

Population dynamics and parasitism rate of leafhopper species (Hemiptera: Cicadellidae) in maize (*Zea mays* L.) crop

Atila Atmaca, Mehmet Mamay and Çetin Mutlu *

Department of Plant Protection, Faculty of Agriculture, Harran University, Şanlıurfa 63050, Turkey.

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Abstract

Maize is an important crop in Turkey that is infested by various leafhopper species during the whole season. Monitoring population dynamics and parasitism rate of these species would help to devise effective management practices. This study determined population dynamics of four leafhopper species, i.e., *Zyginidia sohrab* Zachvatkin, 1947, *Empoasca decipiens* Paoli, 1930 and *Psammotettix striatus* (Linnaeus, 1758) in second maize crop. Similarly, population dynamics and parasitism rate of egg parasitoid (*Anagrus atomus*) of these leafhopper species was also studied through July to November 2018 in Akçakale, Harran and Haliliye districts of Şanlıurfa province, Turkey. Population density of all species significantly varied among studied districts with the highest density of *A. atomus* recorded on 7 September with 30 adults/trap in Haliliye district. The parasitism rate on *Z. sohrab* eggs was 78% in Akçakale, 82% in Harran and 63% in Haliliye district. It was followed by *E. decipiens* with 18% in Akçakale, 14% in Harran and 32% in Haliliye. The highest population density of *Z. sohrab* was recorded on 21 September in Akçakale (4328 adults/trap), Harran (3920 adults/trap) and Haliliye (4592 adults/trap). Similarly, *E. decipiens* had the highest (1216 adults/trap) population density on 10 August in Harran, 12 October (368 adult/trap) in Akçakale and 17 August (2184 adults/trap) in Haliliye. Population dynamics of leafhoppers and their egg parasitoid coincided with each other. The parasitism rate was lower than other provinces in Turkey which is owed to high pesticide use in Şanlıurfa province. Therefore, chemical control should be decided by considering population development of beneficial insect species.

Keywords: *Zyginidia sohrab*; *Anagrus atomus*; Population monitoring; Sticky trap; Corn

1. Introduction

Maize (*Zea mays* L.) is one of the most important crops contributing towards human and animal nutrition around the world as well as in Turkey. It occupies third position in term of production after wheat and barley in Turkey [1]. Numerous insect species, i.e., Mediterranean corn borer (*Sesamia nonagrioides*), European corn borer (*Ostrinia nubilalis*) and leafhoppers are known to infest maize grown as second crop [2]. *Zyginidia sohrab* Zachvatkin is considered as a serious pest of second crop maize [3,4,5,6,7,8,9]. The insect has attracted increased attention since early 2000's in maize, particularly the one grown as second crop in Turkey. Leafhoppers' damage has been reported on maize from some part of Anatolia region of Turkey [10,11]. *Zyginidia sohrab* is the main pest of maize crop in Turkey and its population density has been significantly increased since last two decades. It has become the only dominant leafhopper species with >90% frequency of occurrence in maize production areas of the country. *Empoasca decipiens* (Paoli), *Asymmetrasca decedens* (Paoli), and *Psammotettix striatus* (Linnaeus 1758) are other leafhopper species infesting maize crop (<10% frequency of occurrence) in Turkey [6,8]. *Empoasca decipiens* is a polyphagous species and economically serious pest in many parts of the world. *Psammotettix striatus* is a serious pest of wheat and maize crops in Turkey [6,12]. Moreover, it serves as a vector of wheat blue dwarf (WBD) phytoplasma [13]. Besides *Asymmetrasca decedens* also infests maize and wheat crops; it serves as a disease vector of *Candidatus Phytoplasma phoenicium* in maize [14].

* Corresponding author: Çetin Mutlu

Department of Plant Protection, Faculty of Agriculture, Harran University, Şanlıurfa 63050, Turkey.

The biology of *Z. sohrab* has been extensively studied by Mutlu and Sertkaya [10]. They reported five generations of the species per year in southeastern Anatolia region and number of adults of the species on yellow sticky traps in the second crop maize were eight time higher than main crop maize. Leafhopper adults and nymphs mainly feed on the ventral surface of the leaf and cause direct damage to the plant by sucking bottom leaves [8]. The sucking and puncturing by leafhoppers result in shrinking, browning and ultimately death of primary bottom leaves exposed to the pests. The infected leaves turn to stripe-like purplish color which ultimately turn brown [4,8]. The drying of these leaves exert heavy economic loses in maize yield. Heavy infestation of leafhoppers causes complete drying of maize plants -a condition commonly known as "hopper-burn" [15,16].

Mymarid egg parasitoid (*Anagrus atomus*) is the most important antagonist species of maize leafhoppers [9]. It is a cosmopolitan egg parasitoid of different leafhopper species observed under diverse environmental conditions [17,18,19]. The parasitism rate of *A. atomus* has been recorded between 50.2% and 93.7% in maize crop grown in southeastern Anatolia region of Turkey [9]. Similarly, the parasitism rate of the species in Italy has been reported between 50% [20,21]. Likewise, the parasitism rate of the species was 50-80% in Germany [18].

Monitoring seasonal occurrence/dynamics of insect pests is of fundamental importance in effective pest management [22,23]. Assessing peak occurrence time of pest species significantly contributes towards pest management strategies [24]. Forecasting/determining the peak occurrence time of pest species helps to inform producers regarding the most effective time for pest management [23]. Several monitoring methods (i.e., color sticky traps, pheromone traps, and light traps etc.) are used for pest management [25,22,26]. The use/choice of these traps depends on insect and plant/crop species. Yellow sticky traps attract flying insects, especially those belonging to Hemiptera order [25,18,27,28]. Due to the reason, these traps are used to monitor and control/manage sucking pests in greenhouses and field conditions. However, the effect of these traps on the attraction/trapping of predators and parasitoids in maize crop is unclear. Therefore, the efficacy of these traps in attracting predators and parasitoids needs to be determined. Yellow sticky may exert negative effects on maize ecosystem by trapping natural enemies, especially egg parasitoids of harmful pest species. Keeping in view, this study was conducted to determine the population dynamics of the four leafhopper species and their egg parasitoid in second crop maize grown in different districts of Şanlıurfa province, Turkey. It was hypothesized that studied districts will differ in the infestation/density of leafhopper species. It was further hypothesized that yellow sticky traps will significantly attract egg parasitoid species of leafhopper species infesting maize crop. The results of this study would provide empirical information regarding the peak infestation time of leafhopper species. Accordingly, the optimum management time for leafhopper species could be determined based on the results of current study.

2. Material and methods

2.1. Study area

The current study was conducted in farmer fields in Harran plain, Şanlıurfa province, Turkey (36°52'39.0"N, 39°02'02.0"E; 400-450 m elevation). Harran plain has approximately 150.000 hectares irrigated area in recent years[29]. Mostly cotton and two different maize crop (main and second) are produced in the Harran plains.

2.2. Population dynamics of leafhopper species and their egg parasitoid

The experiment to determine population dynamics of leafhopper species and their parasitoid was conducted in second crop maize fields situated in Akçakale (36.773424 °N, 38.955222 °E), Harran (36.898083 °N, 38.964500 °E) and Haliliye (37.154583 °N, 39.403722 °E) district in Şanlıurfa. Population dynamics of four leafhopper species, i.e., *Zyginida sohrab*, *Empoasca decipiens*, *Assymetrasca decedens* and *Psammotettix striatus* was monitored by yellow sticky traps. Plexiglass yellow sticky traps (20 × 25 cm) were coated with sticky polymers (Tangle-Trap Insect Trap Coating; The Tanglefoot Company, Grand Rapids, MI, USA) on both sides, and attached vertically to an iron rod, which was fixed in the ground. Three yellow sticky traps were fixed in each field (during two-four leaf stage of maize plants) 10 meter inside from the field edge to avoid the border effect. The traps were adjusted to plant height weekly by lifting the iron rod in upward direction. The traps were replaced weekly, and the number of leafhopper adults trapped on both sides of traps were counted. *Empoasca decipiens* and *A. decedens* were difficult to identify; hence, these were counted together and interpreted as *E. decipiens* + *A. decedens* complex in the traps counts. The field study lasted from July to November in 2018.

Likewise, population dynamics of *A. atomus* (egg parasitoids of studied leafhopper species) was monitored weekly on yellow sticky traps in the same maize fields. The sticky traps were carefully examined for the presence of *A. atomus* under Floor Standing Magnifier (20 X).

2.3. Parasitism rate of *Anagrus atomus*

Leaf samples were collected weekly from maize fields to evaluate the parasitism rate of *A. atomus*. Three leaves infested with leafhoppers eggs were collected from 5 random places in the field making 15 leaves from each field during every week. The leaves were collected from bottom, middle and upper parts of maize plants from each location within the field. A total 45 leaves were collected from three fields during each sampling. Since leafhoppers eggs are laid under leaf surface, these are difficult to detect with naked eye [8]. Hence, collected leaves were placed in 1.5-liter transparent plastic bottle containing 96% alcohol to clean the chlorophyll in leaves so that parasitized and non-parasitized eggs in the leaf tissue can be seen more clearly (Figure 1). Infested leaves with leafhopper eggs were kept in the containers for 15 days in laboratory. Afterwards, leaves were boiled for 5-10 minutes in 5% KOH solution to soften the hardened leaves [10]. The leaves samples were examined under illuminated binocular microscope and parasitized and non-parasitized eggs were counted (Figure 1)

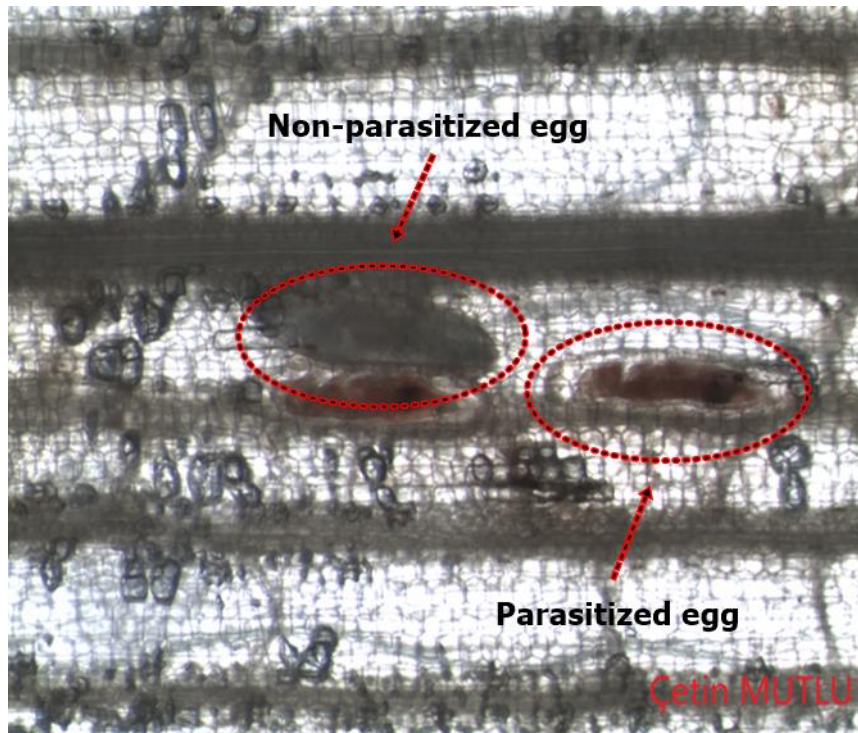


Figure 1 The parasitized and non-parasitized leafhoppers eggs inside maize leaf tissue

2.4. Statistical analysis

Data regarding density of leafhopper species in different districts were tested by paired *t* test to observe the differences among districts. The analysis was repeated for each week. Data regarding the density of leafhopper species was visualized in Microsoft Excel to determine the peak infestation time. The data relating to weekly density of the studied leafhopper species and their egg parasitoid was presented and interpreted in the manuscript. All statistical computations were done on SPSS statistical software.

3. Results

3.1. Population dynamic of leafhopper species and their egg parasitoid

Significant variation was noted for the number of adults belonging to *Z. sohrab*, *E. decipiens*+ *A. decedens* and *P. striatus* trapped by yellow sticky traps (Figs 2-4).

Population density of different leafhopper species was significantly altered by individual and interactive effects of weeks, locations and species (Table 1).

Table 1 Analysis of variance for different weeks, locations and species for population density of leafhopper species

Source	DF	Sum of squares	Mean squares	F value	P value
Week (W)	15	4357781.81	290518.79	86.86	< 0.0001
Location (L)	2	57295.81	28647.91	8.56	0.000
Species (S)	2	11562670.84	5781335.42	1728.43	< 0.0001
W × L	30	761393.15	25379.77	7.59	< 0.0001
W × S	30	6456369.90	215212.33	64.34	< 0.0001
L × S	4	445674.41	111418.60	33.31	< 0.0001
W × L × S	60	1013019.52	16883.66	5.05	< 0.0001

Bold values in the p value column indicate that relevant explanatory variable significantly altered dependent variable

Population dynamics of *Z. sohrab* monitored by yellow sticky traps is given in Fig. 2. The highest number of adults of *Z. sohrab* were recorded/trapped in Akçakale district compared to the rest of the locations included in the study. The highest population density of *Z. sohrab* was recorded at 2-4 leaf stage of maize during early August. Population density of *Z. sohrab* observed a sharp increase from late August when maize in ten leaf stage and reached to the highest level at the end of September. Afterwards, the population density started decreasing; however, significant number of *Z. sohrab* were still caught by these traps. The number of individuals were quite low during the middle of November. Although number of *Z. sohrab* individual's trapped varied among districts, population dynamics coincided for all locations according to the vegetation period of maize crop.

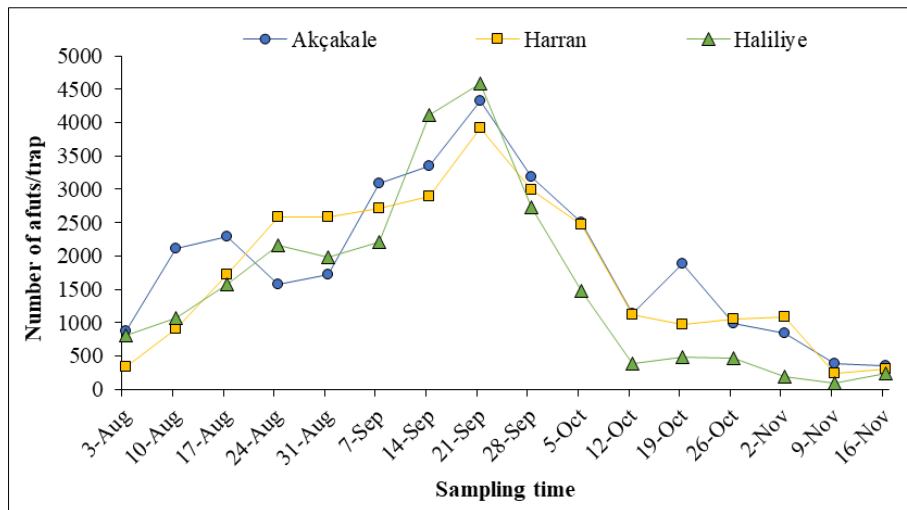


Figure 2 Population dynamics of *Zyginiida sohrab* monitored by yellow sticky traps in three districts of Şanlıurfa province, Turkey

The highest density of *Empoasca decipiens* + *A. decedens* population was recorded during early August in Haliliye and Akçakale districts (2184 and 1216 adults/trap, respectively) compared to Harran district (336 adults/trap) (Fig. 3). Population of these leafhoppers increased in middle of August and reached to the highest level (1216 adults/trap) during generative stage of maize crop in Haliliye district. The population fluctuated between September and October when maize reached to maturity. Population density of these leafhoppers started to decrease during middle of October in all districts when maize leaves reached senescence.

Population density of *P. striatus* was quite low during early vegetation period of maize Haliliye, Akçakale and Harran districts (192, 184, 88 adults/trap, respectively) and no significant fluctuations was noted in the population density during the vegetation period of maize (Figure 4). Population density reached to the highest level during tasseling and maturation stages (496 adult/trap in Haliliye) of maize crop at the end of September. *Psammottetix striatus* abundance declined between October and November.

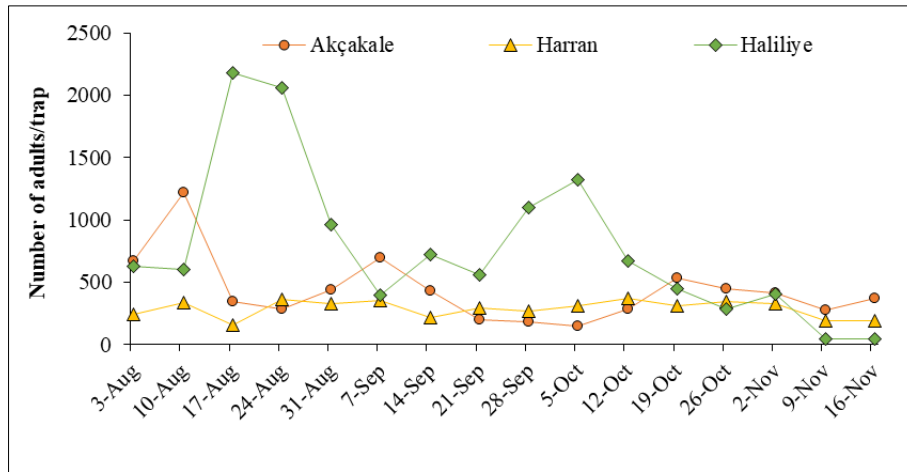


Figure 3 Population dynamics of *Empoasca decipiens* + *Assymetrasca decedens* monitored by yellow sticky traps in three districts of Şanlıurfa province, Turkey

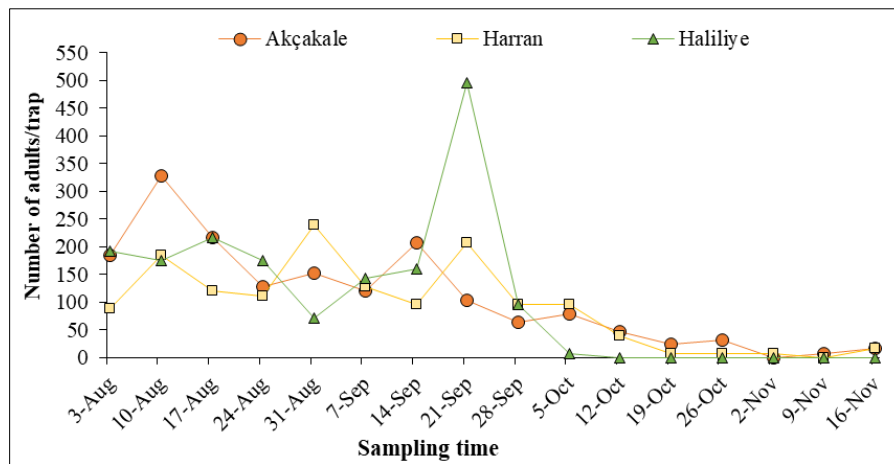


Figure 4 Population dynamics of *Psammotetix striatus* monitored by yellow sticky traps in three districts of Şanlıurfa province, Turkey

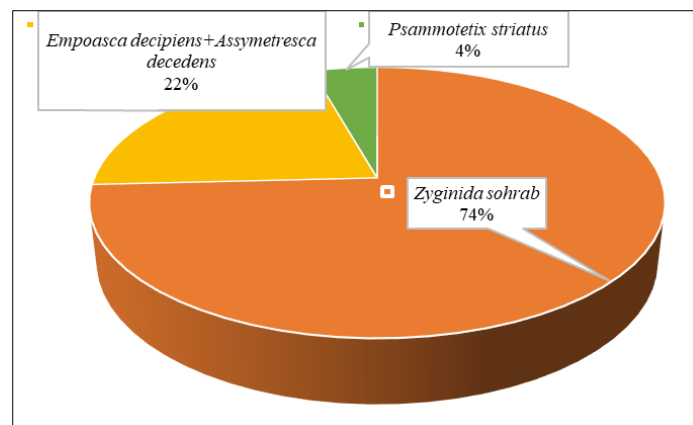


Figure 5 Relative occurrence of four leafhopper species in second crop maize cultivated in three districts of Şanlıurfa province

Zyginida sohrab was the most dominated species in second crop maize grown in Şanlıurfa province, which was followed *A. decedens+ E. decipiens*. The lowest relative occurrence was recorded for *P. striatus* (Figure 5).

One mymarid parasitoid species, i.e., *A. atomus* was trapped by yellow sticky traps at all study locations during the whole vegetation period of maize crop. Population dynamics of parasitoid species coincided with the leafhopper species (Fig. 6). Population density of the parasitoid species increased until the first week of September at all locations. The population density of *A. atomus* reached to the highest level in middle September in all districts included in the study. Thereafter, population destiny of the parasitoid species dropped and remained low until end of the season.

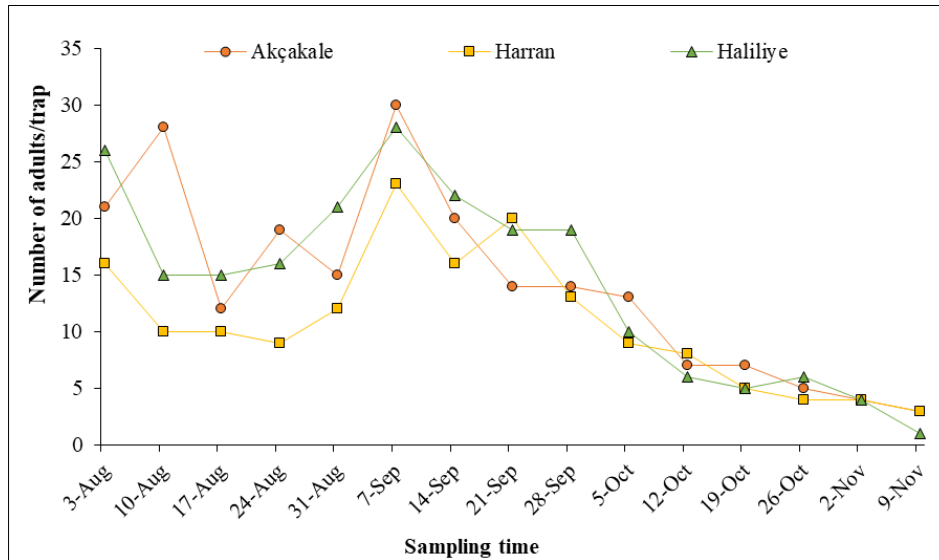


Figure 6 Population dynamics of *Anagrus atomus* monitored by yellow sticky traps in three districts of Şanlıurfa province, Turkey

3.2. Parasitism rate of

The average parasitism rate of in *A. atomus* Akçakale, Harran and Haliliye districts was 56.6, 57.8 and 59.5%, respectively (Fig. 7). The parasitism initiated during first week of August and witnessed a continuous increase till first week of November. Although slight changes were observed in the parasitism rate, overall increased till last sampling time. The peak parasitism rate in Akçakale, Harran and Haliliye was 76.5, 84.2 and 76.4%, respectively.

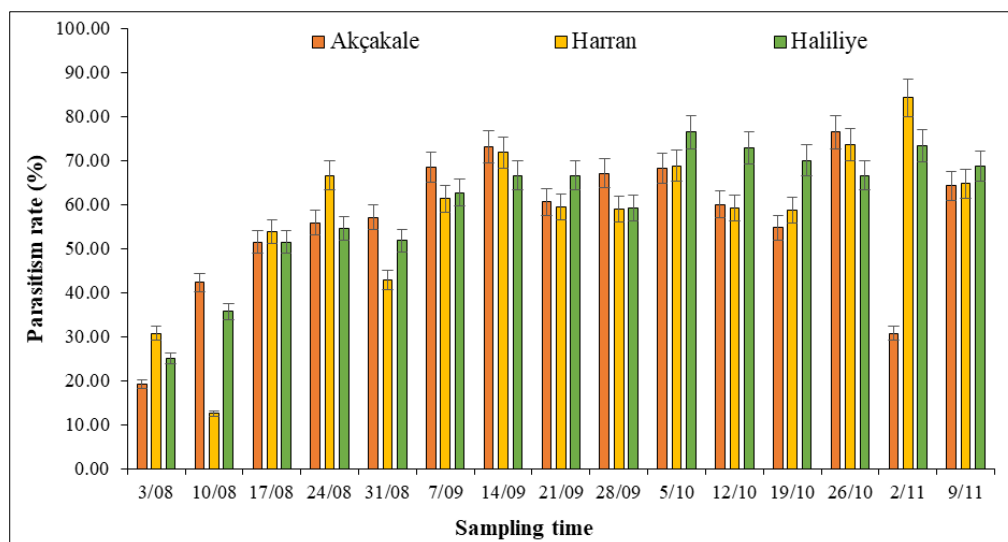


Figure 7 Parasitism rate of *Anagrus atomus* in three districts of Şanlıurfa province, Turkey

4. Discussion

Population density of studied leafhopper species significantly varied among studied districts, as hypothesized (Table 1). The differences among studied districts are owed to the varying climatic conditions as well as slight changes in the vegetation period of maize. The other major driver of the changes in population dynamics is the varying weed infestation in the maize fields in different districts. The studied leafhopper species, being polyphagous, infest numerous weed species [6]. Higher weed infestation either within the field or along the field edges significantly affect population dynamics of studied leafhopper species [7,8,10].

The yellow stick traps attracted egg parasitoid of leafhopper species; however, the density of the parasitoid was extremely low compared to the density of the leafhopper species. This did not support our second hypothesis that the used traps significantly attract parasitoid species. This can be explained with the fact that pesticides are extensively used for pest management in second crop maize grown in southeastern Anatolia, which probably suppress the population of parasitoid species. However, no such data is available to support this inference.

Population dynamics of leafhopper species observed an initial increase in the density, reached to the peak and then declined. This is the particular behavior of insect species where they increase their density, damage the crop and then generation is terminated. The peak density coincided with the damage timing of the studied leafhopper species in maize crop. Hence, management strategies against the leafhopper species must be opted when their population density observed increase. Nonetheless, economic threshold value of these insects must be considered through regular pest scouting to avoid significant damages. Yılmaz and Karsavuran (2010) reported that population density of *A. decedens* reached to the highest level during the maturation period of maize crop and after this period, decreasing temperature forces the plants to enter senescence period and plant tissues get hardened [30]. Furthermore, irrigation is stopped after the crop matures, which leads towards the senescence of maize and weed plants. Due to these reasons, population density of leafhoppers decreases near to the harvest period of maize. Mutlu (2008) also reported that decrease in the population density of leafhoppers is linked with the senescence of weed species within and edges of maize fields [6].

The population density of *P. striatus* reached to the highest level during 2-4 leaves stage of maize crop in two districts of Diyarbakır province in Turkey. Population density of *P. striatus* decreased rapidly in the second crop maize during the generative period, and the number of individuals decreased to almost zero during maturation period [6]. The highest density of the species was recorded during tillering period of maize crop in a survey study conducted Çüngüş district of Diyarbakır province [3]. Göçmen et al. (1996) reported that individuals of this species feed on cotton and then shift to another crop [31]. Therefore, it is thought that *P. striatus* individuals transitioned from cotton fields adjacent to the studied maize fields and they continued to feed on young leaves of maize crop and complete their last progeny [6].

Parasitism rate on the leafhopper species was quite low than other studies conducted in southeastern Anatolia region, Turkey. The reasons of low parasitism are extensive use of pesticides on cotton as well as maize crops in Şanlıurfa province. Şanlıurfa is the largest cotton production zone of Turkey [1] and extensive pesticides are used to manage the insect pests of the crop (field observations). However, there is no study relating to impact of pesticide use on beneficial insects/parasitoids on maize. In a study conducted in Diyarbakır province (Bismil and Silvan districts) during 2012, parasitism rates of *A. anagrus* for *Z. sohrab* in second crop was 83.5-86.5% [9]. Higher parasitism rate reported in this study compared to those obtained in the current study can be owed to higher pesticides' use in Şanlıurfa than Diyarbakır. This shows that excessive pesticide use suppresses the population of beneficial insects in maize. In another study, McKenzie (1973) reported that parasitism rate of the harmful leafhopper *Erythroneura ziczac* Walsh by *A. epos* in vineyards of Canada ranged between 21-87% throughout the season [32]. Meyerdirk and Hessein (1985) conducted a study in southern California to observe population dynamics and parasitism rate of *C. tenellus* and *Empoasca* s. in sugar beet crop [33]. These species were *Anagrus giraulti* Crawford, *Polynema* sp., *Gonatoerus* sp. (Mymaridae), *Paraentobia* sp. ve *Aphelinoidea* sp. (Trichogrammatidae) and parasitism rate was 81%. Vidano and Arzone (1985) concluded that *Z. pullula* should not be considered as a serious pest of cereals in Italy, since its eggs are effectively parasitized by *A. atomus*, despite its intensive feeding and migration capacity [34]. Yiğit and Erkiş (1987) reported that *O. pallida* and *A. atomus* parasitize 85-99% eggs of harmful vineyard pest, i.e., *A. adanae* in southern Anatolia Region of 85-99% due to which chemical control was not required [35].

Anagrus atomus parasitizes the eggs of *E. vitis* causing 90% mortality of the pest [21]. Gladstone et al. (1996) reported that *Anagrus* sp. and *Paracentrobia* sp. parasitized *D. maidis* [36]. Sutre and Fos (1997) reported that *A. atomus* was the most effective natural enemy of harmful *E. vitis* in vineyards in France [37]. In another study, it was determined parasitism rate of *A. atomus* on *E. decipiens* in four bean cultivars was 24.34% in Iran during 2004 and 33.33% during 2005 [38]. Bayoun et al. (2008) determined that *C. tenellus* was parasitized by *A. nigriventris* the USA [39] and *E. vitis*

was parasitized by *A. atomus* at a rate of 29- 52.7% in the vineyard areas in Italy [40]. These studies have shown once again that *Anagrus atomus* was very important egg parasitoids on harmful leafhoppers.

5. Conclusion

In order to suppress the population of harmful leafhopper species in second crop maize fields and to increase the effectiveness of parasitoid of *A. atomus*, which is important in natural biological control. It is necessary to minimize the chemical control and pay attention to the specific effectiveness of the pesticides to be used.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest. The authors declare that there is no conflict of interests regarding the publication of this paper. Study design: Ç.M and M.M. Field study: A.T. Data analysis: Ç.M. Drafting the manuscript: Ç.M.

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