Journal of Agricultural Sciences (JAS) 32(2):375-384
DOI: 10.15832/ankutbd.1743480

J Agr Sci-Tarim Bili
e-ISSN: 2148-9297
jas.ankara.edu.tr

Abundance Patterns of the Wheat Aphid, *Sitobion avenae* (F.) (Hemiptera: Aphididae) and Beneficial Insects in Wheat Field

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ARTICLE INFO
Research Article
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Received: 16 July 2025 / Revised: 09 December 2025 / Accepted: 10 December 2025 / Online: 24 March 2026

Cite this article
Atakan E (2026). Abundance Patterns of the Wheat Aphid, *Sitobion avenae* (F.) (Hemiptera: Aphididae) and Beneficial Insects in Wheat Field. *Journal of Agricultural Sciences (Tarim Bilimleri Dergisi),* 32(2):375-384. DOI: 10.15832/ankutbd.1743480

ABSTRACT
Aphids were previously considered insignificant pests in wheat production areas in the Mediterranean region of Türkiye. However, in recent years, it has been observed that the honeydew they produce negatively affects plant development due to the increase in their population density. Although abiotic factors (primarily climate) and natural enemies may play an important role in the population development of aphids, their effects are not yet well understood, revealing this information may contribute to aphid's pest management. The field study was conducted in 2022 and 2023 in the Soil and Water Research Station in Tarsus, Mersin province located in the eastern Mediterranean region of Türkiye. The wheat aphid *Sitobion avenae* (F.) (Hemiptera: Aphididae) and their predators and parasitoids were randomly sampled from leaves and ears and counted in the wheat field (cultivar Adana 99). A significant number of aphids and beneficial insects such as coccinellids, syrphids and mummified aphid individuals were collected from the ears. Although no significant relationship was observed between aphid population and climatic factors, relatively warmer (daily average temperature exceeded 20 °C) and drier (varying between 0.95 and 2.27 kg/m^2) spring period may have shortened the vegetation period, leading to earlier plant maturation, thereby reducing aphid development and density in 2023. Despite the positive and strong relationships found between aphid and beneficial insect population densities (total) in both years, this was not sufficient to prevent aphid density when on average, there was slightly more than 20 aphids per leaf + ear, while the number of predators was approximately 2, consequently leading to formation of honeydew and sooty mold in 2022. Therefore, to avoid chemical control, first, habitat planning is recommended to promote earlier colonization of beneficial insects in wheat fields.

Keywords: Aphids, Density, Dry season, Ear, Predation risk, Wheat

1. Introduction

Approximately 20% of the calories obtained from food worldwide come from wheat. Commercially valuable products such as bread, pasta, biscuits, cakes, crackers, bulgur, and breakfast cereals are produced using wheat and milling products with different properties (İslamoglu & Dizlek 2018). In general, in Türkiye, wheat with a protein content of 10–13% is considered suitable for bread-making, while wheat with more than 13% protein is considered suitable for pasta production (Bilgicli & Soylu 2016; İslamoglu & Dizlek 2018).

Globally, in 2024, the wheat cultivation area was 228 270 000 ha, and wheat production was 792 900 000 tonnes. The top five countries in terms of production volume were China (17.45%), India (13.53%), Russia (9.72%), the USA (6.82%), and France (5.30%). Türkiye ranked 10th in the world in terms of wheat cultivation area with 6 600 000 ha and 10th in wheat production with 20 800 000 tonnes (Ozdemir 2025). In Adana province, wheat was planted on an area of 127 426.6 ha in 2024, and a total of 452 219 tonnes of wheat was produced (Anonymous 2025). The average yield was 35.5 kg per ha in 2024. Over the past 30 years, the wheat cultivation area in Türkiye decreased from 9 450 000 ha to 6 600 000 ha, while yield increased from 21.2 kg/ha to 29.6 kg/ha (Anonymous 2025). To increase wheat production despite the decline in cultivation areas, it is essential not only to use high-yield seeds, irrigation, and fertilization techniques but also to control diseases, pests, and weeds, which are among the primary causes of production losses in wheat fields.

Aphids (Hemiptera: Aphididae) are harmful to wheat plants both directly, by feeding on plant sap and, indirectly by transmitting viruses and producing honeydew (Gerding et al. 1989; Stary et al. 1994; Zepeda-Paulo et al. 2013; Raymond et al. 2015). In various wheat-growing regions in Türkiye, the species *Metopolophium dirhodum* (Walker), *Sitobion avenae* (F.), *Rhopalosiphum padi* (L.), *Rhopalosiphum maidis* (Fitch), *Schizaphis graminum* (Rondani), *Sipha maydis* (Passerini), *Sipha elegans* Del Guercio, and *Diuraphis noxia* (Mordvilko) (Hemiptera: Aphididae) have been reported (Tuatay & Remaudiere 1964; Lodos 1982; Elmali 1993; Elmali & Toros 1994; 1996; Ozder & Toros 1999; Aslan 2002; Toros et al. 2002). In Türkiye, *S. avenae* caused an average

of 2.25% crude protein loss in seven wheat varieties in Konya and a 14.2% decrease in thousand-kernel weight (Elmali & Toros 1997).

In the Eastern Mediterranean region and even across Türkiye, there is a prevailing opinion that wheat aphids, as a minor pest in winter-season cereals (such as wheat and barley) are under control due to high parasitism rates and the pressure exerted by effective predators (like coccinellids and syrphids), therefore, applying insecticides unnecessary. Accordingly, insecticide use against wheat aphids is not recommended in Türkiye's integrated pest management guidelines for the cereal pests. However, globally, climate change can influence not only crop production itself but also the prevalence and distribution of biological factors that negatively impact crop yield, such as diseases, pests, and weeds (Scherm et al. 2000; Hullĕ et al. 2010; Boggs & Inouye 2012). In recent years, despite the absence of specific insecticide recommendations, farmers in the Eastern Mediterranean region of Türkiye have been observed to use various groups of insecticides indiscriminately. Indeed, field observations indicate that, under favorable climatic conditions, aphids can become a significant problem in wheat-producing areas in certain years. The occurrence rates and natural enemies of aphid species associated with cereal crops have been reported (Frazier 1988; Gerding et al. 1989; Stary et al. 1994; Hodek & Honek 1996; Sertkaya & Yigit 2002; Bilgin 2006; Obrycki et al. 2009; Zepeda-Paulo et al. 2013). It has been reported that, before the establishment of parasitic wasps, during early spring, coccinellids serve as important predators of aphids in various agricultural systems (Frazier 1988; Hodek & Honek 1996; Obrycki et al. 2009). As previously noted, the development of aphid populations is regulated by both biotic (natural enemies) and abiotic factors, and the influence of these factors may vary across different ecological and geographic regions. Although the importance of predators and parasitoids in suppressing aphid populations within a region has been emphasized, their role in achieving effective aphid control remains poorly understood. Given the significance of aphids in wheat production, the population dynamics of *S. avenae* and its natural enemies were investigated. Additionally, the relationships between abiotic factors (temperature, humidity, and precipitation) and the aphid population dynamics were also examined.

2. Material and Methods

2.1. Sampling area

This study was conducted in 2022 and 2023 at the Tarsus Soil and Water Resources Research Station, which is affiliated with the Alata Horticultural Research Institute (Mersin province, Türkiye) (36. 89789° N, 34.95754° E) located at Tarsus District of Mersin province, Türkiye. This research station conducts studies on field crops, particularly wheat, maize, and soybean.

2.2. Sampling of insects and identification

The wheat variety Adana 99, which is commonly cultivated in the region, was sown on November 15, 2021, and November 18, 2022. The experimental area was 0.1 hectares and divided into four equal subplots, thereby providing replications. Sampling was carried out six times in both years during the period between March 31 and May 5. In each sampling unit, 10 plants were randomly selected from each subplot. Aphids (nymphs and adults) and predatory insects and parasitic wasps i.e. mummified aphid individuals on the flag leaves and ear of each plant were directly counted and recorded. Insect samplings were performed between 08:00 and 10:00 in the morning. mummified aphids were cultured to obtain parasitoid's adults under the laboratory conditions with 25 ºC, and dark period. Key identification guides published by Uygun (1981) and Sengonca (1980) were used for the identification of predatory Coccinellidae and Chrysopidae species, respectively. Parasitoids obtained in mummified aphids was identified by help of key identification in genus level published by Ferrer-Suay et al. (2025).

2.3. Climatic data

Climate data were collected from the meteorological station of the Tarsus Soil and Water Resources Research Station, which is affiliated with the Alata Horticultural Research Institute (Mersin, Türkiye). Using the daily temperatures (maximum, minimum, and average), relative humidity, and precipitation data for the months of March, April, and May, the relationships between these climatic variables and aphid abundance was investigated.

2.4. Analysis of data

The data did not exhibit a normal distribution according to Shapiro-Wilk test; instead, they followed a negative binomial distribution model. The effects of plant parts (leaf and ear), sampling date, year, and their various interactions on aphid and beneficial insects' population densities were analyzed using a Generalized Linear Mixed Model (GLMM) (Ruíz et al. 2023). Aphid or beneficial insect count was the dependent variable, while plant part, sampling date, and year were considered as independent variables and replications as a random factor. A logarithmic transformation was applied to ensure the normalization of the data. Since the effects of different plant organs on aphid beneficial insects' populations varied significantly by sampling date and year, differences between mean aphid numbers were compared using independent-sample t-test at a significance level of $P<0.05$. In this study, because of predatory insects (coccinellids, syrphids) and aphid parasitoids (i.e., mummified aphid individuals) were recorded in low numbers throughout the sampling dates, their counts from all sampling dates were pooled, and the total number of beneficial insects was reported. The larvae and adults of coccinellids were evaluated during the samplings.

Since adult chrysopids and syrphids are not predaceous, only their larvae were included in the assessments. The ratios of predator/beneficial insects (predators and parasitoid insects) were calculated. For this purpose, the sampling period was divided into early (early April to mid-April) and late (after mid-April or the first sampling week of May). The data from 2 or 3 sampling dates were combined in each period. The relationship between average temperature, relative humidity, and precipitation data and the average aphid population density was examined using linear analysis. Similarly, the relationship between the total average population density of beneficial insects and the average number of aphid individuals (nymphs + adults) was examined using the same correlation analysis across both years. The data were analyzed by help of statistical package program SPSS© version 25 (SPSS 2016).

3. Results

3.1. Aphid species and beneficial insects

In 2022, the aphid species *S. avenae* and *R. padi* were identified. In 2023, only *S. avenae* was found. *Rhopalosiphum padi* was recorded only on the first sampling date in 2022, with a total of 20 individuals found on the leaves. At that time, no infestation of *S. avenae* was observed yet. As predatory coccinellids, *Coccinella septempunctata* L. and *Hippodamia variegata* L. were collected, with *C. septempunctata* found to be more common than the other species (Table 1). Syrphidae larvae are predators, primarily feeding on aphids, and are therefore known as aphidophagous. The aphid parasitoids obtained from mummified individuals cultured in the laboratory were determined to belong to the genus *Aphidius*. Minimal number of larvae of green lacewing of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) were found.

Table 1- Beneficial insect species collected from the experimental fields in 2022 and 2023

Order/family	***Insects***	***2022***	***2023***	***Total (2022 + 2023)***
Coleoptera/Coccinellidae	*Hippodamia variegata* L.	4	0	4
	Coccinella septempunctata L.	25	3	28
Diptera/Syrphidae	Syrphids fly (larvae)	27	3	30
Hymenoptera/Braconidae	*Aphidius* sp.	46	11	57
Neuroptera/Chrysopidae	*Chrysoperla carnea* (Stephens)	3	1	4
	Total	105	18	123

3.2. Distribution of aphids on plant parts

The plant part, sampling year, sampling date, and their interactions (plant part × year, plant part × sampling date, year × date, plant part × year × date) significantly affected the aphid population (Table 2). The population density of aphid in 2022 according to sampling dates is shown in Figure 1a. Until March 21, the aphid population was found at low densities in both leaf and ear samples, with 1–3 individuals per leaf and 0–3 individuals per ear. On April 24, a sudden and rapid increase in population density occurred, reaching 15.42 ± 5.63 individuals per ear and 4.10 ± 0.63 individuals per leaf. The average number of individuals decreased sharply by early May (May 5).

Table 2- Results of generalized linear mixed models run for *Sitobion avenae* in wheat

	2022			***2023***		
Source	***df***	***F***	***P***	***df***	***F***	***P***
Intercept	1	78.942	0.000	1	17.017	0.000
Plant part	1	5.113	0.024	5	4.220	0.001
Date	4	12.994	0.000	3	4.300	0.005
Replication	3	1.451	0.228	1	11.515	0.001
Date × replication	12	3.163	0.000	15	1.593	0.072
Date × plant part	4	8.902	0.000	5	3.116	0.009
Replication × plant part	3	2.303	0.077	3	2.929	0.033
Date × replication × plant part	12	2.124	0.015	15	1.072	0.381

Aphid population on March 31 was significantly higher on leaves (F = 22.935, df = 1,6, P = 0.003, t = 2.204) (Figure 1a). On the ears, significant aphid numbers were sampled on April 24 (F = 41.735, df = 1,6, P = 0.001, t = 6.660) and May 5 (F = 10.038, df = 1,6, P = 0.019, t = 3.168) (Figure 1a). In 2023, the population density of aphid by sampling date is also shown in Figure 1b. Compared to 2022, aphid densities in 2023 were lower in both leaves and ears. No aphid individuals were detected on leaves until April 28. The highest recorded density on leaves was 0.20 ± 0.09 individuals/leaf on April 28. On ears, aphid individuals were sampled on most dates, although in small numbers, with the exception of April 14. On the ears, aphid populations on April 28 (F = 6.270, df = 1,6, P = 0.046, t = 2.504) and May 5 (F = 17.383, df = 1,6, P = 0.006, t = 4.169) were relatively higher and statistically significant compared to the leaf population densities (Figure 1b).

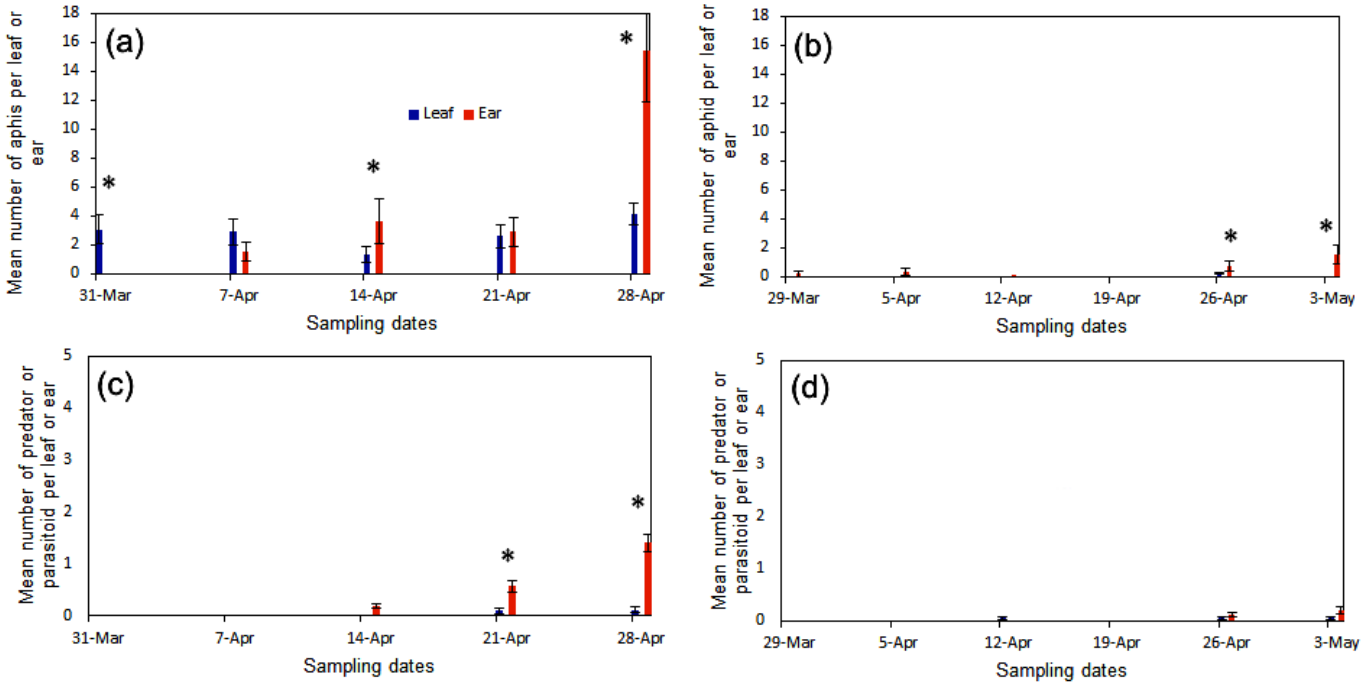


Figure 1- Average densities of *Sitobion avenae* on two different plant parts in wheat in 2022 (a) and 2023 (b), and beneficial insects (total) in 2022 c) and 2023 (d), Asterix denotes the significant difference according to independent-sample t-test at P<0.05

3.3. Distribution of beneficial insects on plant parts

The plant part, sampling year, sampling date, and their interactions (plant part × year, plant part × sampling date, year × date, plant part × year × date) significantly affected the beneficial insect's population (total) (Table 3). The distribution of beneficial insects (predatory insects + parasitized aphid individuals) on the leaf and ear organs of the plant throughout the sampling dates in the years 2022 and 2023 is shown in Figures 1c, d. In both years, beneficial insects appeared later than the aphid populations. The first parasitized individuals were recorded on the leaves. The average numbers of beneficial insects were significantly higher on the ears on April 21 (F = 14.747, df = 1,79, P = 0.0001, t = 3.840) and April 28 (F = 55.047, df = 1,79, P = 0.0001, t = 4.169) than those found on leaves (Figure 1c). In 2023, the number of beneficial insects, similar to aphids, was considerably lower across all sampling dates in both plant organs compared to the previous year (Figure 1d). On April 12, very few parasitized individuals were found on the leaves, and none were observed on the ears, but this difference was not statistically significant (F = 2.053, df = 1,79, P = 0.156, t = 1.433; Figure 1d). On May 3, the average number of beneficial insects on the ears was higher than on the leaves, and this difference was statistically significant (F = 4.229, df = 1,79, P = 0.043, t = 2.056).

Table 3- Results of generalized linear mixed models run for beneficial insect (total) in wheat

	2022			***2023***		
Source	***df***	***F***	***P***	***df***	***F***	***P***
Intercept	1	94.188	0.000	1	14.268	0.000
Plant part	1	59.582	0.000	5	7.111	0.000
Date	4	2.008	0.056	3	0.145	0.598
Replication	3	96.494	0.000	1	3.128	0.078
Date × replication	12	3.967	0.001	15	3.502	0.000
Date × plant part	4	40.020	0.000	5	3.128	0.009
Replication × plant part	3	10.953	0.000	3	1.426	0.235
Date × replication × plant part	12	6.016	0.000	15	1.017	0.436

3.4. Population dynamics of aphids

According to climatic factors (Figures 2a, b), population densities of aphids and beneficial insects on two plant parts (Figures 2c, d) are shown. Aphid population density during the vegetation period from the first sampling date until April 21 varied similarly between 3-5 individuals per leaf + ear (Figure 2c). The pest aphid population clearly increased on May 28, reaching its peak at 19.40 ± 3.68 individuals per leaf + ear. On this date, the beneficial insect population also increased, reaching its highest population density (1.57 ± 0.15 individuals per leaf + ear; Figure 2c). During the period when the aphid population developed in

2022, the average temperature was 16-17 °C and relative humidity was between 50-64% (Figure 2b). On the date when the population density increased significantly, the average temperature rose to 20 °C. Unlike the previous study year, in 2023, the aphid population density remained low throughout all sampling dates (Figure 2d). Starting from April 19, the aphid population began to increase, reaching its highest average number of individuals at 1.60 ± 0.65 per leaf + ear on May 3. Beneficial insects were absent or recorded in very low numbers in many sampling dates up to May 3rd (Figure 2d). Due to the increase in pest density in May, the total average number of beneficial insect individuals also increased (0.25 ± 0.05 individuals per leaf + ear). Unlike the previous sampling year, April was warmer and rainier compared to previous sampling year. In 2023, average temperatures in April were 17-18 °C, rising up to 20 °C at the beginning of May. While no rainfall was observed during the sampling period in 2022, the rainfall in 2023 ranged between 0.6 and 6.42 kg per m². Accordingly, relative humidity was generally above 70% in 2023.

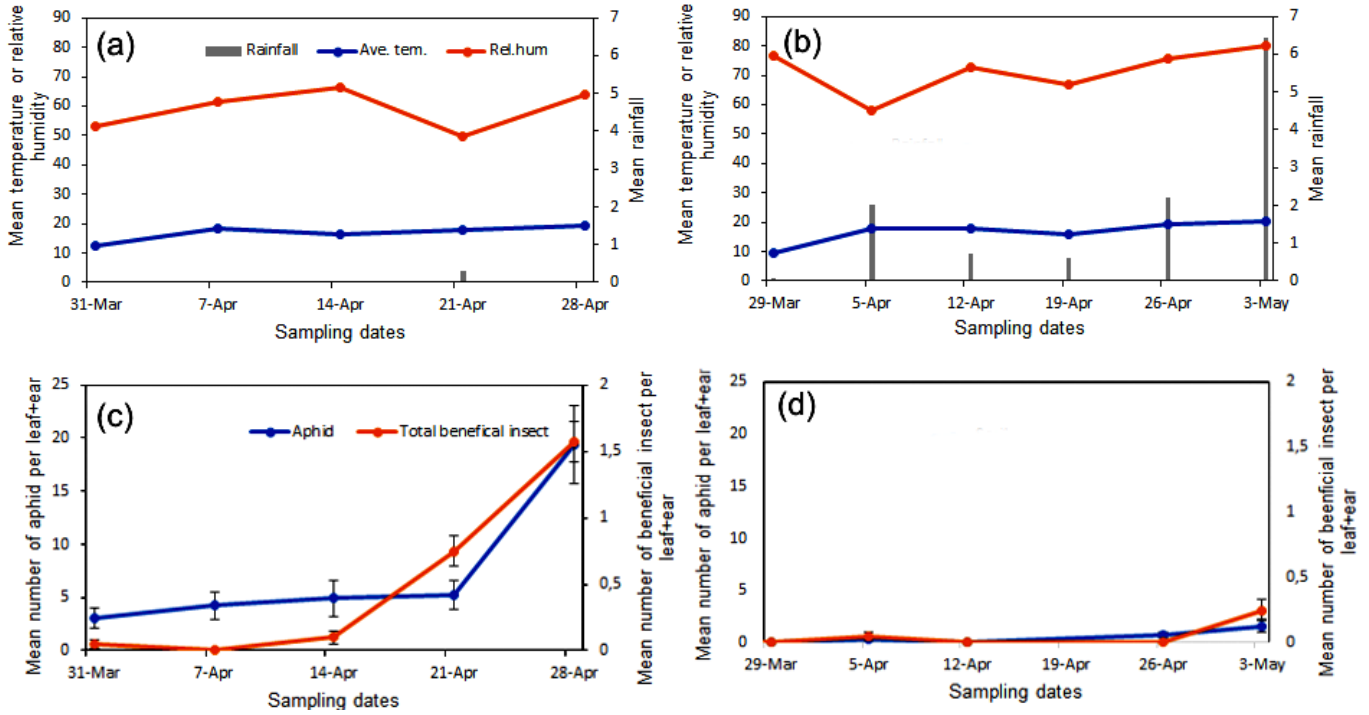


Figure 2- According to climatic factors in 2022 (a) and 2023 (b), average densities of *Sitobion avenae* and beneficial insects (total) in 2022 (c) and 2023 (d) in wheat

3.5. Relationships between abundance of aphid population and climatic data

In March 2022, average temperatures ranged from 5 °C to 11 °C, with a monthly average of 10 °C (Figure 2a). Relative humidity was recorded at 68%. In April, while the monthly average temperature was 15 °C, during the sampling period from April 14 to 28, when the population densities of the aphid's individuals were relatively higher than those of early April, the average temperature was 18 °C and the average relative humidity was approximately 60% (Figure 2a). No significant correlation was detected between the average population density of the aphid and temperature ($R^2 = 0.36$, $F = 1.718$, $df = 1,3$, $P = 0.281$, $t = 1.311$), average relative humidity ($R^2 = 0.36$, $F = 0.547$, $df = 1,3$, $P = 0.513$, $t = 0.747$), or precipitation ($R^2 = 0.03$, $F = 0.095$, $df = 1,3$, $P = 0.778$, $t = -0.308$) (Figure 3a). In March 2023, the average temperatures ranged from 5 °C to 18 °C, with a monthly average of 10 °C (Figure 2b). The average relative humidity was recorded at 73%. In April, while the monthly average temperature was 19 °C, during the period when the densities of aphid's individuals were relatively higher (April 26 to May 3), the average temperature was 22 °C, with an average relative humidity of approximately 78%. During this period, the average precipitation was 5.05 kg/m². No significant relationship was found between the average population density of the aphid and temperature ($R^2 = 0.40$, $F = 2.681$, $df = 1,4$, $P = 0.177$, $t = 1.637$) or average relative humidity ($R^2 = 0.20$, $F = 1.003$, $df = 1,4$, $P = 0.373$, $t = 1.001$), whereas a strong positive relationship was detected with the precipitation ($R^2 = 0.96$, $F = 106.791$, $df = 1,3$, $P = 0.0001$, $t = 10.334$) (Figure 3b).

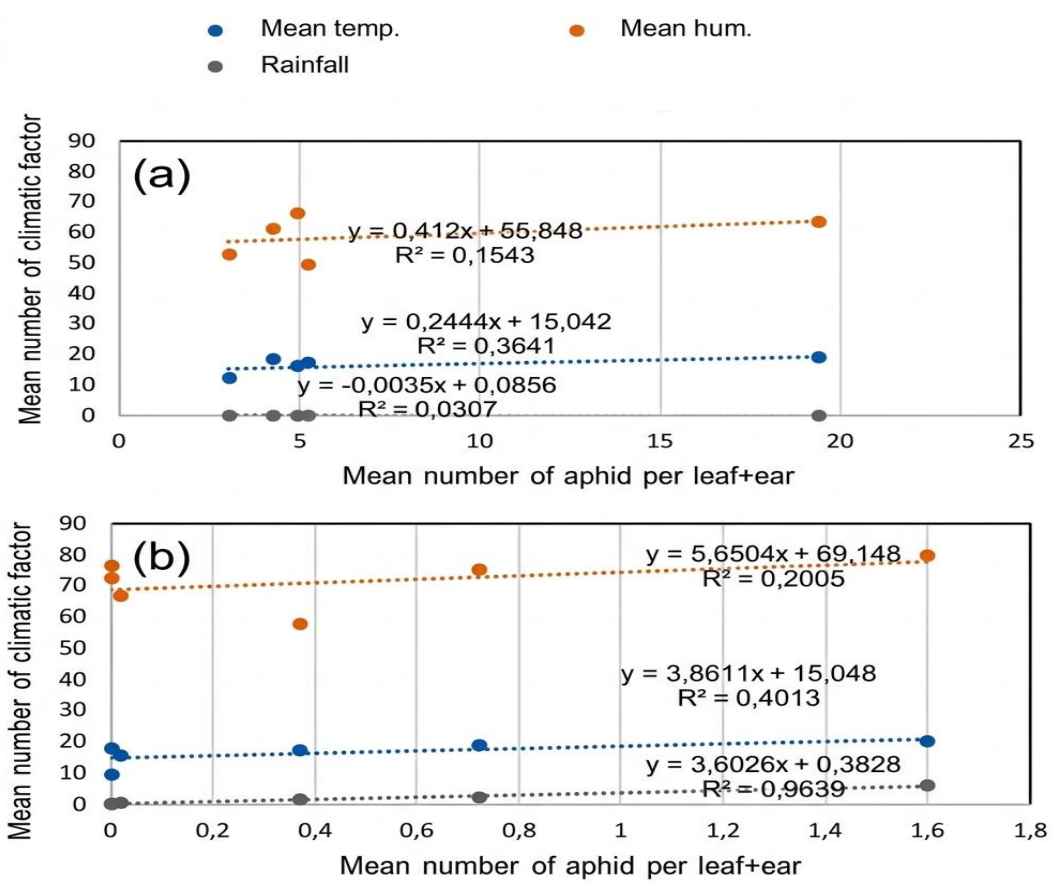


Figure 3- Relationships between climatic factors and average densities of *Sitobion avenae* in wheat in 2022 (a) and 2023 (b)

3.6. Relationships between abundance of aphid population and beneficial insects

At the end of March and in mid-April 2022, when aphid numbers ranged between 3–4 individuals per leaf + ear, only a few beneficial insects were detected. The first group of beneficial feeding on aphids were parasitoids. As the aphid population increased, the density of beneficial insects also rose; however, this increase was less pronounced than the rise in the aphid population. Nevertheless, in 2022, a significant and positive correlation was recorded between the aphid and the beneficial insect population densities on the plant ($R^2 = 0.84$, $F = 16.652$, $df = 1,4$, $P = 0.024$, $t = 4.081$) (Figure 4a). In 2023, very few beneficial insects were collected across all sampling dates due to the extremely low aphid density. No beneficial insects were observed on three sampling dates until the end of April. At the beginning of May, a short-term increase in aphid density was accompanied by a slight rise in the density of beneficial insects. A significant and positive correlation was found between aphid and beneficial insect population densities ($R^2 = 0.72$, $F = 10.747$, $df = 1,4$, $P = 0.031$, $t = 3.278$) (Figure 4b).

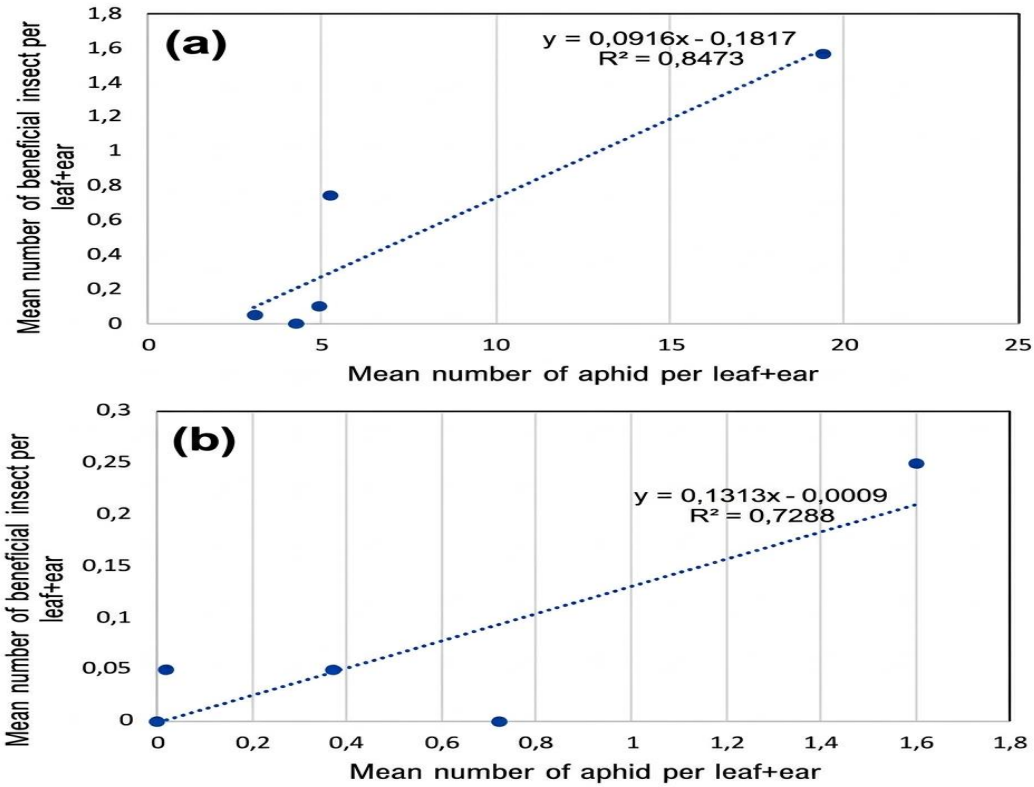


Figure 4- Relationships between average densities of *Sitobion avenae* and beneficial insects (total) in wheat in 2022 (a) and 2023 (b)

Table 4 presents the total numbers and aphid-to-beneficial insect ratios in two different plant organs (leaves and ears), along with the beneficial insect populations during the early (late March–early April) and late (late April) sampling periods. The predation or parasitism risk for aphids due to beneficial insects' attacks in the early season (25 or 26 aphids per beneficial insect on leaves or ears) was lower than found in the late season (7 or 8 aphids per beneficial insect on ears) compared to the early season.

Table 4- Ratios of aphid: beneficial insect in two plant parts (leaf and ear) of wheat in early (late March - early April) and late (late April) sampling time in 2022 and 2023

Year	*Plant part*	*Sampling time*	*Total number of aphid*	*Total number of beneficial insect*	*Ratio of Aphid: beneficial insect*
2022	Leaf	Early	168	0	-
		Late	277	11	25.18
	Ear	Early	221	6	36.83
		Late	732	88	8.31
2023	Leaf	Early	0	6	-
		Late	11	0	-
	Ear	Early	16	0	-
		Late	88	12	7.33

4. Discussion

In this study, two aphid species were identified in the wheat field, although only a few individuals of *R. padi* were recorded. Although both *S. avenae* and *R. padi* are present in wheat fields of the eastern Mediterranean region, *S. avenae* has been reported as the dominant aphid species in Türkiye, consistent with the findings of this study (Yigit et al. 2007). In other wheat-growing regions of Türkiye, the number of aphid species ranges between three and four, with *S. avenae* consistently reported (Elmali & Toros 1996; Tayat & Ozder 2016).

Sitobion avenae is a dimorphic species, with green-colored forms mostly observed on leaves and brown-colored forms recorded on wheat ears. It was frequently and significantly sampled from the ears. The preference of this aphid species may be linked to the chemical composition of the leaves and ears, as the ears are known to be rich in carbohydrates and amino acids. Vereijken (1979) reported that *S. avenae*, *M. dirhodum* and *R. padi* cause more damage on ears. He also noted that excessive nitrogen fertilization delays maturation of ears, making the damage more noticeable. According to the that study, the sugary substances produced by aphids lead to the development of sooty mold fungi, which negatively affect yield. In the current study, sooty mold developed on plants where more than 20 aphids were present on a single ear, due to the sugary secretions produced by the aphids.

Aphids primarily developed on the ears during the milky ripening stage (Figure 1). Density of aphids decreased significantly as the ears began to mature. The sudden increase in temperatures above 25 °C during this period may have adversely affected aphid development. Similarly, previous studies have reported that wheat aphids develop and reproduce extensively from the flowering to early ripening stages, but their densities decline as the crop approaches maturity (Jones & Jones 1984; Yigit et al. 2007; Tayat & Ozer 2016).

The population density of *S. avenae* was lower in 2023 compared to 2022. This may be attributed to biotic and especially abiotic factors, such as temperature. Although the average temperature in April 2023 (22 °C) was for aphid development, temperatures in March exceeded 20 °C, with maximum values reaching 27–28 °C on some days. This may have accelerated crop maturation, thereby rendering the plants less suitable for aphid development. Abbasi et al. (2019) reported that *S. avenae* populations in wheat fields in Pakistan decreased when maximum and minimum temperatures were 24 °C and 9 °C, respectively. Miller & Smith (1998) revealed the optimum temperature range for wheat aphids as 23–24 °C. Furthermore, the rainy days in April in 2023 may have affected the ability of alate aphids to reach the plants. Similarly, Elmali (1997) reported that in Konya province (Central and Akşehir districts), Türkiye, *S. avenae* populations were lower in a rainier year. Among the factors limiting aphid development, predators and parasitoids play a significant role (Yigit et al. 2007; Kindlmann et al. 2015).

In both years of the present study, the first group of beneficial insects observed were parasitoids, with the earliest mummified aphid individuals recorded on the leaves. Predatory insects' individuals the families Coccinellidae and Syrphidae appeared after aphid densities began to increase. Nevertheless, in both years, a significant and positive correlations were found between the total number of beneficial insects and aphids (Figure 4). In the Palampur region of India, *C. septempunctata*, *H. variegata* and *Coccinella transversalis* Fabricus were predominant, and syrphid species (*Episyrphus balteatus* De Geer, *Episyrphus viridaureus* (Wiedemann), *Ischiodon scutellaris* (Fabricius), *Sphaerophoria* spp.) also peaked in early April and exerted a limiting effect on aphid populations (*R. padi* and *S. avenae*) (Sharma et al. 2019). In contrast, in Pakistan, populations of lady beetles and syrphids were insufficient to suppress aphid populations on the wheat plants (Haseeb et al. 2017). According to that study, the minor and short-term increases in the population densities of beneficial insects were observed only after the aphid population had already reached high levels. Similarly, in this current study, beneficial insects appeared only after aphid densities had already increased, and were unable to prevent further aphid population development in 2022. On some plants, intense development of sooty mold on the ears, indirectly caused by aphids, negatively affected plant development. The delayed appearance of beneficial insects in wheat fields may be attributed to various ecological factors. For example, the absence of alternative prey (aphids) on both wild and cultivated plants near the sampled fields, prior to the occurrence of wheat aphids, may have contributed to this delay. This is particularly relevant, as the research institute primarily cultivates field crops.

5. Conclusions

Although the population trends of *S. avenae* was similar in both years, the individual density varied. Since nymphs and adults of aphids fed on ears in significant numbers in both sampling years, current study suggests that ears could be considered as a sampling unit during the flowering–milky ripening stage of the ears in April when the pest's population developments were relatively higher. Although there was no direct correlation between climatic factors such as temperature and humidity and aphid population density, relatively warmer and drier conditions in winter and early spring (March), with average temperature above 20 ºC, may accelerate crop maturity, making plants less suitable for aphid development. Therefore, it is recommended to consider climatic suitability for aphids when deciding on chemical control measures against wheat aphids. Predators and parasitoids together were insufficient in preventing the aphid population increase particularly in first year of the field experiment. In this regard, certain cultural practices such as growing of alternative host plants of wheat aphids or at least yellow-flowered and nectar-rich weedy plants along edges of wheat fields during the winter–early spring period, could be preserved to encourage earlier colonization of beneficial insects in the wheat fields.

Author Declarations

Authors' contributions: Concept: E.A., Design: E.A., Data collection: E.A., Analysis: E.A., Writing: E.A.

Conflict of interest/Competing interests: The author declares that there is no competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Ethics approval/declarations: No need/ Not applicable.

Funding: This research received no external funding.

Consent to participate: No need/ Not applicable.

Consent for publication: No need/ Not applicable.

Data availability: The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request**.**

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