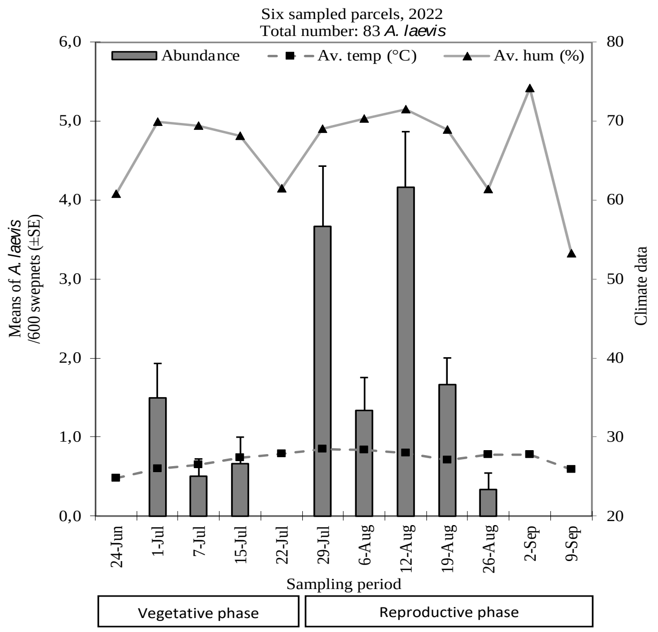

Figure 8. The weekly seasonal population dynamics of *Anaceratagallia laevis* on organic cotton

Şekil 8. Organik pamuk üzerindeki Anaceratagallia laevis 'in haftalık mevsimsel popülasyon dinamikleri

In the following weeks, the population exhibited variability, with a decrease on July 7th (4.67±0.72), a further reduction on July 15th (2.83±0.54), yet nearly returning to initial peak levels on July 22nd (5.83±1.17). Throughout the vegetative phase, the population generally remained at higher levels compared to the subsequent reproductive phase.

As the cotton plant transitioned to the reproductive phase on July 29th, population levels partially declined (5.33±1.56) but reached the highest level within this phase on August 6th (7.50±0.96). The population began to drop after this peak, with a more pronounced decrease evident by August 12th (3.00±0.52), continuing to dwindle in the weeks that followed, reaching a minimal presence by August 26th (0.50±0.22), and disappearing completely on September 2nd and 9th.

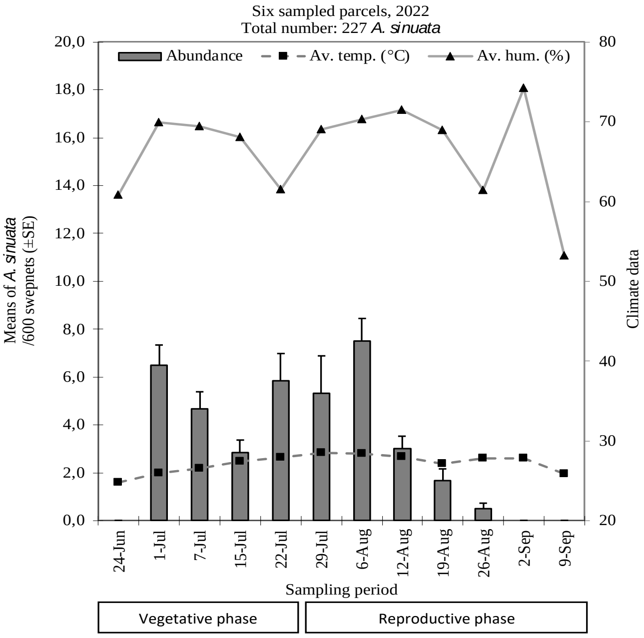

Figure 9. The weekly seasonal population dynamics of *Anaceratagallia sinuata* on organic cotton

Şekil 9. Organik pamuk üzerindeki Anaceratagallia sinuata 'nın haftalık mevsimsel popülasyon dinamikleri

Correlation and Regression Analyses

The statistical analysis summarized in Table 3 reveals significant correlations between the population growth of various leafhopper species and climate parameters. For *A. decedens + E. decipiens*, moderate positive correlations with average (r=0.629, p=0.014) and minimum temperatures (r=0.578, p=0.024) suggest populations increase with warmer conditions, as reflected by regression models y=-3695.73+166.97x and y=-1027.63+78.79x. On the other hand, *Z. sohrab* shows a strong positive correlation with maximum temperature (r=0.790, p=0.001), and a moderate positive correlation with average temperature (r=0.645, p=0.012), indicating a significant rise in numbers during warmer conditions, modeled by y=-475.90+15.87x and y=353.65-14.17x, respectively. Population growth for *C. bipunctella* displays a moderate correlation with maximum temperature as well (r=0.594, p=0.021), with the relationship described by y=-281.51+9.15x. Similarly, *B. hebe* exhibits a trend of increasing numbers with rising maximum temperatures (r=0.608, p=0.018), explained by y=-141.71+4.63x. *P. striatus*, however, has a moderate negative correlation with minimum temperature (r=-0.650, p=0.011), suggesting cooler temperatures might favor its growth, as shown by y=29.67-1.08x. Lastly, *O. orientalis* demonstrates moderate positive correlations with maximum (r=0.637, p=0.013) and average temperatures (r=0.647, p=0.012), as well as a strong positive correlation with maximum humidity (r=0.732, p=0.003), with respective models y=-38.49+1.28x, y=-36.16+1.42x, and y=-18.90+0.255x, indicating that both warmer and more humid conditions are conducive to its population growth. However, no statistically significant correlation has been identified between the population growth of *C. haematoceps*, *A. laevis*, and *A. sinuata* and any climate parameters.

According to the data obtained from the study and the results of statistical analyses, the population distributions and densities of various leafhopper species exhibited variations in accordance with the vegetation stages of cotton. It was observed that certain species' population development could be influenced by different climatic parameters. The species complex comprising *A. decedens + E. decipiens* notably demonstrated the highest prevalence throughout the entire vegetation period of cotton. Similarly, *Z. sohrab*, *P. striatus*, *O. orientalis*, *A. laevis*, and *A. sinuata* exhibited presence during both vegetative and reproductive stages of cotton, with population developments following a fluctuating trajectory. Atmaca et al. (2021) reported that the population of *Z. sohrab* was high during the late August and September periods in cornfields. Likewise, in the current study, *Z. sohrab* was the second most abundant species and its high population density during these months could potentially be explained by the proximity of cornfields to the cotton fields. Conversely, *C. bipunctella* and *B. hebe* populations were only evident during the reproductive phase, with both species observing substantial increases and peaking towards the end of this period (September 9), whereas *C. haematoceps* did not exhibit substantial presence.

Previous studies mentioned that leafhopper population densities reach their maximum during the boll formation and maturation stages of cotton (Baloch & Soomro, 1980; Monsef, 1981; Lodos, 1982; Salem et al., 1988; Göçmen et al., 1996; Atakan et al., 2004, Başpınar et al., 1996; Mart & Sunulu, 2011).

Table 3. Significant correlation coefficient and R^2 values of Cicadellidae populations with respect to climate parameters
Çizelge 3. İklim parametreleri ile Cicadellidae popülasyonları arasındaki önemli korelasyon katsayısı ve R^2 değerleri

Climate parameters (°C / %)	Correlation coefficient (r)	P value	F value	R^2	Line equation
Asymmetrasca decedens (Paoli) + *Empoasca decipiens* (Paoli)					
Average temperature	0.629[b]	0.014	6.56	0.396	y=-3695.73+166.97x
Minimum temperature	0.578[b]	0.024	5.03	0.335	y=-1027.63+78.79x
Zyginidia sohrab (Zatchvakin)					
Maximum temperature	0.790[a]	0.001	16.58	0.624	y=-475.90+15.87x
Average temperature	0.645[b]	0.012	7.13	0.416	y=353.65-14.17x
Cicadulina bipunctella (Matsumura)					
Maximum temperature	0.594[b]	0.021	5.44	0.352	y=-281.51+9.15x
Balclutha hebe (Kirkaldy)					
Maximum temperature	0.608[b]	0.018	5.85	0.369	y=-141.71+4.63x
Psammotettix striatus (Linnaeus)					
Minimum temperature	-0.650[b]	0.011	7.30	0.422	y=29.67-1.08x
Orosius orientalis (Matsumura)					
Maximum temperature	0.637[b]	0.013	6.83	0.406	y=-38.49+1.28x
Average temperature	0.647[b]	0.012	7.18	0.418	y=-36.16+1.42x
Maximum humidity	0.732[a]	0.003	11.55	0.536	y=-18.90+0.255x

[a]High correlation (P<0.05)
[b]Moderate correlation (P<0.05)

In accordance, this study observed that *A. decedens* + *E. decipiens*, *Z. sohrab*, *O. orientalis*, *A. laevis* and *A. sinuata* achieved their highest population densities in the same period. In a study by Kaya and Başpınar (2019) conducted within an agroecosystem encompassing diverse plant parcels, including cotton, notable population densities of *C. bipunctella* using light trap data was reported, with the highest populations observed at the end of August and at the beginning of September. Similarly, in this study, the population of *C. bipunctella* reached a peak during comparable dates, achieving significantly high levels.

Statistical analyses conducted to determine the relationship between population development and climatic parameters have shown that, except for *C. haematoceps*, *A. laevis*, and *A. sinuata*, various temperature parameters (°C) have a statistically significant moderate to high positive effect (excluding *P. striatus*) on the population development of all other species (r=0.578-0.790, p<0.05). Unlike the others, it has also been observed that maximum humidity (%) may have a high and positive impact on the population development of *O. orientalis*, in addition to temperature (r=0.732, p<0.05). In alignment with these findings, Trebicki et al. (2010) similarly documented an increase in the activity of *O. orientalis* correlating with rising temperatures. These results generally suggest that increases in temperature may promote the population growth of leafhopper species.

CONCLUSION

In this study, the population dynamics of leafhopper species in organically cultivated cotton fields in Hatay province were determined, and the relationship between the population developments and climatic parameters was examined. Data obtained from the study indicate that the presence and densities of leafhopper populations varied within the vegetation stages of cotton. Furthermore, this study has provided insights into the potential influence of various climatic parameters on the population development of leafhopper species. These findings can assist in timely detection of pest presence in cotton cultivation areas and support the development of accurate and more cost-effective pest management strategies to suppress harmful leafhopper species.

Contribution Rate Statement Summary of Researchers

The authors declare that they have contributed equally to the article.

Conflicts of Interest

The authors declare no conflict of interest.

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