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Research Article

Temporal variations in aphid-parasitoid interactions on fruits crops in semi-arid region

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Abstract. The management of the biological control against aphids by parasitoids requires a deep knowledge of the specific diversity of the target insect in the target area, and understanding the interactions between pests and parasitoids within temporal variations. From April 2022 to Ocober 2023, using a checking method, aphids and their parasitoids on fruits orchard multi-speciecs of apple, pear, peach and apricot trees were collected on Ain Zitoun, Oum El Bouaghi, North Algeria. The first objectif is to evaluate the population dynamics of aphids and their Hymenopteran parasitoid. Secondly, an investigation of temporal effect on the degree of trophic specialization. This study reported that the parasitoid *Lysiphlebus testaceipes* was polyphagous and generalist for the most aphid species on studied trees but it presented a preference to *Aphis pomi* and *Dysaphis plantaginea* on apple trees within the optimal season. The parasitoid *Diaeretiella rapae* can be the specific agent for biological control against *Myzus persicae* on Peach trees, it representing 100% in 2022 and 56.25% in 2023 of parasitoids. The study showed an important presence of the secondary parasitoid species on apple and peach trees that can affect parasitoid efficiency to control aphids, hyperparasitism rate reaching more than 30% on peach and on apple and varied between 37.33% in 2022 and 1.77% in 2023.

Keywords: Aphid parasitoids, temporal variations, preference, specialization, population dynamism

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Introduction

Many species of aphids are considered a very important enemy of crops, forests and ornamental trees (Sullivan, 2008), feeding on phloem sap and injecting phytotoxic compound and phyto-viruses (Van Emden & Harrington, 2007). Using insecticides is useful for controlling aphids, however, their effect on beneficial organisms, appearance of resistant strains of aphids. Moreover, they have effects on the environment, such as the pollution of air, groundwater and an effect on human health (Horrigan *et al.,* 2002). Two groups of parasitoids that attack aphids are Aphidiidae and Aphelinidae (Glinwood, 1998). Parasitoids wasps have been considered as important agents in biological control programs of aphids (Rehman & Powell, 2010), owing to their dispersion, capacity of adaptation and their specificity (Godfray, 1994; Boivin, 2001; Villegas *et al.*, 2017). Furthermore, the specific diversity of host plant and natural enemies has important consequences on polyphagous and their abundance (Aquilino *et al.,* 2005). Therefor it is important in the use of biological control to explore the study of tri-trophic associations (plant-aphid-parasitoid) in target region (Kavallieratos *et al.,* 2016). In agricultural landscape, understanding fine-scale mechanisms is essential to be able to set up efficient methods to support biodiversity and associated ecosystem services within study food webs (Jeavons *et al.,* 2022). Studying aphid–parasitoid interactions permitted to identify the host resources actually exploited by parasitoids at the local scale even they are considered as generalists or specialists at a global scale (Derocles *et al.,* 2020).

In Algeria, there has been little research investigating the diversity and the pest management strategies still involved the use of insecticides. The biological control needs sufficient information about identification of the most abundantly species because this information will be useful to selecting the most convenient parasitoid species to release (Aparicio *et al*., 2019). The aim of this study is firstly, the inventory and the knowledge of the distribution of these hymenopterans present on fruits trees in a semi-arid region (Oum El Bouaghi province, Algeria) in order to choose and use the most effective and frequent species in this Algerian sector agriculture. The second is understand the extent of preference and specialization of aphid and their parasitoids. The third aim is the comprehension of the influence of climatic conditions on the population dynamics and food web interactions in a fruits intercropping system to improve the biological control of aphids.

Materials and methods

Sampling site

Surveys were conducted in agricultural orchard of fruits trees located in the northeast of Algeria (Ain Zitoun: Oum El Bouaghi) (846m, 35°40'55''N 6°55'43''E). This region is characterized by a semi-arid bio-climate that is hot in summer and cold in winter.(Seddik et al., 2010). The orchard contains apple, pear, peach and apricot trees. The orchard was under a pesticide management program.

Insects sampling

Monitoring was carried out from April 2022 to October 2023. Once a week samples were collected using a checking methods. Because the variation of the number of infested trees between trees species and dates, random samples was done. As far as was possible we sampled the infested leaves per tree species according the 4 cardinal points for each tree species. Aphids were placed in tubes containing ethanol 70% by using a fine paintbrush. In laboratory the aphids were identified using keys Blackman & Eastop (2006) and Leclant (2000). The hymenopter parasitoids were obtained after emergence from aphid mommies that placed in small-ventilated plastic boxes. Those were conserved in tubes containing Ethanol for later identification. The identification of parasitoids based on several keys such as Kavallieratos *et al.* (2004); Rakhshani *et al.* (2012, 2015).

Data analysis

Aphid and parasitoid dynamics

A count of total number of wings and apterous adults and larvae stage of each aphid species also, the number of emerged parasitoids was done for each date of sampling, to evaluate the population dynamics of the aphids and parasitoids on examined crops. Pearson correlation between number of aphids and parasitoids of each fruit plant species in each date of sampling and climatic factors mean of temperature, humidity and accumulation of rainfall of the week before sampling date. Correlation was done using SPSS version 22.

Food web structure

The quantitative indices were calculated to generate the quantitative representations of food webs; - the relative frequency host range per parasitoid; - the relative frequency parasitoid range per aphid species. These quantitative food webs were drawn using the R software 4.4.0.

Results

Aphids

During the investigation, five species of aphid in total were determined: *Aphis gossypii, Aphis pomi, Dysaphis plantaginea*, *Hyalopterus pruni* and *Myzus persicae* (fig. 1).

Fig. 1. Variations in aphid community assemblage among plant species and years.

Hymenopter Parasitoids

Seven species of primary parasitoids and six others hyper parasitoid species were determined on fruits trees in the studied region. The Primary Parasitoids are *Aphidius colemani, Aphidius. matricariae, Aphidius transcaspicus, Aphelinus mali, Diaeretiella rapae, Lysiphlebus fabarum* and *Lysiphlebus testaceipes* (Fig. 2). The hyper parasitoids species are: *Alloxysta victrix, Asaphes vulgaris, Asaphes suspensus, Pachyneuron aphidis, Syrphophagus aphidivorus* and *Pteromalus sp.* (Fig. 3). Hyper parasitoids were presented on apple and peach in both years of study with hyperparasitism rate varied between 37.33% in 2022 and 1.77% in 2023. On peach parasitism rate varied between 33.33% and 38.46% in 2023 respectively.

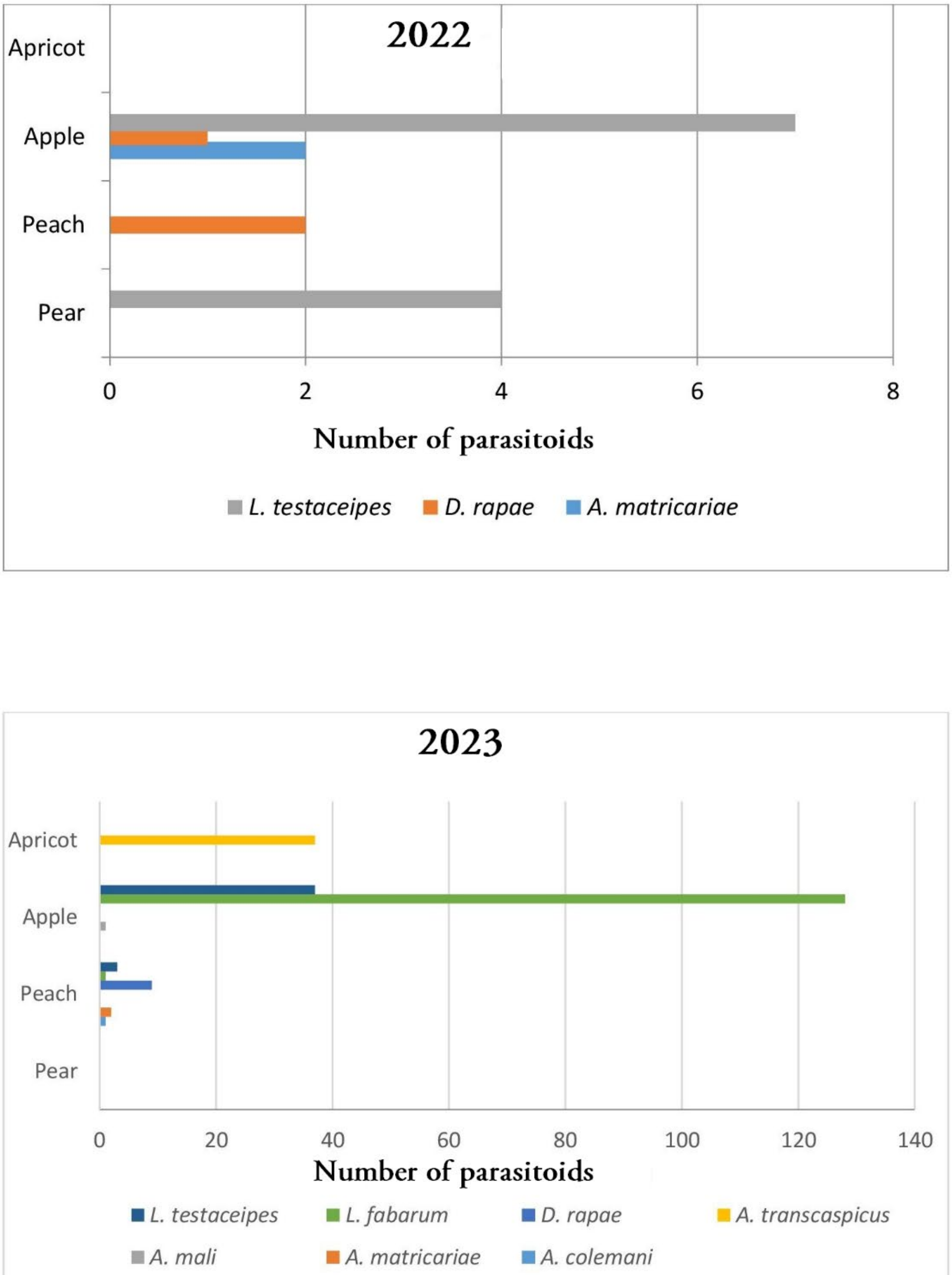
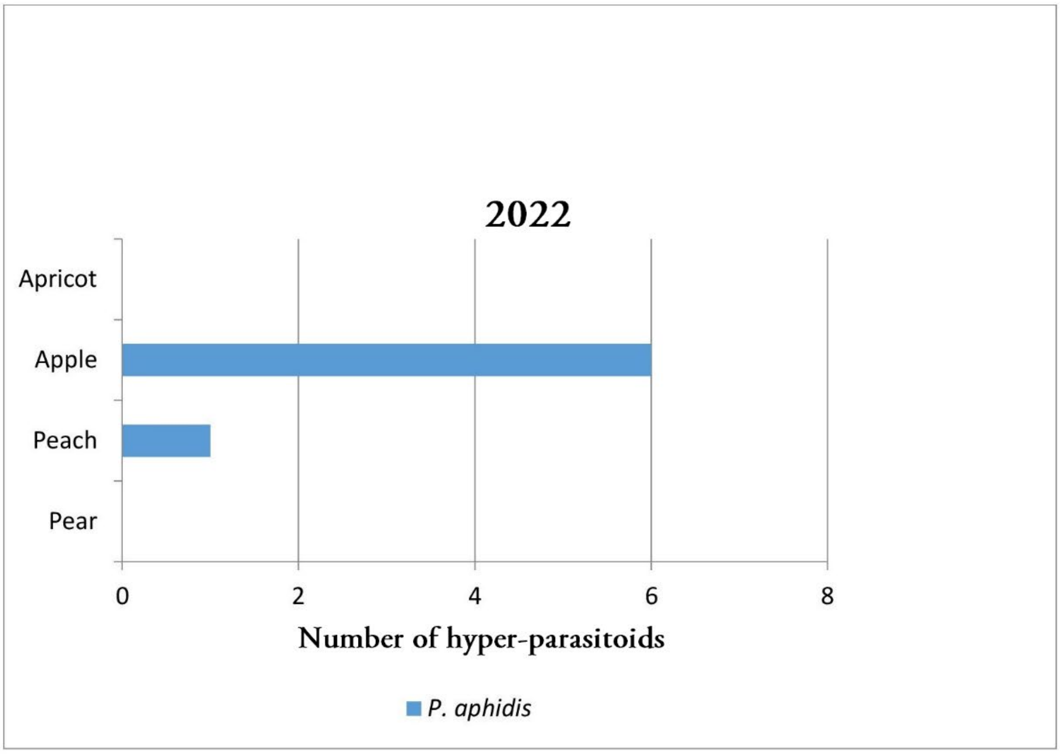


Fig. 2. Variations in primary parasitoid community assemblage among plant species and years

Aphid and parasitoids dynamic

In general, we noted a progressive increasing in the number of aphids until reaching the peak in end of April and May. Aphids infested Apple trees in the beginning of April until October. aphids infested the peach, pear and apricot trees in the end of April until June. While the parasitoids activity is important in May (Fig. 4).



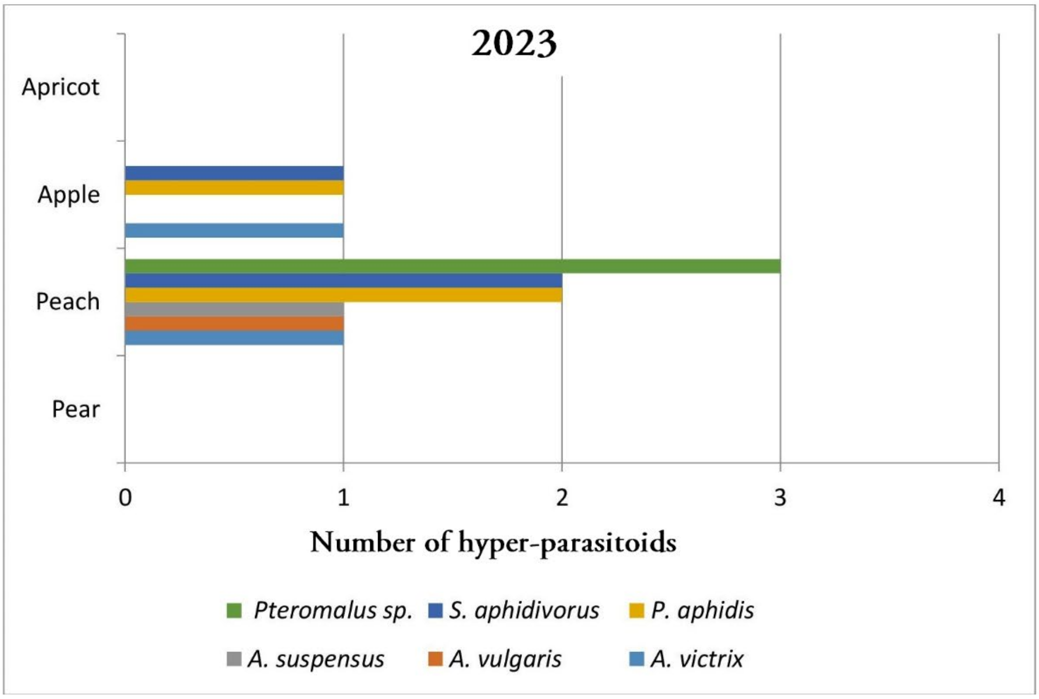
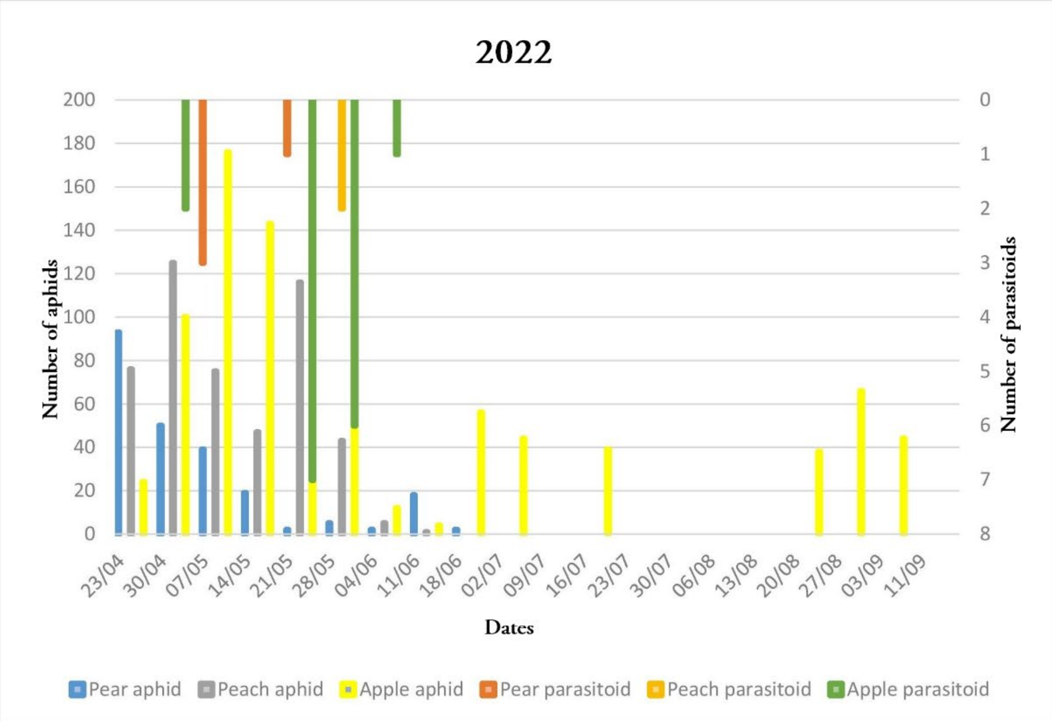


Fig. 3. Variations in Hyper parasitoid community assemblage among plant species and years

Pearson correlation

Correlation between number of aphids and parasitoids of each fruit plant species and climatic factors mean of temperature, humidity and accumulation of rainfall date N=46 (Table1).



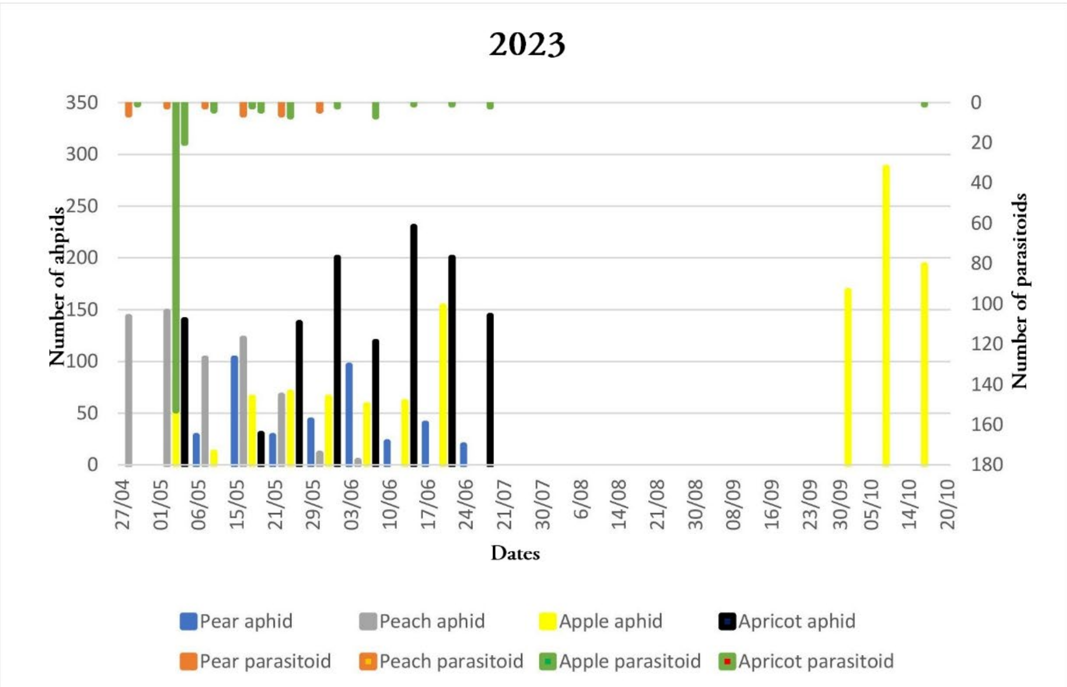


Fig. 4. Seasonal abundance (number per plant host species) of aphids and their parasitoids recorded in the field study carried in 2022 and 2023

Aphid–primary parasitoid food web (Fig. 5)

The years of 2023 showed a hight diversity of parasitoids and interactions compared with the first year 2022. The presence of specific bi-trophic interaction of aphid species and their host plant effect on the tritrophic interactions.

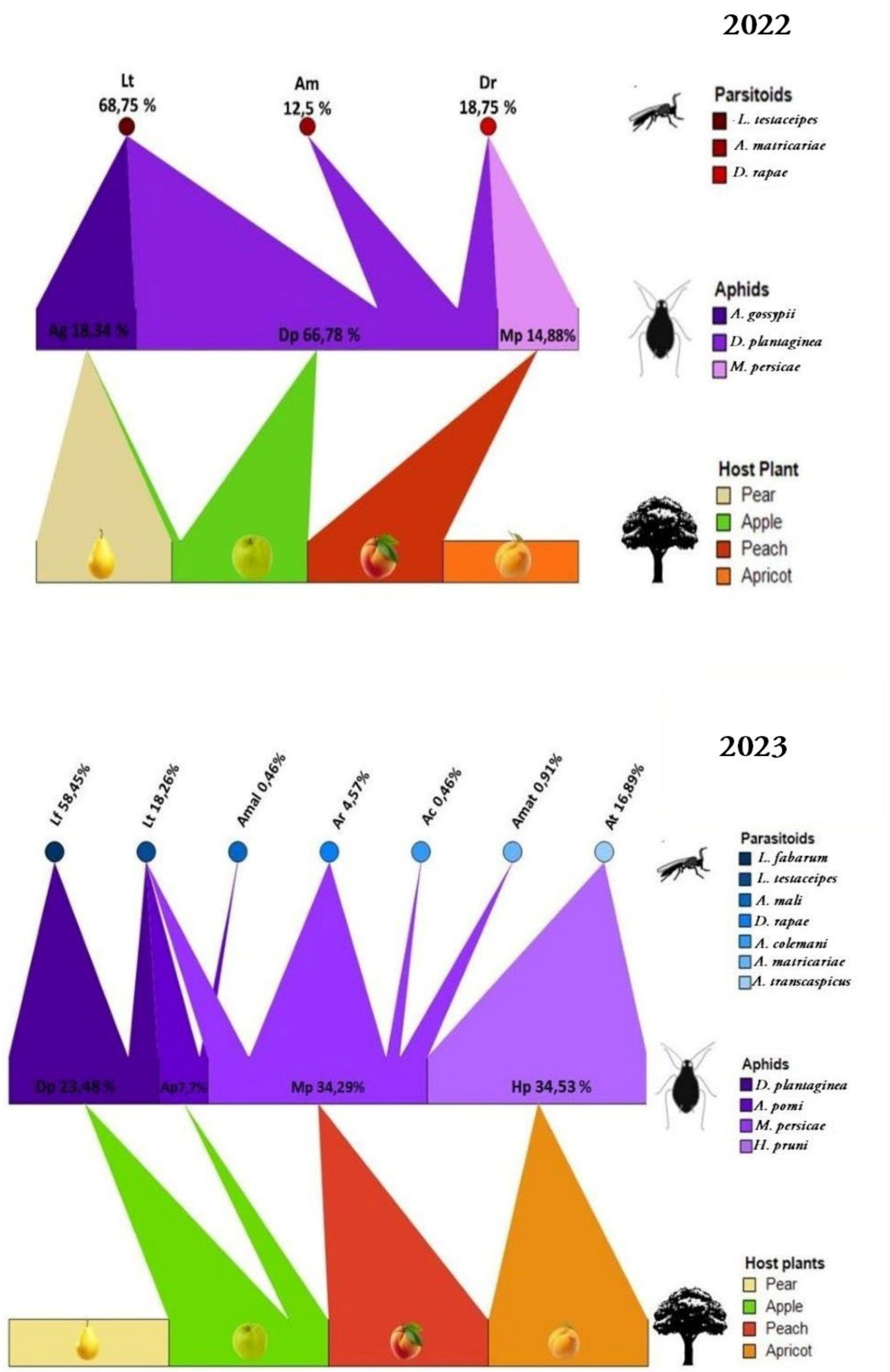


Fig. 5. Global food web structure on fruits crops

Table 1. Correlation between number of aphids and parasitoids of each fruit plant species and climatic factors (mean of temperature, humidity and accumulation of rainfall) N=46.

Correlations												
		Pear parasitoids n	Pear Aphids n	Peach parasitoids n	Peach aphids n	Apple parasitoids n	Apple aphids n	Apricot parasitoids n	Apricot aphids n	T (°C)	H (%)	R (mm)
Pear parasitoids	Corre Coeffi	1,000	0,121	-0,072	0,263	-0,19	0,313	-0,049	-0,80	-0,261	0,203	-0,038
n	Sig. (2-tailed)	.	0,424	0,635	0,078	0,898	0,034	0,746	0,596	0,080	0,175	0,802
Pear Aphids	Corre Coeffi	0,121	1,000	0,340*	0,402**	-0,67	0,179	0,210	0,451**	-0,682**	0,657**	0,408**
n	Sig. (2-tailed)	0,424	.	0,021	0,006	0,657	0,234	0,161	0,002	0,000	0,000	0,005
Peach parasitoids	Corre Coeff	-0,072	0,340*	1,000	0,595**	0,166	0,010	0,215	0,226	-0,491**	0,418**	0,175
n	Sig. (2-tailed)	0,635	0,021	.	0,000	0,270	0,950	0,151	0,131	0,001	0,004	0,245
Peach aphids	Corre Coeffi	0,263	0,402**	0,595**	1,000	0,457**	0,168	0,411**	0,063	-0,582**	0,209	-0,054
n	Sig. (2-tailed)	0,078	0,006	0,000	.	0,001	0,263	0,005	0,678	0,000	0,163	0,722
Apple parasitoids	Corre Coeffi	-0,019	-0,067	0,166	0,457**	1,000	0,094	0,916**	0,302*	-0,094	-0,079	-0,075
n	Sig. (2-tailed)	0,898	0,657	0,270	0,001	.	0,533	0,000	0,041	0,536	0,602	0,619
Apple aphids	Corre Coeffi	0,313*	0,179	0,010	0,168	0,094	1,000	0,104	0,192	-0,548**	0,462**	0,132
n	Sig. (2-tailed)	0,034	0,234	0,950	0,263	0,533	.	0,491	0,201	0,000	0,001	0,382
Apricot	Corre Coeffi	-0,049	0,210	0,215	0,411**	0,916**	0,104	1,000	0,528**	-0,196	0,135	0,057
parasitoids n	Sig. (2-tailed)	0,746	0,161	0,151	0,005	0,000	0,491	.	0,000	0,191	0,372	0,707
Apricot aphids	Corre Coeffi	-0,080	0,451**	0,226	0,063	0,303*	0,192	0,528**	1,000	-0,341*	0,556**	0,598**
n	Sig. (2-tailed)	0,596	0,002	0,131	0,678	0,041	0,201	0,000	.	0,020	0,000	0,000
T (°C)	Corre Coeffi	-0,261	-0,682**	-0,491**	-0,582**	-0,094	-0,548**	-0,196	-0,341*	1,000	-0,774**	-0,281
	Sig. (2-tailed)	0,080	0,000	0,001	0,000	0,536	0,000	0,191	0,020	.	0,000	0,059
H (%)	Corre Coeffi	0,203	0,657**	0,418**	0,209	-0,079	0,462**	0,135	0,556**	-0,774**	1,000	0,512**
	Sig. (2-tailed)	0,175	0,000	0,004	0,163	0,602	0,001	0,372	0,000	0,000	.	0,000
R (mm)	Corre Coeffi	-0,038	0,408**	0,175	-0,054	-0,075	0,132	0,057	0,598**	-0,281	0,512**	1,000
	Sig. (2-tailed)	0,802	0,005	0,245	0,722	0,619	0,382	0,707	0,000	0,059	0,000	.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Discussion

Aphids and parasitoids dynamic

Herein, the impact of the abiotic factors temperature and precipitation is clear on the diversity of species of aphids, their parasitoids and their interactions. The year 2023 chowed a high number of parasitoids and hyper-parasitoids than 2022 especially on peach. During May and June 2023 the average monthly rainfall was higher (90.93 mm 98.81mm) compared to May and June 2022 (11.43, 5.08 mm) respectively.

According to Agarwala & Das (2012), the selection of the host plant by Aphids depends of the density distribution and nutritional quality of plants and the nutritional quality of the plant vary depending on its stage of development as well as its response to seasonal variations. The two species *A. gossypii* and *A. pomi* were present on Pear and Apple trees. The first one was present in the two years of this study. A significant effect on aphid diversity and density due to weather changes between years (Temperature and Rainfall) was detected (Fig 1 and Fig 4), the occurrence of *A. pomi* on Apple and pear trees in the second year, which is more optimal to this aphid species. Its occurrence correspond with temperature high than 20°C in May 2023 comparing to May 2022 and under than 30°C, while *A. gossypii* can develop in 17°C and resist to 33°C. Correlation analyses showed a correlation between climatic factors on aphids number on pear and apple (Table 1). Apple trees were infested by three species *A. gossypii, A. pomi* and *D. plantaginea* The rosy apple aphid *D. plantaginea* is considered a major insect pest on Apple orchards, which causes leaf-rolling, deformation of fruit (Brown & Mathews, 2014). *A. gossypii* can infested 100 crops species, it is a highly polyphagous pest (Hulle *et al.,* 2020). In early spring the first generation fundatrix females of *D. plantaginea* hatches from egg on Apple which is the primary host (Blommers *et al.,* 2004). The normal development of insects can be influenced by a higher temperature in spring and winter (Bale & Hayward, 2010). The dominance of *D. plantaginea* in April and May in the two years, *Aphis gossypii* in June and July 2022 .

In 2023 dominance of the *A. pomi* . Presence of *A. gossypii*, *A. pomi* and *D. plantaginea* in the end of May, with dominance of *A. pomi* and a presence of *A. gossypii* and *A. pomi* with dominance of *A. pomi* in June, end of September and October. This presence corresponding to temperature between 20°C and 24°C. Higher temperatures were associated with decreasing abundance in *D. plantaginea* and increasing abundance in *A. gossypii* and *A. pomi*. According to Liu *et al.* (2021), *A. gossypii* can resist in high temperatures between 29°C and 35°C.

On apple trees, the parasitoid activity started in the end of April with the *Aphidius matricariae* species until the end of May with the species of *Lysiphlebus testaceipes*, *Diaeretiella rapae* species and hyperparasitoid *Pachyneuron aphidis* in 2022. In 2023 we noted a less dominance of *D. plantaginea* in the end of April and the beginning of May due to the effective presence of the Parasitoids species *L. fabarum* and *L. testaceipes*. Interestingly, the Parasitoid assemblage changed as the season progressed, while the most frequent parasitoid in both years was *L. testaceipes*. In 2023 *L. fabarum* appeared early in the season with a high number (128 specimen). *L. testaceipes* gained relevance later also a high number compared to 2022. The Peach species were infested by the green peach aphid *Myzus persicae*, peach trees are the primary host plant of them (Blackman & Eastop, 2000). This species is an important pest on many crops worldwide (Hill, 2008). On apricot we noted that the species *H. pruni* which is specific to Apricot trees, it is a sensitive to weather conditions, their presence was noted in the second year of this investigation. Correlation analyses showed a significant correlation between the three climatic factors temperature, humidity and rainfall on aphids and their Parasitoids of peach and Apricot. The demographic balance between Aphids and Parasitoid wasps can determine the efficiency of biological control (Furlong *et al.,* 2017). The seasonal changes in host quality determine the within-year dynamics of aphids. In spring, the leaves grow and import amino acids via the phloem. Aphids do best when amino acids are actively translocated in the phloem (Kindlmann *et al.,* 2007). The number and efficiency of primary parasitoid were determined by biotic and abiotic factors, particularly, temperature, humidity, availability of nutrition and the activity of different secondary parasitoids (Stary, 1970).

Aphid Parasitoid interactions

In the second year, we noted a dominance and preference that can be specialization of *Lysiphlebus fabarum* to *D. plantaginea* aphid (Fig. 5). Competition between aphids can be driven by an array of interactions with different species of Parasitoids, which the case of *A. pomi* in the second year of study. The specific composition of the community of hosts, and their relative abundance explain the relative abundances of parasitoids. Therefore we noted on aphid level; a preference of *L. testaceipes* to *A. pomi* than *D. plantaginea* within colonies composed of *A. pomi, A. gossypii* and *D. plantaginea* on Apples trees. However, on plant level, a preference of *L. testaceipes* to Apples trees than Pear trees. Indeed, the study of Derocles *et al.* (2020) has revealed that aphid parasitoids considered as generalists behaves at local scale as specialists. Our results disagree with Remaudière *et al.* (1976) the specificity of parasitoid depend to aphid host and not necessary to the plant host. The peach trees showed the high diversity of parasitoids in 2023, despite the presence of one aphid species *M. persicae.* We noted also the importance of hyper-parasitoid in the two years of this study. In the second year 2023, we noted a combination between *D. rapae* and *A. colemani* in the beginning of May, and a combination between *D. rapae* and *A. matricariae* in the end of May. In Spain the study of Aparicio *et al.* (2019) suggest that it will be feasible to implement biocontrol methods for aphids in integrate pest management programs by Parasitoid against *Myzus persicae* and *Hyalopterus spp* on peach trees. On peach, the hyper-parasitoid *Pachyneuron aphidis* was observed after the apparition of primary parasitoids in the two years, the other hyper-parasitoid species showed only the second year 2023. According to Raymond *et al.* (2016), for aphid parasitoids, generalism may provide advantages to the individuals and populations in agricultural landscapes as a changing environment. However, under more stable condition selection can offer more level of specialization. Indeed, the presence of specific Aphid for apricot, provide a specific parasitoid species *Aphidius transcaspicus*. To our knowledge, the strategy investigated in Alhmedi *et al.* (2023) work was the first attempt to evaluate the potential role of fruit trees as insectary plant candidates for aphid control in apple orchards.

These results highlight the importance of studying the mechanisms of local specialization within food webs, to be considered when implementing the use of such parasitoids in pest regulation within agro-ecosystems. The presence of the preferred and specific host plant of aphid effect on the parasitoid species, the presence of *D. plantaginea* and *A. pomi* on apple trees offer more level of specialization with *L. fabrum and L. testaceipes* respectively compared with A. gossypii that is not on his preferred host plant, which is the case of *M. persicae* on peach and *H. pruni* on apricot. Thisresults suggest that the parasitoid *Lysiphlebus testaceipes* should be the first generalist agent of biological control on fruits crops in the study region and *Diaeretiella rapae* on peach. *Lysiphlebus testaceipes* and *Lysiphlebus fabarum* for the apple trees. For *L. Fabarum* more studies must be done to understand its occurrence and its specialization on *D.plantaginea* on Apple in this region. An importance of the hyper parasitoids *Pachyneuron aphidis* was noted. This study presented the effect of climatic conditions between years on Aphid parasitoids occurrence and their preference.

Author's Contributions

Fatima Gagui : Conceptualization; methodology, formal analysis, investigation, draft preparation, final review and edit, visualization and supervision. **Malik Laamari** : Supervision; project administration and funding acquisition. **Souad Tahar-Chaouche** : Confirmed identification,final review and edit. **Abdelmoneim Tarek Ouamane :** Formal analysis.

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Data Availability Statement

The specimens collected in this study examined are deposited in the following institutions: Laboratory of biology, University of Khenchela Algeria, Laboratory of ATPPAM, Department of Agronomy, Institute of Veterinary and Agronomy Science, Uiversity of Batna, Ageria and Scientific and Technical Research Centre for Arid Areas (CRSTRA) Biskra, Algeria.

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Ethics Approval

Insects were used in this study. All applicable international guidelines for the care and use of animals were followed. This article does not contain any studies with human participants performed by the author.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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اثر تغییرات زمان روی روابط متقابل شته و پارازیتویید روی درختان میوه در منطقه نیمه خشک

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چکیده: مدیریت کنترل بیولوژیک شته ها با استفاده از پارازیتوئیدها نیاز به درک و دانش عمیق از تنوع گونه ای دقیق حشرات هدف در منطقه مورد نظر و فهم نحوه تعامل بین آفات و پارازیتوئیدها در طی زمان دارد. در این مطالعه، با روش جمع‌آوری نمونه، شته‌ها و پارازیتوئیدهای آن در فاصله آوریل ۲۰۲۲ تا اکتبر ۲۰۲۳ روی درختان درختان سیب، گلابی، هلو و زردآلو در منطقه ام البواقی، عین زیتون در شمال الجزایر جمع آوری شد. هدف نخست این پژوهش، مطالعه پویایی جمعیت شته‌ها و بال‌غشاییان انگل بود. هدف دیگر، مطالعه تأثیر زمان بر میزان تخصص تغذیه‌ای بود. این بررسی نشان داد که زنبور *Lysiphlebus testaceipes* ، گونه ای پلی فاژ و عمومی روی گونه‌های شته در درختان مورد مطالعه بود، اما در فصل بهینه تغذیه از شته های *Aphis pomi* و *Dysaphis plantaginea* را روی درختان سیب ترجیح می دهد. *Diaeretiella rapae* می تواند عامل ویژه ای برای کنترل بیولوژیک شته *Myzus persicae* روی درختان هلو باشد، که در سال ۲۰۲۲ ، ۱۰۰ درصد و در سال ۲۰۲۳، ۵۶.۲۵ درصد پارازیتوئیدها را تشکیل داد. این مطالعه حضور مهم گونه‌های هیپرپارازیتوئید را روی درختان سیب و هلو نشان داد که روی کارایی پارازیتوئیدهای فعال روی شته‌ها، اثر می‌گذاشتند. نرخ هیپرپارازیتیسم روی درختان هلو به بیش از ۳۰ درصد می‌رسید در حالی که این میزان روی درختان سیب بین ۳۷.۳۳ درصد در سال ۲۰۲۲ و ۱.۷۷ درصد در سال ۲۰۲۳ متغیر بود.

کلمات کلیدی: پارازیتوئیدهای شته، تغییرات زمانی، ترجیح، تخصص میزبانی، پویایی جمعیت

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