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RESEARCH PAPER

Distribution and structure of aphid and their parasitoids community in the Kurdistan Region-Iraq

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A B S T R A C T

Aphids are significant pests to many host plant species throughout the world. Aphids are on the other hand parasitized by a variety of parasitoid wasps which can potentially be used as biocontrol agents. The focus of the present study is on the pattern and distribution of the aphids and their parasitoids in the Kurdistan region in the northern part of Iraq. A field study was conducted at four locations with different bio-geographic elements and climatic conditions on several different host plant species. It turned out that the highest number of aphids and parasitoids was recorded in Darbandi Gomaspan and the lowest number of aphid and parasitoids was in Choman. Number of parasitoids were generally lower than the number of aphids. The parasitoids presented in this work have been reared from 13 aphid host taxa occurring on plants sampled from different locations. Most of the species of parasitoids belonging to the families Braconidae and Aphelinidae. The results of this study can be considered as a first data on the population of aphids and their parasitoids in this region. Further research will be undertaken for promising the biological control of aphid pests in this region.

KEY WORDS: Aphid population, bio-geographical, cultivate plant, weed
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1. INTRODUCTION

Aphids are common terrestrial pest species and can be found in everywhere in the world and exploit a large group of host plant species (Blackman and Estop, 2006; Völkl *et al*., 2007; Guerrieri and Digilio, 2008).

Due to their reproduction potential, they often give rise to large populations which are considered as good resources for many natural enemies, including hymenopteran parasitoids (Le Ralec *et al*., 2010). Hymenopteran parasitoids of aphids are found in two taxa, the sub-family Braconidae and the genus *Aphelinus* (Hymenoptera: Aphelinidae). These two taxa are

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endoparasitoid and specialized on aphids (Starý 1970,1988; Boivin *et al*., 2012). The wasps lay eggs inside the body of aphid larvae and adult aphids causing mortality of aphids at the end of the larval development of the parasitoid (O'Donnell, 1987). There are many biotic and abiotic factors that lead to dense aphid populations (Foyer *et al*., 2016). The most important factors are the host plant specialization and climatic conditions, however, these factors effect on the populations of parasitoids as well (Le Ralec *et al*., 2010). Kurdistan region is well-known with the complex biodiversity due to its climatic conditions and biogeographic area in Iraq. It is considered a significant habitat, where many herbivores with their natural enemies can be found including aphid and their parasitoids. There are few investigations that have been conducted on the aphid parasitoids in Iraq (Starý, 1969; Al-Azawi, 1970; Starý and Kaddou, 1971). So far, only one study has been carried out on aphids and their parasitoids in the Kurdistan region of Iraq (Bandyan *et al*., 2021).

Understanding of the parasitoid community associated with aphid pests and host plants in different habitat is crucial to conserve and enhance the native parasitoid populations and to develop biological control programs of aphid pests in this region. However, the knowledge on distribution and structure of the population of aphids and their parasitoids naturally active on different host plants (cultivated and non-cultivated) in different climatic conditions in this region is lacking so far. Therefore, the aim of this study was to evaluate the distribution and population of the aphids and their parasitoids covering most of the crops and non-cultivated (weed) plants around the field as well in different biogeographical areas in the Kurdistan region and to provide information about the population structure to compare their diversity in various areas and host plants as a background for further research for promising the biological control of aphid pests in this region.

2.MATERIALS AND METHODS

2.1. Study area

The field survey was carried out from April to July 2017 at four various locations within the Kurdistan region of northern Iraq (Erbil, Darbandi Gomaspan, Harir and Choman) (Figure1), which is representative different agroecosystem in the region lowland and mountainous area, covering the altitudes range from 430 to 950 meters above mean sea level.

2.2. Field collection

Fields were regularly examined twice a month for collection aphids and their parasitoids on several host plants cultivated and non-cultivated plants including *Vicia faba* L., *Solanum melongena* L., *Sorghum bicolor* L., *Capsicum annuum* L., *Citrullus lanatus* L., *Triticum aestivum* L., *Altheae sp* L., *Brassica nigra* L., *Carduus pycnocephalus* L., *Glycyrrhiza glabra* L., *Silybum marianum* L., *Sonchus asper* L., *Avena fatua* L., *Carthumus sp* L.. and *Pisum sp* L. during the study period.

2.3. Aphid collection methods

Samples from plants bearing aphid colonies consisting of living and mummified aphids were gently cut with scissors and put separately in paper bags with labels and transferred to the laboratory for processing. The aphid densities were assessed by visual assessment of samples. Around 100–125 leaves, straws and small branches were sampled in each field and around the area. The number of aphids (nymph, adult winged, adult alate) and mummies were recorded. A few live adult aphids were killed and preserved in 75% ethanol (Eastop and van Emden, 1972) for later identification. The aphids were identified to species level using the key of Blackman and Eastop (2000).

2.4. Rearing parasitoids

Parasitoids were reared from the live aphid samples and mummified aphids in the laboratory. Pieces of plants bearing aphid colonies (living aphid and mummies) were placed separately in plastic Petri dishes (Ø 9 cm × 1.5 cm) and kept at laboratory conditions (22°C, 65% relative humidity, 16:8 L:D photoperiod) to obtain emergence of adult parasitoids for at least 14 days post-collection (Kavallieratos *et al*., 2004). The

Petri dishes had a circular opening in their lid covered with muslin for ventilation in order to maintain conditions inside the Petri dishes similar to those existing in the laboratory room. The mummies were inspected daily for the emergence of adults. As soon as the adult parasitoids emerged, they were immediately captured using an aspirator and transferred into Eppendorf tubes containing 96 % ethanol and stored at -20°C (Tomanović *et al*., 2014) for later identification. The parasitoids specimens on crops were identified to species level using morphological as well as molecular traits (Bandyan *et al*. 2021). Parasitoids reared on weeds were identified morphologically on subfamily level and then classified just as morphospecies.

2.5. Data analysis

Data were analysed by one-way ANOVA in SPSS© version 21. Significant differences between host plants and date of collection according to the locations and descriptive methods were used to calculate the means and standard deviation.

3.RESULTS

3.1. Aphid and parasitoids per site

A total of 14454 aphids and 3164 parasitoid wasps were collected during the sampling survey on several different crop and weed plants. Generally, the results showed that the aphids are more abundant than their parasitoids. The highest mean number of aphids and parasitoids was collected from Darbani Gomaspan (66.7 and 17.6) respectively and lowest mean number of aphid and parasitoids was sampled from Choman (8.93 and 25.0) respectively. There was a significant difference between the populations of aphids and their parasitoids in all locations (Table1: one-way ANOVA: P< 0.001).

Table 1: Mean (±SD) aphid and parasitoids densities according to the locations in the Kurdistan Region.

Locations	Total of Aphids	Mean ±SD of aphids per plants	Parasitoids	Mean ±SD of parasitoids per plants
Erbil	3992	38.01 ± 66.46	359	3.41 ± 7.33
DarbaniGomaspan	7006	66.72 ± 123.32	1858	17.69 ± 39.82
Harir	2518	23.96 ± 54.68	682	6.49 ± 23.16
Choman	938	8.93 ± 45.10	265	2.52 ± 13.99
Kurdistan Region Total	14454	34.41 ± 81.07	3164	25.01±7.53
One way ANOVA		F (3,416) =10.30, P<0.001		F (3,416) = 8.63, P<0.001

3.2. Aphids and parasitoids per host plant

Aphids and parasitoids were collected on 15 host plant species including crop and weed plants during the survey study. In Erbil almost all host plants are attacked by aphids and parasitized by parasitoids (Figure 2a). The highest number of aphids was recorded on *Citrullus lanatus* and *Solanum melongena* 122 and 110 respectively and the mean number of parasitoids was 6.57 and 5.14 respectively. While the highest number of parasitoids was recorded on *Altheae sp.* and *Glycyrrhiza glabra* 11.7 and 11.2 respectively on which 82.8 and 76.7 aphid were recorded. In *Pisum sp.* the mean number of aphids was 4.71 but no parasitoids were recorded on the same plant. on *Carthumus sp.*, *Capsicum annuum* and *Carduus pycnocephalus* there were no specimens recorded on those plants during the study. *Vicia faba*, *Triticum aestivum*, *Sorghum bicolor*, *Silybum marianum*, *Avena fatua*, *Brassica nigra* and *Sonchus asper* the mean number of aphids were 53.1, 32.5, 47.0, 17.1, 7.71, 9.14 and 6.71 and parasitoids 6.71, 3.0, 1.0, 3.71, 0.28, 1.71 and 0.14 respectively. There is a significant difference between host plants in relation to the number of specimens in Erbil area (Figure 2a: one-way ANOVA: P< 0.001).

The maximum mean number of aphids and parasitoids recorded on *Glycyrrhiza glabra* in Darbani Gomaspan, Harir and Choman were 316, 156 and 108 and 133, 76.5 and 35.0 respectively. In Drabani Gomaspan, on *Pisum sp.* the mean number of aphids was 3.71 and no parasitoids was recorded. There were no specimens found on *Citrullus lanatus*, *Sorghum bicolor*, *Solanum melongena* and *Capsicum annuum*. The mean number of aphids and parasitoids on *Vicia faba*, *Triticum aestivum*, *Altheae sp.*, *Carthumus sp.*, *Sonchus asper*, *Silybum marianum*, *Avena fatua*, *Brassica nigra* and *Carduus pycnocephalus* were 148, 78.2, 98.5, 120, 90.2, 63.0, 17.4, 18.5 and 46.0 and 50.2, 2.8, 37.0, 8.57, 9.85, 7.85, 0.28, 3.57 and 11.4) respectively. There was a significant difference between host plants in

relation to the numbers of aphids and parasitoids in Darbandi Gomaspan. (Figure 2b: one-way ANOVA: P<0.001).

Specimens not recorded on *Vicia faba*, *Altheae sp.*, *Citrullus lanatus*, *Carthumus sp.*, *Solanum melongena*, *Silybum marianum*, *Carduus pycnocephalus* and *Pisum sp.* in Harir and Choman. As well as *Sorghum bicolor*, *Avena fatua* and *Capsicum annuum* in Choman. In Harir, the mean number of aphids and parasitoids collected on *Sorghum bicolor*, *Triticum aestivum*, *Capsicum annuum*, *Brassica nigra*, *Avena fatua* and *Sonchus asper* were 66.8, 55.8, 48.2, 19.4, 5.4, 7.85 and 5.71, 4.14, 6.57, 3.28, 0.85, 0.28 respectively. There was a significant difference between host plants and specimens in Harir (Figure 2c: one-way ANOVA: P< 0.001).
In Choman, the mean number of aphids and parasitoids on *Sonchus asper*, *Brassica nigra* and *Triticum aestivum* were 12.0, 8.57 and 4.85 and 0.57, 2.0 and 0.28 respectively. There is a significant difference between host plants and specimens in Choman (Figure 2d: one-way ANOVA: P< 0.001).

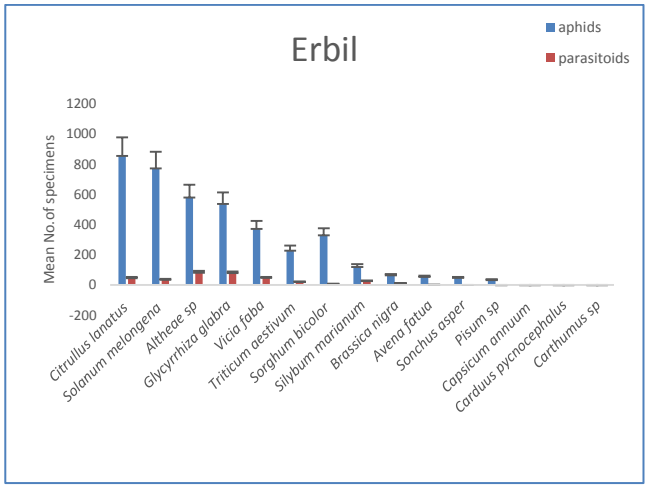

Figure 2 (a): Mean number of aphids and parasitoids on the different host plants in Erbil.

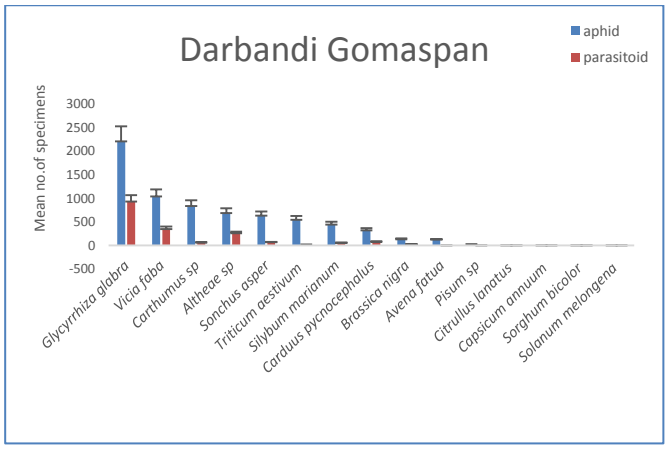

Figure 2 (b): Mean number of aphids and parasitoids on different host plants in Darbandi Gomaspan.

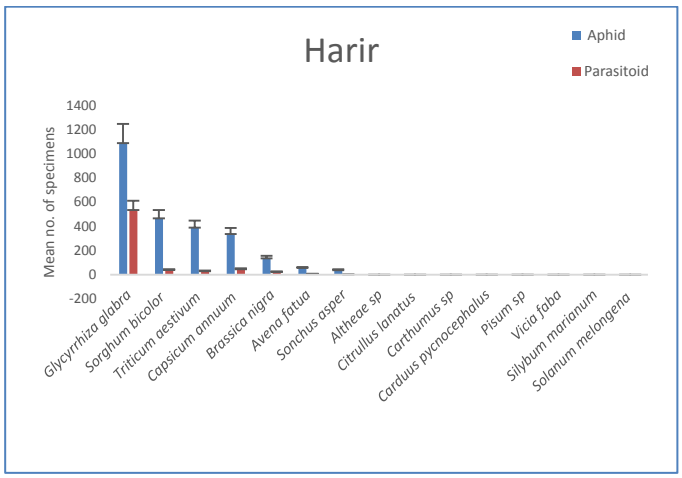

Figure 2 (c): Mean number of aphids and parasitoids on different host plants in Harir

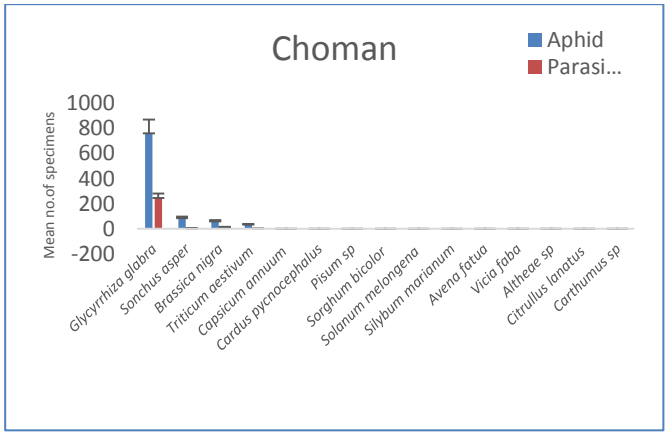

Figure 2 (d): Mean number of aphids and parasitoids on the different host plants in Choman

3.3. Aphid and parasitoids per month

The specimens were collected during cropping season from April to July 2017 in this region (Figure 3). Generally, in Erbil the mean population of aphids in the begin April was 2.13 and there were no parasitoids found. The mean number of aphids and parasitoids were dramatically increased in middle May reaching 82.3 and 6.33 respectively and the mean numbers decreased in late July to 11.8 and 1.93. In Harir, the mean number of aphids and parasitoids in begin April was 33.3 and 4.06 respectively and in middle April it decreased to 15.8 and 3.6 while the mean number of aphids increased to 31.2 in begin May and parasitoids reached to 12.2 in late May. In Darbandi Gomaspan, the mean number of aphids and parasitoids in the beginning of April was 16.1 and 12.3 respectively and then dramatically increased to 133 and 28,4 in middle May. In late July, their number decreased to 13.9 and 16.4. In Choman, there was high difference in the existed period of aphids and parasitoids compared to the previous locations, there was no specimens collected until middle May. The populations growth of aphids and parasitoids occurred in middle May 4.26 and 0.26 in this location and reached to the peak in late June 26.9 and 6.80 respectively. The number of aphid and parasitoids then decreased in late July to 9.0 and 4.0 respectively.

3.4.Parasitoids species per family

The collected parasitoids belonged to different families, two families of primary parasitoids were recorded, i.e., Braconidae and Aphelinidae, and seven families as hyperparasitoid were recorded including Eurytoimidae, Encyrtidae, Eriaporidae, Figitidae, Platygastridae, Pteromalidae and Signiphoridae. The most species were recorded in Braconidae and Aphelinidae were 7 and 4 respectively and one single species was collected for each hyperparasitoids families (Figure 4).

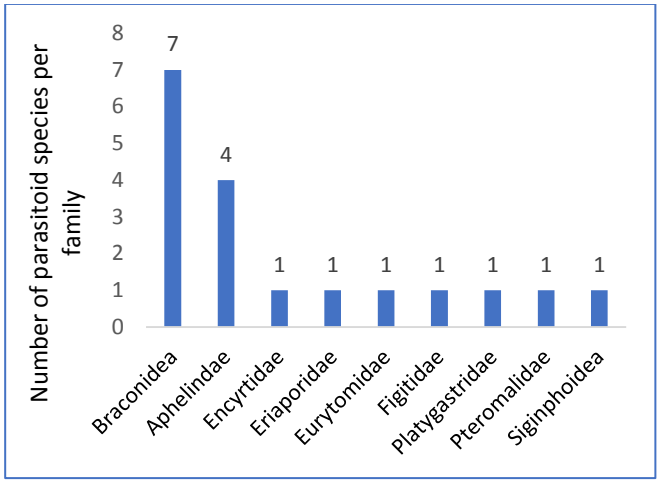

Figure 4: Parasitoids species per family

3.5. Aphid species per plant

Different aphid species were found at each host plant during the study (Figure 5). *Triticum aestivum* and *Sonchus asper* were infested by different aphid species 5 and 4 respectively, and three different aphid species were recorded on each *Carduus pycnocephalus*, *Glycyrrhiza glabra* and *Solanum melongene*. On the *Altheae sp.*, *Silybum marianum*, *Sorghum bicolor*, *Brassica nigra*, *Citrullus lanatus*, *Vicia faba*, *Carthamus sp.* and *Avena fatua* two different species were found and only one single species was found on *Pisum sp.* and *Capsicum annuum*.

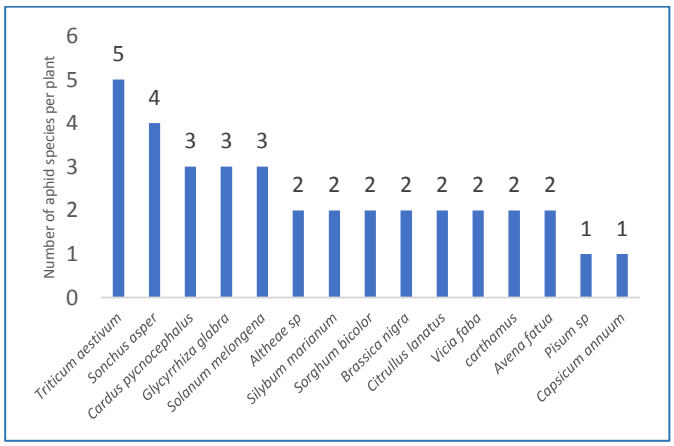

Figure 5: Aphid species per plant

4. DISCUSSION

The present study focused on the pattern of population and distribution of the aphids and their parasitoids in Kurdistan region of Iraq. Kurdistan region represents a large territory area with different bio-geographical elements and various climatic conditions.

Our assessment on the structure of population and distribution of aphid and their parasitoids indicates the most preferable climate condition and host plant species could be potentially considered to promising the biological control programs in this region.

The result of the current study indicates that abiotic factors such as climatic conditions and biogeography area are the main factor to distribution and reproduction of aphids and their parasitoids, therefore, the highest number of specimens was collected from Darbandi Gomaspan in middle and late spring, which is the suitable time for population growth and reproduction. The average temperature was 27.3 ˚C ± 1.2˚C with 55% RH and this area has favorable climatic condition and with the geographical aspect is like valley area and one side is surrounded by Safin mountain its mixture with the highland and lowland which lead to drives grow vegetation and agricultural plants. In contrast, the number of specimens were low in Choman, it is more pronoun, the climatic condition may differ considerably, the average temperature was around 20.1˚C±1.3˚C with 23% RH because it is considered the coldest area in Iraq even during the summer. According to Sigsgaard (2002) the cold weather which leads to hardly living the holocyclic aphid population and immigrating specimens to the warm area and maintaining no overwinter parasitized in this area. According to Kavallieratos *et al*. (2004) and Tomanović *et al*. (2009) in the Mediterranean climatic conditions generally favour the presence of host aphids on plants and the most suitable period for aphids infesting plant and then the parasitoids' activity is between March and June.

Aphid parasitoid species collected were mostly belonging to Aphidiinae and *Aphelinus* group which are parasitizing different aphid species on various host plants (cultivated and non-cultivated) and plants were attacked more than one aphid species during the study which is indicated that the host plant as a biotic factor has significant role to population and distribution of aphid and their parasitoids in this region. Žikić *et al.* (2017) reported that the host plants have a vital impact on the diversity of the aphids and their parasitoids. More recently, Bandyan *et al*. (2021) identified 8 species of aphids which have been parasitized by 15 species of aphid parasitoids on crops that have surveyed in this study in this region. However, it needs further study to identify the specimens that were collected on the non-cultivated plants. However, this study showed that the numerous of specimens have been collected on the non-cultivated plants for example the highest number of specimens have been collected on the *Glycyrrhiza glabra* as a non-cultivated plant that can be found around the fields and present in four locations in our study it would be preferable plant by the parasitoids this plant belonging to family Fabaceae. Considerably more work will need to be done to determine the chemical substance of this plant that might be attractive to the parasitoids. On the other hand, the high number of parasitoids on the non-cultivated plants means that the parasitoids can survive and maintain by attacking other aphid species from non-cultivated as an alternative host around the field crops. Tomanović *et al*. (2009) concluded that it is the population of large numbers of non-crop aphid hosts which leads to a build-up of many important species of parasitoids around the agroecosystems.

Additionally, Mkenda *et al*. (2019) found that field margins around fields are favorable habitats to establish a huge number of natural enemies that move to adjacent vegetable crop plants to provide biological pest control services. The current study shows that the non-cultivated plants have a significant importance to maintain the parasitoids actively in this region and support larger parasitoid populations, but aphids also profited from it, thereby counterbalancing possible biological control of aphids by parasitoids, therefore, the growers should be encouraged to avoid using herbicides and implementing agricultural practices to remove those non-cultivated plants around their fields in this region.

5. CONCLUSION

The study indicates that the Kurdistan region, as a multiple climate and geographical area and well established in local agroecosystem with the numerous of the alternative hosts that are present during the growing season which leads to grow and distribution of aphid parasitoids. The findings of this study will be taken as a basic information on the population of the aphid parasitoids in this region. In addition, this data is crucial for further study on the aphid parasitoids in more details to implement it in the biological control programs in the Kurdistan region of northern Iraq.

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Figure 1. Study sites in Northern Iraq, Kurdistan region (Red dots).

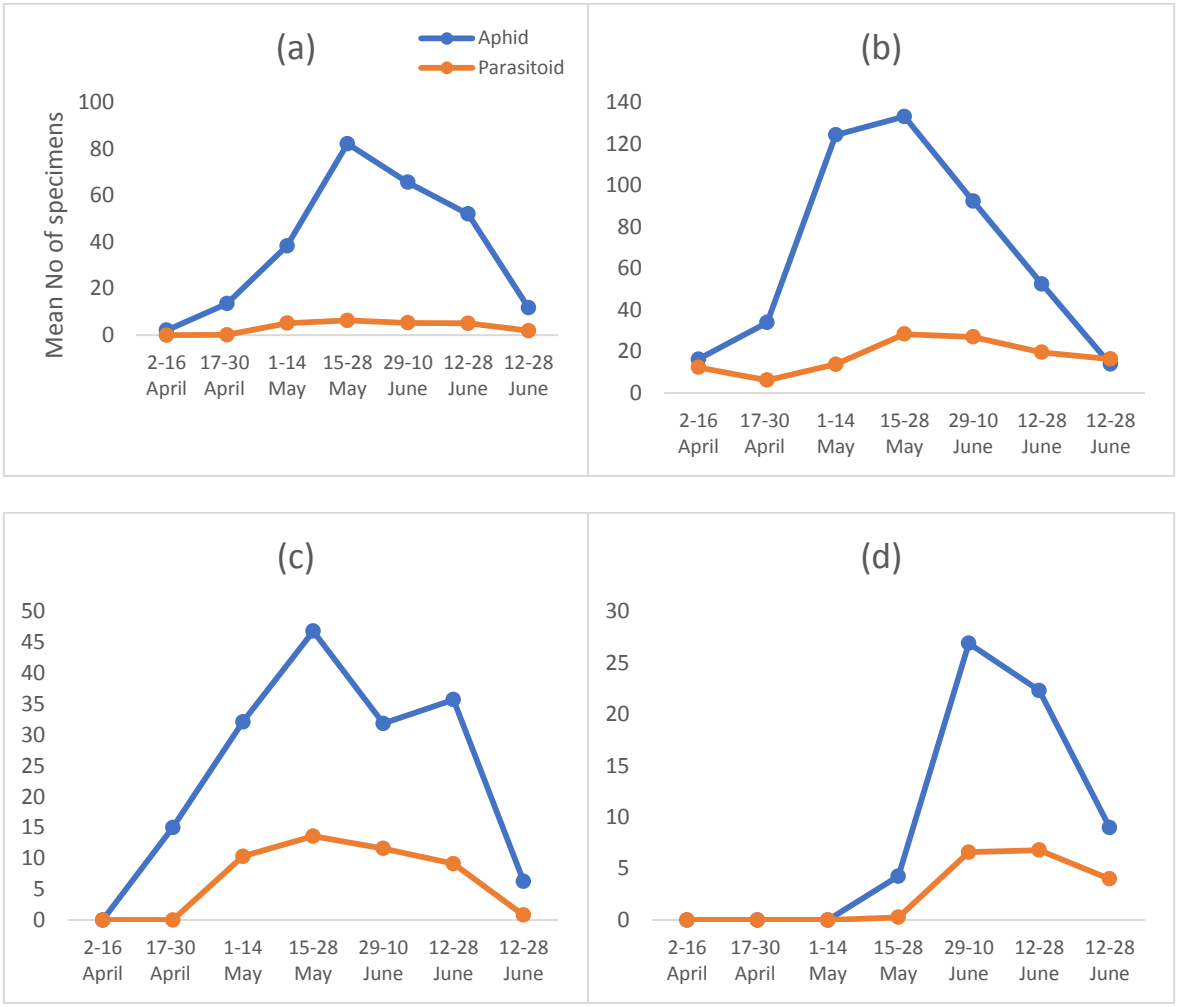

Figure 3: Mean number of aphids collection and their parasitoids during the study period in (a) Erbil, (b) Darbandi Gomaspan, (c) Harir, (d) Choman in Kurdistan Region.