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Tritrophic associations (plant- aphid- parasitoids) observed in the palm groves of southern Algeria: the case of Ghardaia

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Abstract

This study was conducted in Algeria (case of Ghardaia). Its primary objective is to investigate the biodiversity of aphid parasitoids on both cultivated and non-cultivated plants in the Ghardaia region and to identify the various tritrophic relationships. This study allowed us to identify eight species of primary parasitoids: *Lysiphlebus fabarum*, *Aphidius matricariae*, *Aphidius ervi*, *Aphidius colemani*, *Aphidius funebris*, *Trioxys angelicae*, and *Praon volucre*. The last two species are reported for the first time. One unidentified hyperparasitoid species was found to be active on the larvae of primary parasitoids. In terms of associations (plant- aphid- primary parasitoid), we identified 23 associations.

Keywords: tritrophic, parasitoid, aphid, plant, association, Ghardaia.

1. Introduction

Aphids are an extremely widespread group of insects globally, having diversified alongside flowering plants, almost all of which serve as their hosts. Currently, they have become major pests of forests, and ornamental plant crops. They are particularly known for their rapid development and their life

cycle, which in most cases requires alternating between wild and cultivated plants (Ait-Amar and al., 2022).

Due to the harmful effects of insecticides on the environment and the increasingly frequent cases of resistance in aphids, humanity is becoming increasingly concerned with environmental preservation through the use of biological control (Woolley and al., 2022; Kishinevsky and al., 2023)

Hymenoptera play a discreet yet important role. Several species are commercially utilized for biological control. Hymenoptera include two parasitoid families of aphids, with the most significant being the Braconidae family, which encompasses 27 genre of the Aphidiinae subfamily (Talebi et al., 2009; Tahar Chaouche, 2019).

Several studies have highlighted the importance of the tri-trophic relationship between plants, aphids, and parasitoids. It is particularly the plant-aphid complex that determines the current distribution of parasitoids worldwide. Additionally, human intervention has to be considered, especially regarding the introduction of plants along with their pests from one continent to another, as well as the introduction of auxiliary organisms to address certain phytosanitary issues.

This study is part of a work program initiated in Algeria years ago, aiming to highlight the biodiversity of parasitoids associated with aphids, particularly in natural environments, and to enhance the different plant-aphid-parasitoid associations in the Ghardaia region for better preservation and utilization of data in biological control.

2. Material and methods

The plant material used during the various sampling phase consisted of twigs, leaves, and inflorescences from plants found mainly in uncultivated land, field borders, and weeds. The animal material comprised colonies of aphids and mummies encountered on plant in their natural environment. The study was conducted in five locations in the ghardaia region (Laadira, Toutouz, Old Palm Grove, N'tissa, and El Atteuf).

The quantitative assessment of aphids and their parasitoid hymenoptera requires meticulous and repeated examinations of a maximum number of species and plant organs during the study period. Due to the heterogeneity of the surveyed environments and strata, it is challenging to follow a well-defined sampling method. Additionally, it was very difficult to find an aphid colony showing signs of mummification. For this reason, all aphid colonies containing mummies, collected over time and space, are considered for the calculation of emergence rates and hyperparasitism.

The aphids found, along with the mummies, are collected together with the plant organs to which they are attached. These are then placed into Petri dishes, which are labeled with the host plat, the date of collection, and the location of the harvest. The Petri dishes reserved for the mummies are covered with a piece of tulle to facilitate the respiration of the parasitoids inside the mummies. Once brought to the laboratory, healthy aphids and emerged parasitoids are preserved in 75% ethanol for identification. The mummies that have not emerged are left in the Petri dishes for up to 21 days.

Accurate identification of aphids requires observation of the frontal sinus, the length and number of antennal segments, the presence or absence of sensory organs and their arrangement, the shape of the tail, the cornicles and cauda, the wing venation, the abdominal ornamentation, and the presence or absence of dorsal plates.

Regarding the parasitoid hymenoptera of aphids, identification is based on keys developed by Talebi and al. (2009); Rakhshani and al. (2019).

Identifying these parasitoids requires the observation of specific morphological characters, such as the individual's color, wing venation, presence or absence of setae on the wings, stigma shape, the form of the first abdominal tergite (petiole), propodeum shape, and the form and number of antennal segments. Occasionally, the identification of these parasitoids necessitates microscopic examination of certain features, particularly the hairs on the flagellum, the number of placodes, the shape of flagellomeres, and the shape of the ovipositor (Ghelamallah and al., 2018).

The resultants obtained are utilized to compile a list of inventoried parasitoid species and to understand various tri-trophic associations.

3. Results and discussion

3.1 Inventory of aphid-associated parasitoid hymenoptera

In this study, a total of 8 parasitoid species were found among the aphid colonies infesting both cultivated and uncultivated plants in the Ghardaia region. These species are listed in table 1 according to the classification adopted by Talebi and al. (2009); Ghelamallah and al. (2018); Rakhshani and al. (2019).

Table 1: List of parasitoid hymenoptera of aphids associated with fruit trees in the Ghardaia region

Primary parasitoids				
Superfamily	Family	Subfamily	Genus	Species
Ichneumonidea	Aphidiidae	Aphidiinae	<i>Ahidius</i> Nees, 1819	<i>A. matricariae</i> Haliday,1834 <i>A. colemani</i> Viereck, 1912 <i>A. ervi</i> Haliday, 1834 <i>A. funebris</i> Mackauer, 1961
			<i>Lysiphlebus</i> Forester, 1862	<i>L. fabarum</i> Marshall, 1898
		Trioxynae	<i>Trioxys</i> Haliday, 1960	<i>T. angelicae</i> Haliday, 1833
		Praina	<i>Praon</i> Haliday, 1833	<i>P. volucre</i> Haliday, 1966
Hyperparasitoids				
Superfamily	Family	Subfamily	Genus	Species
Chalcidoidea	Pteromalidae	/	/	Unidentified specie

Through the obtained results, we observe a significant biodiversity of parasitoids active on colonies of aphids infesting both cultivated and non-cultivated plants in the Ghardaia region. Data analysis reveals, for the first time, the presence of the species *Praon volucre* of the genus *Praon*, as well as the subfamily Trioxyna, with *Trioxys angelicae*. The Aphidiinae are the most diverse, with four parasitoid species: *Aphidius colemani*, *Aphidius ervi*, *Aphidius matricariae*, and *Aphidius funebris*. These findings are consistent with those obtained by Chehma and Laamari (2014). The species *Lysiphlebus fabarum* is characterized by intense activity across all surveyed regions. Hyperparasitoids are represented by only one species, which is *Pteromalidae* sp.

The species *Praon volucre* (Fig. 1a) is an aphidiid known for its polyphagy (Derocles and al., 2019). It is a parasitoid of Nearctic origin (Mkenda and al., 2019). The nymphosis of its larvae typically occurs beneath the host aphid. It has a significant biotic potential and its appearance is seasonal. According to Hemidi (2023), this parasite has the ability to shift its hosts according to the season of activity. It can live on several aphids belonging to the Aphidinae and Lachnidae groups.

Among its hosts, it parasitizes *Diuraphis noxia* (Laamari and al., 2012). In the Mediterranean region, it is considered a biological control agent against *Hyperomyzus lactucae* (Aggoun and al., 2022). It inhabits forests, steppes, and other environments. It has been reported in Europe (Aparicio and al., 2019), Irak (Bandyana and al., 2021), Tunisia (Ayadi and al., 2017), and Algeria (Laamari and al., 2012) in the majority of the studied regions. In Ghardaia, *P. volucre* (Haliday) is found on *Aphis craccivora* established on *Medicago sativa*. According Derocles and al. (2019), this species is often associated with *Lysiphlebus fabarum*. In some cases, *Praon volucre* appears at the end of spring and the beginning of summer to replace *L. fabarum*.

For the species *Trioxys angelicae* (Haliday) (Fig. 2b), it is a seasonal parasite, common from spring to autumn. According to Alhmedi and Belien (2015), it is of Palaearctic origin (Mediterranean province). It inhabits forests, steppes, and other intermediate habitats. It also lives on Aphidinae, notably *A. craccivora*, *Brevicoryne brassicae*, and *Myzus persicae*. It has the ability to alter its host spectrum according to environmental conditions. In Algeria, it inhabits various types of habitats but is particularly active on aphids associated with trees in urban environments (Laamari and al., 2012). In the study regions, it has been found with *Lysiphlebus fabarum* on the same colony of *A. craccivora* and also *Praon volucre*. This association is noted by Bandyana and al. (2021) in the Kurdistan Region. The complementarity between parasitoids is a valuable trait, as the aphid can be controlled at any location, season, and host plant.

Among the primary parasitoids encountered in the study regions, *Lysiphlebus fabarum* (Fig. 1c) is a Palaearctic-origin parasitoid, very common in Europe and the Mediterranean basin. It is a generalist and polyphagous parasitoid. It can attack 144 aphid species (Tomanović and al., 2022). The range of attacks by this parasitoid in the Ghardaia region is very broad this year, as its presence has been reported on the majority of the aphid species collected. In contrast, Chehma and Laamari (2014) reported it on *Capitophorus eleagni*, *Brevicoryne brassicae*, *Aphis gossypii*, *Aphis fabae*, and *Aphis craccivora*.

The results obtained from these studies demonstrate that this parasitoid can live outside the Palaearctic region (Mediterranean province).

The Aphidiinae, particularly the genus *Aphidius*, is the best represented. According to Hemidi (2023), the genus *Aphidius* with 70 species is considered the richest among the Aphidiinae subfamily, comprising cosmopolitan species. In the study region, this genus is represented by *A. matricariae*, *A. colemani*, *A. ervi* Haliday, *A. funebris*.

Aphidius matricariae (Fig. 1d) is the most dominant. It is a parasitoid with a wide host range, found in almost every country in the world (Ward and al., 2021). This parasitoid is present throughout almost the entire study period, with heightened activity during the spring.

The species *Aphidius ervi* (Fig. 1e) has parasitized *Aphis craccivora* and *Acyrtosiphon pisum* in the study region. This parasitoid is of Palearctic origin. It can develop up to 10 generations per year in temperate zone. This parasitoid can develop on any stage of its host. Experiments have shown that it particularly prefers the second and third larval stages (Ismail and al., 2021).

The species *A. colemani* (Fig 1f) was found only once on a spontaneous plant (*Xanthium strumarium*) with a very small population, in Chehma and Laamari (2014) in the same region, it was recorded on several species of aphids with significant on *Citrus sinensis*. It is highly polyphagous and can establish itself on many aphids associated with crops.

Aphidius funebris (Fig. 1g) was collected from the mummies of *Uroleucon*. It is a specific parasitoid of aphids from the genera *Uroleucon*, *Brachycaudus*, *Hyperomyzus*, and *Aphis*, which are associated with plants in the Asteraceae family.

The last species of Hymenoptera encountered in the study area belong to the family Pteromalidae (Fig. 1h). It is a hyperparasitoid found among colonies of aphids parasitized by *A. ervi*, and *P. volucre*. This highly virulent hyperparasitoid has a broad range of host species in the regions surveyed this year, and warrants a specific study.

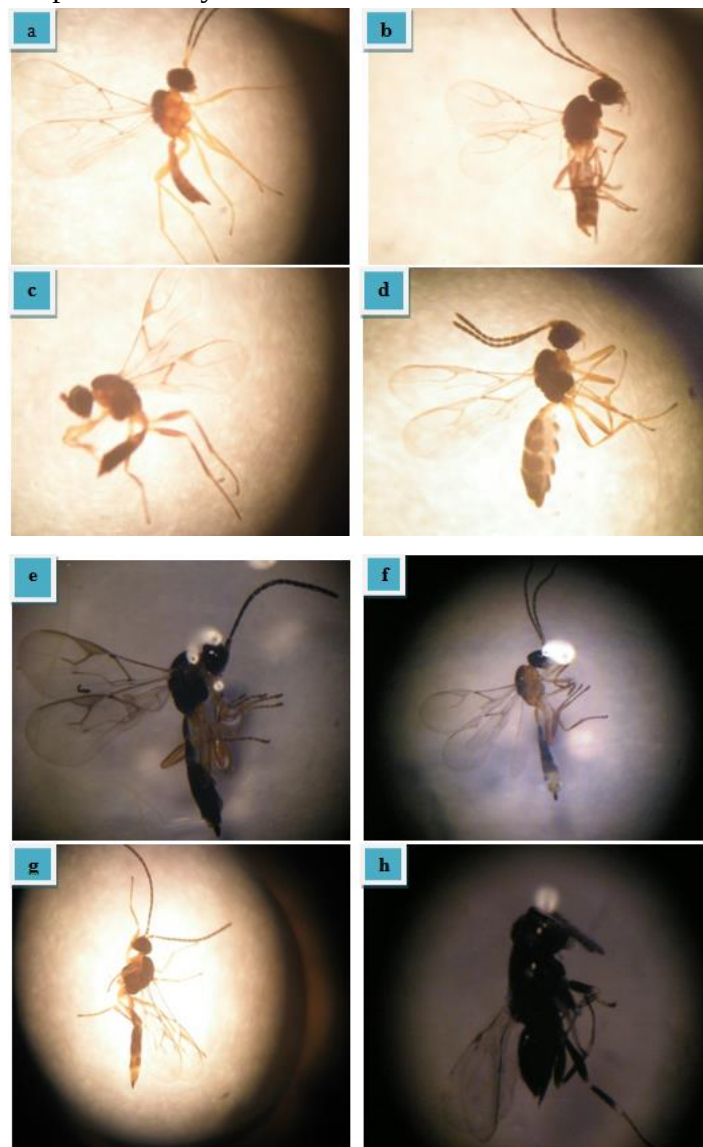


Figure1: Parasitoid species of aphids found in the Ghardaia: a, *Praon volucre*; b, *Trioxys angelicae*; c, *Lysiphlebus fabarum*; d, *Aphidius matricariae*; e, *Aphidius ervi*; f, *Aphidius colemani*; g, *Aphidius funebris*; h, *Pteromalidae* sp.

3.2. Tritrophic relationships (Parasitoid-Aphid-Plant)

According to the results reported in Table 2, tritrophic relationships involving plants, aphids, and parasitoids have been recorded in the study region. Some parasitoids have a fairly wide host range. This is the case for *Lysiphleus fabarum*, *Aphidius matricariae* and *Aphidius ervi*, each with five associations. On the other hand, the two species *Praon volucre* and *Trioxys angelicae*, which have been reported for the first time in the region, have formed only one association.

Table 2: Different parasitoid-aphid-plant host relationships noted in the study region

Parasitoid	Locality	Aphid	Plant species	Families
<i>Aphidius ervi</i>	Al atteuf Palmerie ancienne	<i>Aphis crassivora</i> <i>Acyrtosiphon pisum</i>	<i>Vicia fabae</i>	Fabacea
	N'tissa Tzouz	<i>Aphis craccivora</i>	<i>Xanthium strumarium</i>	Asteraceae
	N'tissa	Esp .non identifiée	<i>Amaranthus retroflexus</i>	Amaranthaceae
	N'tissa Al atteuf	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae
<i>Aphidius funebris</i>	N'tissa	<i>Aphis craccivora</i>	<i>Xanthium strumarium</i>	Asteraceae
	Palmerie ancienne	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae
	Al atteuf	<i>Aphis crassivora</i> <i>Acyrtosiphon pisum</i>	<i>Vicia fabae</i>	Fabaceae
	-	<i>Uroleucon sp</i>	<i>Sonchus asper</i>	Asteraceae
<i>Aphidius matricariae</i>	Al atteuf	<i>Aphis craccivora</i> <i>Acyrtosiphon pisum</i>	<i>Vicia fabae</i>	Fabaceae
	-	<i>Uroleucon sp</i>	<i>A.craccivora</i>	Asteraceae
	N'tissa	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae
	N'tissa	Esp .non identifiée	<i>Amaranthus retroflexus</i>	Amaranthaceae
<i>Aphidius colemani</i>	Tzouz	<i>Aphis craccivora</i>	<i>Xanthium strumarium</i>	Asteraceae
<i>Lysiphlebus fabarum</i>	Tzouz Al atteuf	<i>Aphis craccivora</i>	<i>Xanthium strumarium</i>	Asteraceae
	Palmerie ancienne Al atteuf	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae
	Al atteuf	<i>Aphis craccivora</i>	<i>Vicia fabae</i>	Fabaceae
	Al atteuf	<i>Aphis craccivora</i>	<i>Vicia fabae</i>	Fabaceae

	Palmerie ancienne	<i>Acyrtosiphon pisum</i>		
	-	<i>Uroleucon sp</i>	<i>Sonchus asper</i>	Asteraceae
<i>Praon volucre</i>	Al atteuf	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae
<i>Trioxys angelicae</i>	Al atteuf	<i>Aphis craccivora</i>	<i>Medicago sativa</i>	Fabaceae

Aphids are of three types: polyphagous, oligophagous, and monophagous. The listed species belong to two types. The species *Aphidius craccivora* is polyphagous, whereas *Acyrtosiphon pisum* is oligophagous to the Fabaceae, and *Uroleucon sp.* is oligophagous to the Asteraceae. The first two species are very dangerous to crops, in contrast to *Uroleucon* species.

According Baaren and al. (2019), many parasitoids, including aphid parasitoids, use volatile chemical compounds to locate their hosts. These substances are either emitted by the plant (the first trophic level) in response to damage caused by phytophages, or are kairomones produced by the host or pests (the second trophic level), such as aggregation, sexual, and alarm pheromones, or by auxiliary insects (parasitoids and predators), the third trophic level.

Aphids, causing significant crop damage by extracting phloem sap from their host plants, excrete a thick and sticky substance through their digestive system: honeydew. It is known that honeydew acts both as a volatile kairomone and as a contact kairomone. The volatile compounds associated with and emitted by honeydew are believed to originate from the natural alteration (fermentation, oxidation, etc.) of the sugars and amino acids it contains. These abiotic factors (temperature, light, relative humidity) can similarly explain the emission of volatile compounds that are detected by the sensilla present on the antennae of beneficial insects.

Several studies suggesting the olfactory perception of honeydew by various predators and parasitoids indicate that using semiochemicals emitted during honeydew degradation (bacteria, fungi, etc.) seems to be a promising approach to attract and retain beneficial insects in a target area. The biological control technique would then rely solely on the placement of dispensers containing synthetic semiochemicals identical to those associated with natural honeydew.

Based on the results reported in Table (2), 23 associations (plant-aphid-primary parasitoid) were identified in the study region. The genera *Aphidius* and *Lysiphlebus* exhibited the highest number of associations, with 5 each.

The species *Aphidius matricariae* parasitized *Aphis craccivora*, *Acyrtosiphon pisum*, *Uroleucon sp.*, and an unidentified aphid species. According Gagui et al. (2023), *A. matricariae* is a polyphagous, generalist parasitoid originating from northern India and Pakistan, and it currently has a wide distribution worldwide. According to Talebi and al. (2009), it is the most widely used in biological control against aphids in Iran. It was reported in Tunisia by Ayadi and al. (2017), and in Algeria, it was reported by Laamari and al. (2012) in all surveyed regions. In Biskra, this species is dominant and exhibits invasive activity in various habitats according to Tahar Chaouche (2019). The results obtained in this study confirm the data from Chehma and Laamar (2014), and consequently, this species remains ranked second in activity in Ghardaia.

The species *Aphidius ervi* has a very broad host range: it can parasitize about twenty species (from the genus *Acyrtosiphon* such as *A. pisum*, *A. caraganae*, *A. nigripes*, as well as the cereal aphid *Sitobion avenae*, or the peach aphid *Myzus persicae*, etc.) (Gagui and al., 2023). For many years, *A. ervi* has been used as a biological control agent for aphid population and has been introduced into several countries to combat these pests, although it is highly specialized on the pea aphid (Zamora-Mejías and al., 2017).

In a situation of host specialization in a parasitoid, parasitoids encounter locally very structured and heterogeneous host populations (both genetically and phenotypically). According to Ghaliou and al. (2018), this host specialization could have effects on their natural enemies: it could lead to parasitic specialization in the parasitoids. This phenomenon is referred to as the “Cascade Effect”.

Specialization in parasitoids involves strong fidelity to their host and better performance on that host. According to Alaserhat and al. (2017), this process constitutes a significant generator of entomophagous biodiversity: the great diversity of phytophagous insects has facilitated the diversification of their parasitoids. This phenomenon is well observed in *Aphidius funebris*, a parasitoid specific to *Uroleucon* associated with *Asteraceae*. However, in some cases and in the absence of its preferred host, it may attack other aphid species of genus *Aphidius*, particularly *A. craccivora* and *A. fabae*, but with very low emergence rates (Martínez-Chávez and al., 2017; Salman and al., 2022).

Apparently, in Ghardaia, the ecological conditions and the polyculture system practiced in the oases have altered the behavior and expanded the range of aphids affected by certain parasitoids. This is the case with *Lysiphlebus fabarum*, which typically lives on a wide range of aphids associated with herbaceous plants (grasses, legumes, and composites), thereby the dominant species.

Based on the results obtained, it is clear that the species *Lysiphlebus fabarum* and *A. matricariae* occupy a broad distribution area in the study region. In contrast, the two species *Praon volucre* and *Trioxys angelicae* were found only in the Al Attuef region. The genera *Aphidius* and *Lysiphlebus* are not highly demanding in terms of environmental conditions and host quality, which may explain their associative behavior. For instance, in several cases, the presence of *Lysiphlebus fabarum* and *Aphidius matricariae* is simultaneous.

4. Conclusion

The results of this study have allowed for the establishment of an inventory of parasitoids associated with aphids on cultivated and uncultivated plants in Ghardaia region and the compilation of a list of 8 species collected from the mummies of 4 aphid species belonging to 4 different genera. The plants supporting these aphids include 6 plant species from 3 botanical families. The data indicate, for the first time, the presence of the species *Praon volucre* and *Trioxys angelicae*. The remaining species are *Aphidius matricariae*, *Aphidius colemani*, *Aphidius ervi*, *Aphidius funebris*, *Lysiphlebus fabarum*, and a single hyperparasitoid of an unidentified species from the family Pteromalidae.

According to the results, 23 associations (plant-aphid-primary parasitoid) were identified in the study region. Some parasitoids have a relatively broad host range. This is the case for *Lysiphlebus fabarum*, *Aphidius matricariae*, and *Aphidius funebris*, each with 5 associations. In contrast, the two species *Praon volucre* and *Trioxys angelicae*, newly reported in the region, have formed only one association each, similar to *Aphidius colemani*.

References

1. Aggoun H., Laamari, M. and Tahar-chaouche S. (2022) *Pauesia silana* Tremblay, A Parasitoid of *Cinara maghrebica*-Aphid in Aleppo Pine Forests in Algeria Case Khenchela Province. *Egyptian Academic Journal of Biological Sciences Entomology*. 15(3), 79-84. <https://doi.org/10.21608/EAJBSA.2022.259859>
2. Ait-Amar S., Benoufella-Kitous k., Medjdoub-Bensaad F. A & Tahar-Chouche S (2022). Diversité des pucerons et de leurs ennemis naturels en cultures sous serre à Tizi-Ouzou, Algérie. *Faunistic Entomology*. 75, 1-15 <https://doi.org/10.25518/2030-6318.5785>
3. Alaserhat I. and Canbay A. (2017) Aphididae Species, Their Parasitoids, Predators, and Parasitism Rates on Pepper (*Capsicum Annuum* L.). *Entomological News*. 127(1): 36-50. <https://doi.org/10.3157/021.127.0106>
4. Alhmedi A. & Beliën T. (2015) Aphids and their parasitoids in fruit orchards. *Fruittteelnieuws*. 12 : 1-8. <https://doi.org/10.1016/j.japb.2021.03.008>
5. Aparicio Y. , Gabarra R., Riudavets J. , Starý P., Tomanovi'c Z., Koci'c K. , Villar J.P., Suay M.F., Porta V.G. and Arnó J. (2019) Hymenoptera Complex Associated with *Myzus persicae* and *Hyalopterus* spp. in Peach Orchards in Northeastern Spain and Prospects for Biological Control of Aphids. *Insects*. 10, 109. <https://doi.org/10.3390/insects10040109>
6. Ayadi M., Stary P., Belkadi M. S. & Ben Halima K. M. (2017) Aphid Parasitoid Species and their Hosts in Western South of Tunisia (Hymneoptera: Aphidiidae; Aphidiinae and Hemiptera: Aphididae). *Egyptian Journal of Biological Pest Control*. 27(2): 223-226 <https://doi.org/10.1186/s41938-020-0214-9>
7. Baaren J.V., Wist T., Soroka J., and Tougeron K. (2019) Host-parasitoid network in extreme conditions: the case of cereal aphids in wheat crops in Saskatchewan, Canada. *Entomologia Generalis*. 13,45. <https://doi.org/10.1127/entomologia/2019/0807>
8. Bandyar S.K., Peters R.S., Nawzad B. Kadir, Mar Ferrer-Suay, Wolfgang H. K. (2021) A survey of aphid parasitoids and hyperparasitoids (Hymenoptera) on six crops in the Kurdistan Region of Iraq. *Journal of Hymenoptera Researcher*. 81: 9–21. <https://doi.org/10.3897/jhr.81.59784>
9. Chehma S. & Laamari M. (2014) Etude bioécologique des Hyménoptères parasitoïdes des pucerons associés au milieu naturel et cultivé dans la région de Ghardaïa. *BioRessource*. 4(2): 62-75.
10. Derocles S.A.P , Navasse Y., , Buchard C., Plantegenest M. and Ralec A.L.(2019) Generalist Aphid Parasitoids Behave as Specialists at the Agroecosystem Scale. *Insects*. 11, 6. <https://doi.org/10.3390/insects11010006>
11. Gagui F., Laamari M., Tahar-chaouche S. (2023) Aphids and their parasitoid Hymenoptera in Oum El Bouaghi Province (Algeria). *Bulletin de la Société Zoologique de France*. 148 (2), 47-54.
12. Ghaliow M., Petrović A., Kocić K., Čkrkić J., Bogdanović A.M., Starý P., Kavallieratos N.G. & Tomanović N.J.Z. (2018) Key for identification of the parasitoids (Hymenoptera: Braconidae: Aphidiinae) of aphids infesting alfalfa in Europe. *Zootaxa*. 4378 (1): 098–110. <https://doi.org/10.11646/zootaxa.4378.1.6>
13. Ghelamallah A., Rakhshani E., Bouhraoua R. T., Michelena J.M., Boualem M., Ferrer-Suay M. & Pujade-Villar J. (2018) New Hymenoptera records (Braconidae: Aphidiinae) from Algeria and the Northern Africa, and notes about other species. *Entomofauna*. 39/1 (13): 301-316. https://doi.org/ent_0039_0301-0316

14. Hemidi W. (2019) Etude de l'influence des systèmes de production oasiens pratiqués dans la région de Biskra sur l'abondance et la répartition spatio-temporelle des hyménoptères parasitoïdes des pucerons. Thèse de doctorat. Université Biskra. 2023; 130 p.
15. Ismail M. , Zanolli P., Muratori F. and Hance T.(2021) Aphids Facing Their Parasitoids: A First Look at How Chemical Signals May Make Higher Densities of the Pea Aphid *Acyrtosiphon pisum* Less Attractive to the Parasitoid *Aphidius ervi*. *Insects*. 12, 878. <https://doi.org/10.3390/insects12100878>
16. Kishinevsky M., Ives A.I. (2023) Longevity of hymenopteran parasitoids in natural versus agricultural habitats and implications for biological control. *Ecological Applications*. e3009. <https://doi.org/10.1002/eap.3009>
17. Laamari M , Benferhat S, Abbas SB, Khenissa N , ST Chaouche, CW Halimi, Stary P. (2012) A review of aphid parasitoids and their associations in Algeria (Hymenoptera: Braconidae: Aphidiinae; Hemiptera: Aphidoidea). *African Entomology*. 2012; 20 (1), 161-170. <https://doi.org/10.4001/003.020.0120>
18. Martínez-Chávez L.M., Duque-Gamboa D.N., Toro-Perea N. (2017) New records of aphid parasitoids (Hymenoptera) from Colombia. *The journal of biodiversity data*. 15 (6): 1083–1091. <https://doi.org/10.15560/15.6.1083>
19. Mkenda P.A. , Ndakidemi P.A., Stevenson P.C., Arnold S.E.J., Belmain S.R., Chidege M., Gurr G.M. and Woolley V. (Characterization of Hymenopteran Parasitoids of *Aphis fabae* in An African Smallholder Bean Farming System Through Sequencing of COI 'Mini-barcodes'. *Insects*. 10, 331. <https://doi.org/10.3390/insects10100331>
20. Rakhshani E., Barahoei H., Ahmad Z., Stary P., Ghafouri Moghaddam M., Mehrpavar M., Kavallieratos N. G, Čkrkić G. & Tomanovic Z. (2019) Review of Aphidiinae parasitoids (Hymenoptera: Braconidae) of the Middle East and North Africa: key to species and host associations. *European Journal of Taxonomy*, 552: 1–132. <https://doi.org/10.5852/EJT.2019.552>
21. Salman A.M.A., El-Sayed E.G.A. and Abdel-Rahman M.A.A. (2022) Impact of hymenopterous parasitoids (Hymenoptera: aphidiidae) attacking the cowpea aphid, *Aphis craccivora* Koch (Homoptera: aphididae) infesting broad bean plants at Assiut governorate. *Journal of Sohag Agriscience*. 7(1): 09-17. <https://doi.org/10.21608/JSASJ.2022.245697>
22. Tahar Chaouche S. (2019) Etude de la biodiversité des Hyménoptères parasitoïdes des pucerons en milieu naturel dans la région de Biskra. Thèse de doctorat. Université de Biskra. 115 p.
23. Talebi A. A., Rakhshani E., Fathipour Y., Stary P., Tomanovic Z. & Rajabi- Mazhar N. (2009) Aphids and their Parasitoids (Hym., Braconidae: Aphidiinae) Associated with Medicinal Plants in Iran. *American-Eurasian Journal of Sustainable Agriculture*. 3 (2): 205-219 <https://doi.org/10.5852/EJT.2019.552>
24. Tomanovi'c Z., Kavallieratos N.G., Ye Z. , Nika E.P., Petrovi'c A., Vollhardt I.M.G. and Vorburger C. (2022) Cereal Aphid Parasitoids in Europe (Hymenoptera: Braconidae: Aphidiinae): Taxonomy, Biodiversity, and Ecology. *Insects*. 13, 1142. <https://doi.org/10.3390/insects13121142>
25. Ward S. E., Umina P.A. Macfadyen S. and Hoffmann A.A. (2021) Hymenopteran Parasitoids of Aphid Pests within Australian Grain Production Landscapes. *Insects*. 12, 44. <https://doi.org/10.3390/insects12010044>
26. Woolley V.C., Tembo Y.L.P., Ndakidemi B., Obanyi G.N., Arnold,a,c Steven S.E.J. Belmain R., Ndakidemi P.A., Ogendo J.O. and Stevenson P.C. (2022) The diversity of aphid parasitoids in East Africa and implications for biological control. *Pest Manag Sci*. 78: 1109–1116. <https://doi.org/10.1002/ps.6723>

27. Zamora-Mejías D. and Hanson P. E. (2017) Key to the species of parasitoids and hyperparasitoids (Hymenoptera) of aphids (Hemiptera: Aphididae) of Costa Rica. *Agron. Mesoam.* 28(3):565-575. <https://doi.org/10.15517/ma.v28i3.24640>