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Diversity of wasps (Hymenoptera) in alfalfa (*Medicago sativa* L.) farms in Basrah Governorate, Southern Iraq

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Abstract

Studies on the diversity of parasitoid wasps in agroecosystems exemplify the first stage of recognizing the best species to be used in biological control programs. There is an increased effort to recognize the diversity of pests in agroecosystems, but information on agricultural environments in Iraq is still unknown. This study is interested in the diversity of wasps in a cultivated area in Basrah governorate and the identification of dominant species for potential application in biological control studies. Samples were collected from alfalfa farms between January and December 2020 using two insect collection methods: sweep nets and yellow pan traps in four stations in Basrah governorate. This paper confirms that there is a high diversity of wasp species in agricultural environments. During this study, 18 wasp species were recorded for the first time in Iraq. *Gronotoma micromorpha* recorded the highest annual relative abundance value of 26.5%, while *Chalcis biguttata* recorded the lowest relative abundance of 0.89% in most agricultural environments. Numerous studies on *G. micromorpha* indicate that it is a parasitoid of *Liriomyza* species (Diptera). Thus, this species may be an important agent in the biological control of this pest.

Key words: alfalfa, insect biodiversity, wasp diversity, Basrah, Iraq

Introduction

Alfalfa (*Medicago sativa* L.) is one of the most widely grown crops in the world. This crop originated in southern Asia. Alfalfa, also referred to as lucerne or purple medic, is a perennial forage legume that belongs to the family Fabaceae and subfamily Papilionoideae. The first reference to alfalfa was written in 1300 BC, indicating the long association of alfalfa with many ancient civilizations (Putnam, 2001).

Alfalfa grows 30–90 cm long and has trifoliate leaves with long, narrow leaflets serrated at the tips. This crop is grown in a wide range of environments and has been cultivated in the Basrah governorate of Iraq for a long time; alfalfa is one of the most cultivated plants, with a planted area of 237 dunam (2.37 hectares) (Al-Sanaf *et al*., 2022; Mansowr *et al*., 2023a,b).

Alfalfa plays a crucial role in a complex food chain and holds significant economic value. It has been vital in sustaining both humans and animals for thousands of years. Alfalfa has several beneficial properties, including the ability to remove carcinogens from the soil, recycle organic waste, protect the soil from erosion, and produce numerous secondary metabolites. These metabolites have been used as valuable ingredients in medicines, cosmetics, seasonings, dyes, and beverages (Putnam, 2001; Chaudhary *et al.*, 2020; Nimaan, 2021).

Alfalfa fields are also known as insectaries due to the large population of beneficial insects that reside within them. Alfalfa provides a relevant habitat for various insect species, which in turn help to control many pests in alfalfa and other crops. These insects are increasingly becoming an important factor in integrated pest management systems (Putnam, 2001).

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Insects are known to provide important ecosystem services. In the terrestrial ecosystem, wasps belong to the order Hymenoptera and are dominant biodiversity components that play an important role in the relationship between various plants and ecosystem processes. Wasps are among the primary pollinators of agricultural plants. These insects strongly influence ecosystem conservation, flora diversity, specialization, and evolution in the plant community, and play a fundamental role in the agroecosystem as predators and parasitoids, helping to control pest populations (Weisser & Sieman, 2008; Widhiono, 2015; Quicke, 2015). Wasps also reduce the damage and economic losses caused by pests in agroecosystems and may be used for biological control programs (LaSalle & Gauld, 1993; Van Driesche *et al*., 2010; Fand *et al*., 2012; Ode & Heimpel, 2016). Furthermore, wasps serve as ecological indicators due to their high sensitivity to environmental changes (Komonen *et al*., 2000; Maeto *et al*., 2009; Anderson *et al*., 2011).

Thus, the survey of wasps, especially in predominantly agricultural environments, could yield useful information about the management state of ecosystems as their richness and abundance can reflect the diversity of other invertebrates (Anderson *et al*., 2011; Stephens, 2005).

In the past two decades, numerous factors have been identified as contributing to the decline in wasp diversity. The primary causes include human disturbances, climate change, the use of pesticides, pollution, and the fragmentation of both natural and agricultural habitats, which all have a negative effect on the natural ecosystem (Skendzic *et al.,* 2021; Dan & Doi, 2020).

The survey and studies on the diversity of wasps in agricultural environments represent an important step in identifying ideal species for use in biological control programs (Jacques *et al*., 2015; Somavilla *et al*., 2016). Species diversity can express the community structure because diversity grants stability and is related to central ecological thinking, which focuses on the stability of ecosystems (Leksono, 2007; Mason & Bello, 2013).

An effort to distinguish the diversity of these insects is growing, but the information on agricultural areas remains limited despite the important role of wasps (Aghadokht *et al*., 2020; Bennett, *et al*., 2019). Furthermore, no studies on the wasp diversity in Iraq have been published. Therefore, the present study mainly aims to determine the distribution, diversity, species richness, and species evenness of the wasp species associated with alfalfa (*Medicago sativa*).

Materials and Methods

Wasp collection and species determination

Wasps were collected monthly with a sweep net and four yellow pan traps at each location. The collected insects were preserved in 75% ethanol. The wasp specimens were identified in the Laboratory of Entomology, Department of Biology, College of Science, University of Basrah, Iraq using the following identification resources: Boucek (1951), Ferriere and Kerrich (1958), Boucek (1959), Askew (1968), Fergusson (1980), Masner (1980), Muesebeck (1980), Nixon (1980), Yoshimoto (1983), Beardsley (1989), Noyes and Valentine (1989), Beardsley (1990), Goulet and Huber (1990), Masner and Garcia (2002), Buhl(2004a,b), Narendran and Achterberg (2016), Iqbal *et al.* (2018), Notton and Mifsud (2019), Buffington *et al.* (2020), and Nastasi *et al.* (2023).

Study sites

Basrah is one of the largest and most important cities in Iraq, and is located in southern Iraq, overlooking the Arabian Gulf. For most of the year, Basrah experiences high temperatures and a semi-arid climate. The temperature averages above 50°C in the summer, while winter temperatures range from 11°C to 28°C. The average annual rainfall in Basrah is 169 mm. The study was conducted on alfalfa (*Medicago sativa*) fields. Four regions were selected for the sampling, namely, Hartha (1), Abo Al-Khaseeb (2), Shatt-Al Aarab (3), and Zubair districts (4) (Fig. 1; Table 1). The collection period spanned from January 2020 until December 2020.

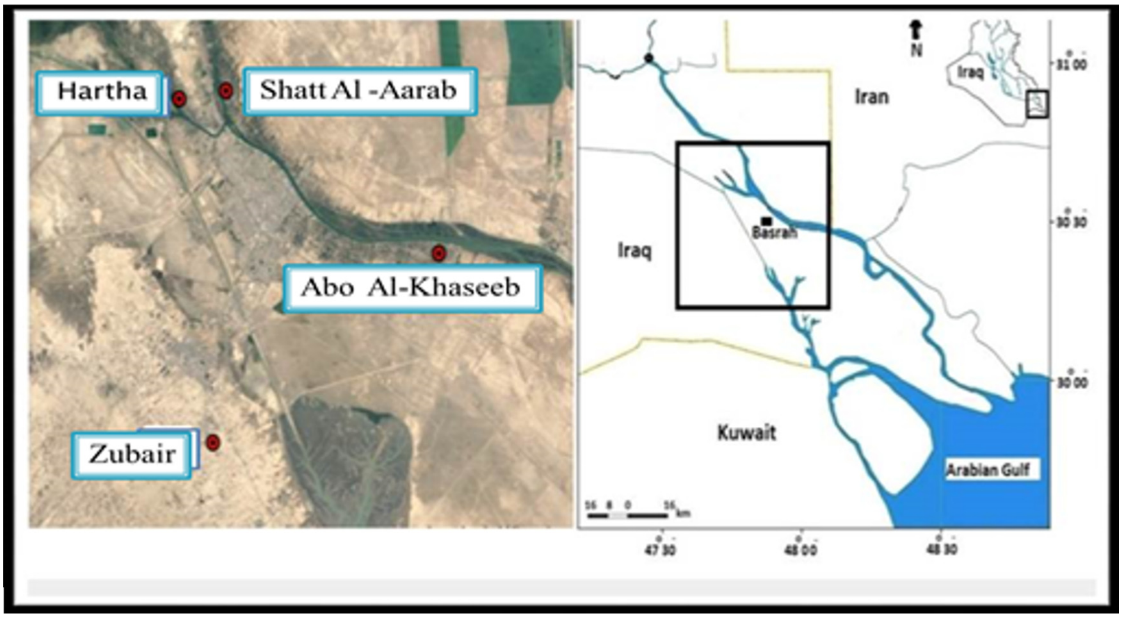

FIGURE 1. Sample collection sites in Basrah Governorate, Iraq.

TABLE 1. Locations of study area.

Stations	Coordinates
Hartha	N 30°36′23.61492″ E 47°42′59.31504″
Abo Al-Khaseeb	N 30°27′9.21024″ E 48°06′29.9436″
Shat Al-Aarab	N 30°36′33.59304″ E 47°46′19.62732″
Zubair	N 30°18′43.76088″ E 47°43′37.14132″

Statistical analysis

Measurements of environmental temperature were taken at four different observation locations. The number of species (S) and individual abundance (N) from the collected samples were determined and are illustrated in the tables and figures. The indices were calculated to determine the diversity of wasps, including Simpson's diversity index, the Shannon-Wienner diversity index, Margalef's richness index, equitability, and the Berger-Parker index. The relative abundance (RA) of the species was calculated using the formula, $RA = ni/N$, where ni is the number of individuals in the species, and N is the total number of individuals in the sample or sampling area. The species richness (R) was calculated using Margalef's index. The formula of Margalef's index is $R = (S - 1)/ \ln(N)$ and R = S/ p N, where S is the number of species. Diversity (D) was calculated using the Simpson diversity index formula D = P ni (ni − 1)/N(N − 1), where D denotes the dominance. In this index, 0 represents infinite diversity, and 1 indicates no diversity. Therefore, Simpson index of diversity $1 - D$ was used. In this case, an increase in the Simpson value $(1 - D)$ indicates an increase in diversity.

Results and Discussion

This study is the first published attempt to determine the diversity of wasps in the agroecosystems of Iraq. Seven hundred eighty individuals were collected from the four stations over the sampling period. Nineteen species—representing five superfamilies, eight families, 11 subfamilies, 17 genera, and 19 species—were registered during the taxonomic investigation. Of these, 18 were identified in Iraq for the first time.

Based on the number of individuals observed and the number of observation locations, four species were dominant: *Gronotoma micromorpha* (Cynipoidea: Figitidae) (520 individuals, 4 stations), *Sympiesis gregori*

(Chalcidoidea: Eulophidae) (87 individuals, 4 stations), *Pnigalio epilobii* (Chalcidoidea: Eulophidae) (81 individuals, 4 stations), and *Ceratacis cochleata* (Platygastroidea: Platygastridae) (69 individuals, 3 stations). Meanwhile, the species with fewer numbers were *Chalcis biguttata* (Chalcidoidea: Chalcididae) (7 individuals, 3 stations) and *Podagrion pachymerum* (Chalcidoidea: Torymidae) (8 individuals, 1 station) (Table 2, Figures 2–9).

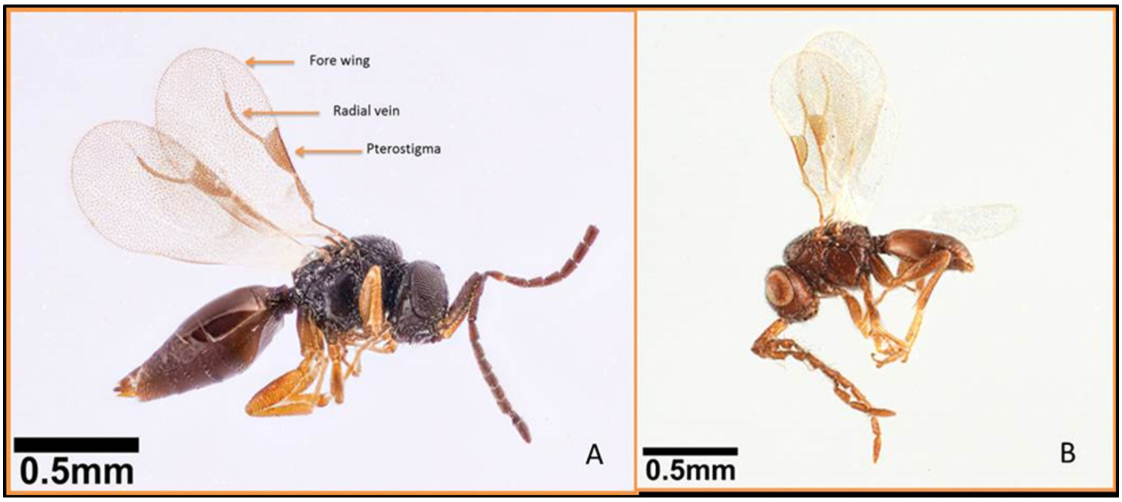

FIGURE 2. Lateral view of *Dendrocerus aphidum*: female (A) and male (B).

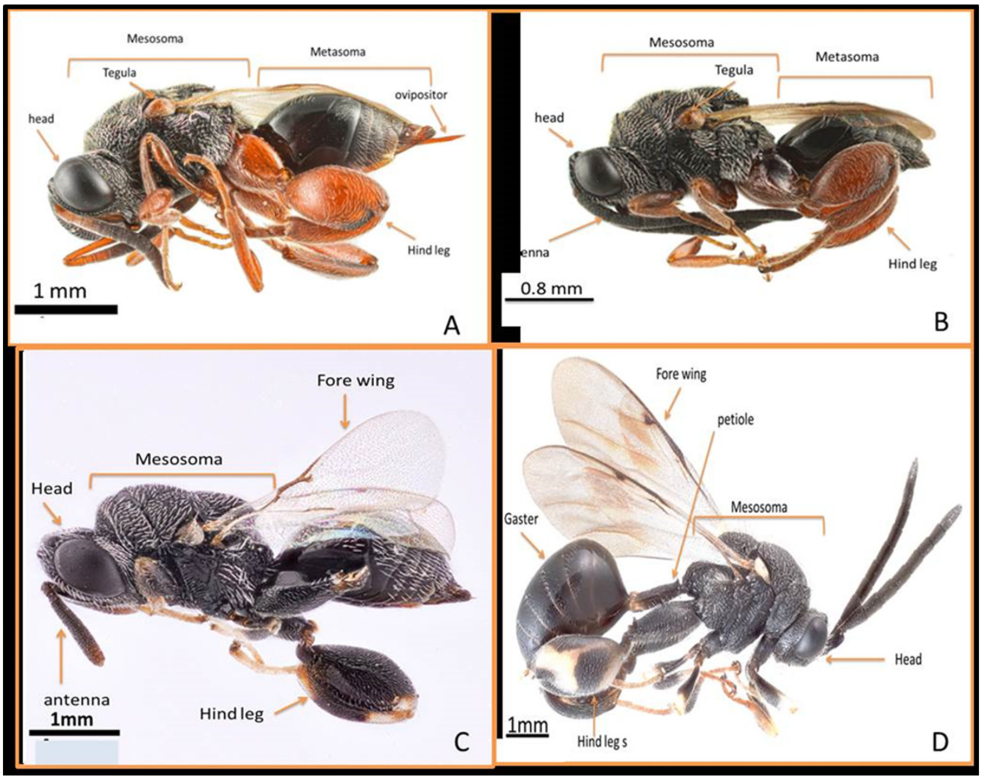

FIGURE 3. Lateral view of *Antrocephalus hypsopygiae* (A), *Antrocephalus sepyra* (B), *Brachymeria excarinata* **(**C) and *Chalcis biguttata* (D).

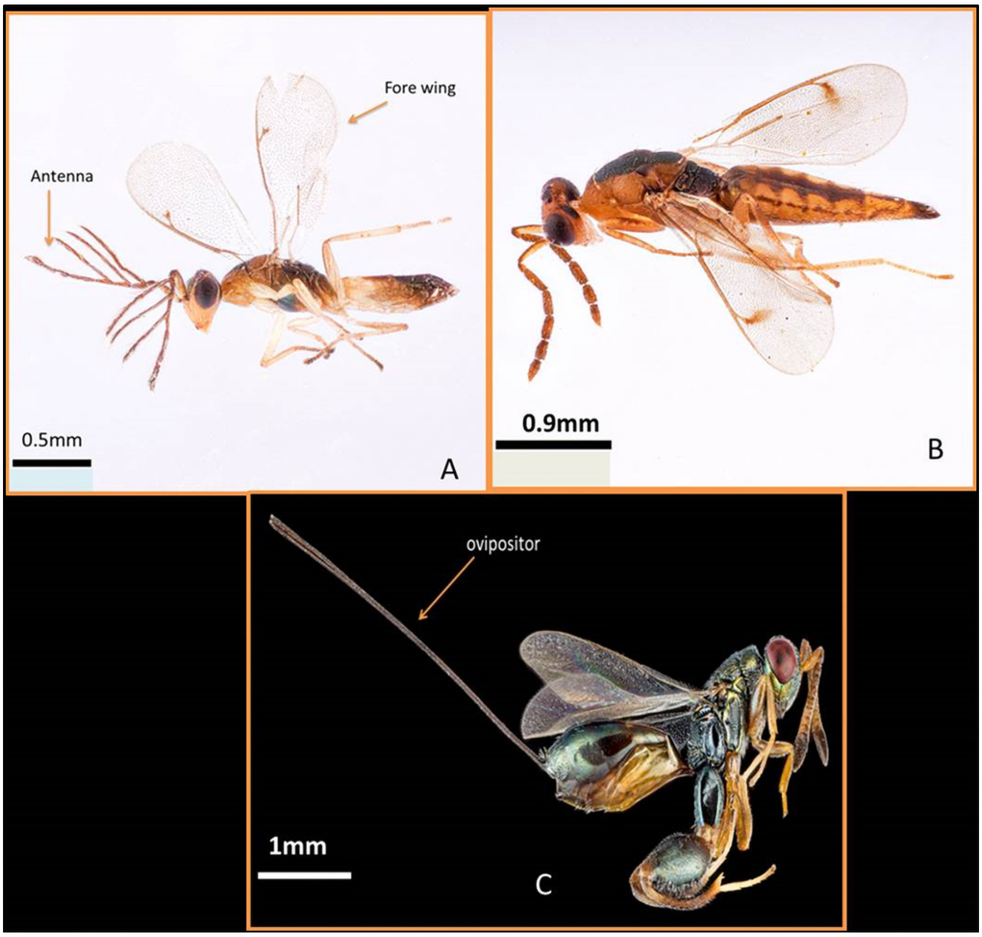

FIGURE 4. Lateral view of *Pnigalio epilobii* (A), *Sympiesis gregori* **(B) a**nd *Podagrion pachymerum* (C).

FIGURE 5. Lateral view of *Gronotoma micromorpha*: female (A) and male (B).

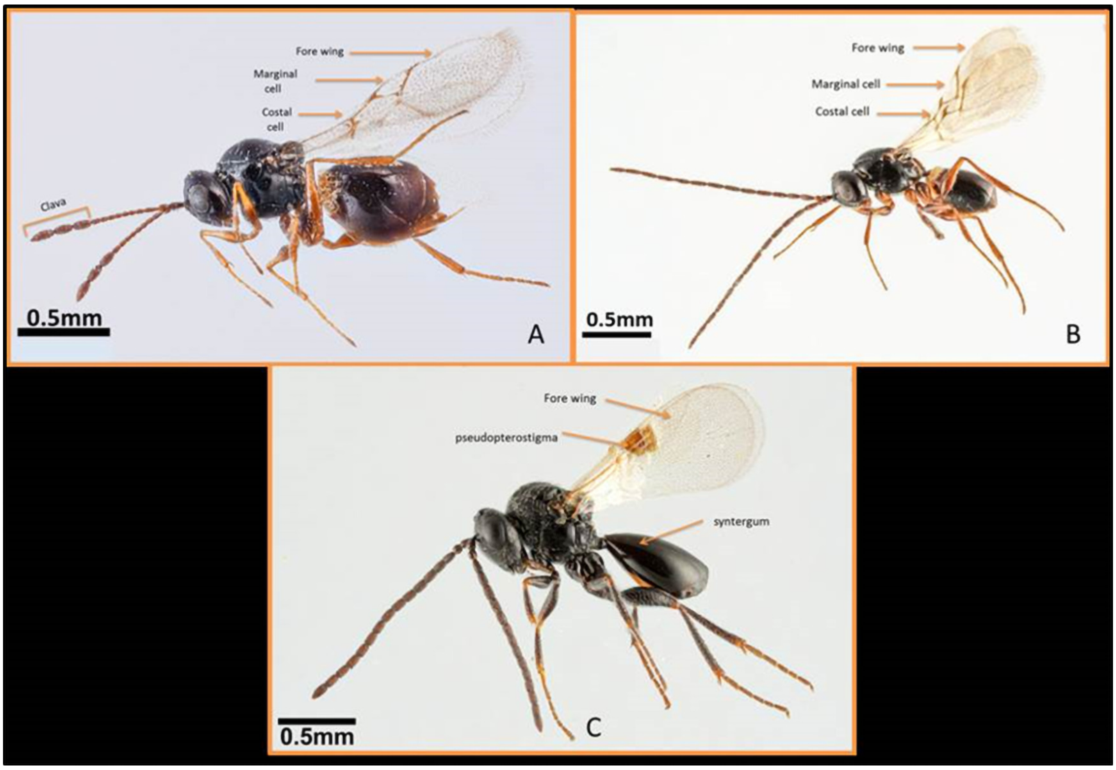

FIGURE 6. Lateral view of female *Kleidotoma kraussi* (A), male *Kleidotoma kraussi* (B) and female *Pycnostigmus incognito* (C).

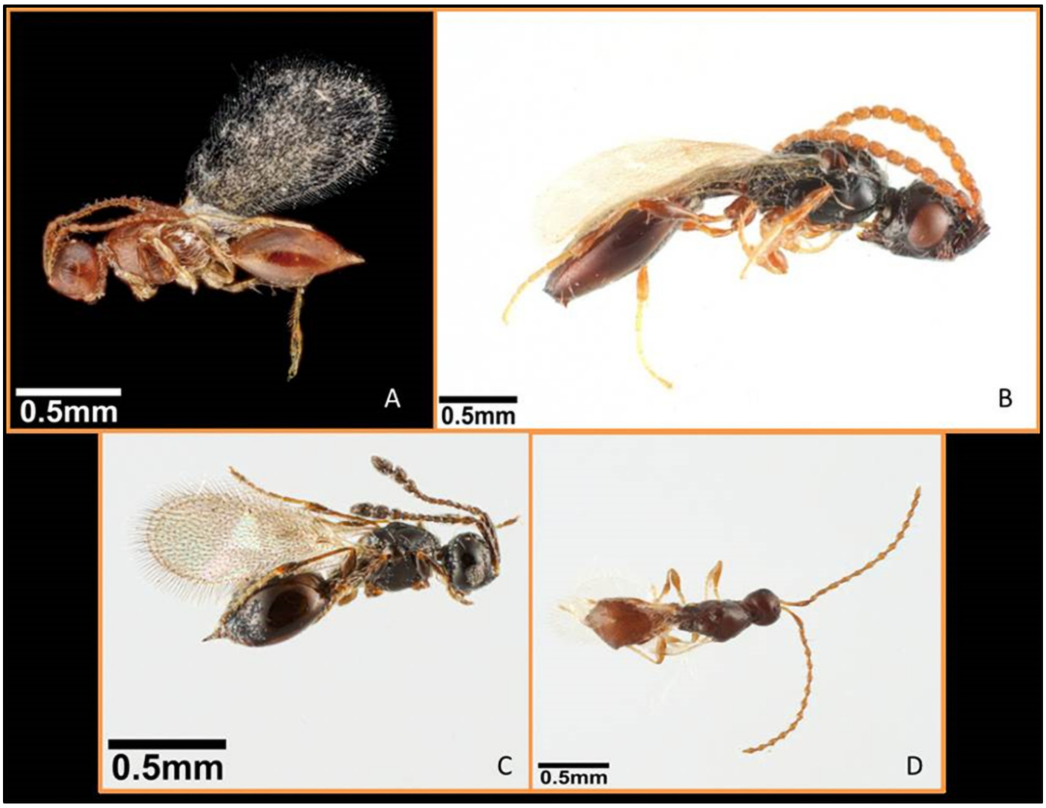

FIGURE 7. Lateral view of female *Basalys exigua* **(**A), male *Coptera occidentalis* (B) and *Trichopria aequata*: female (C) and male (D).

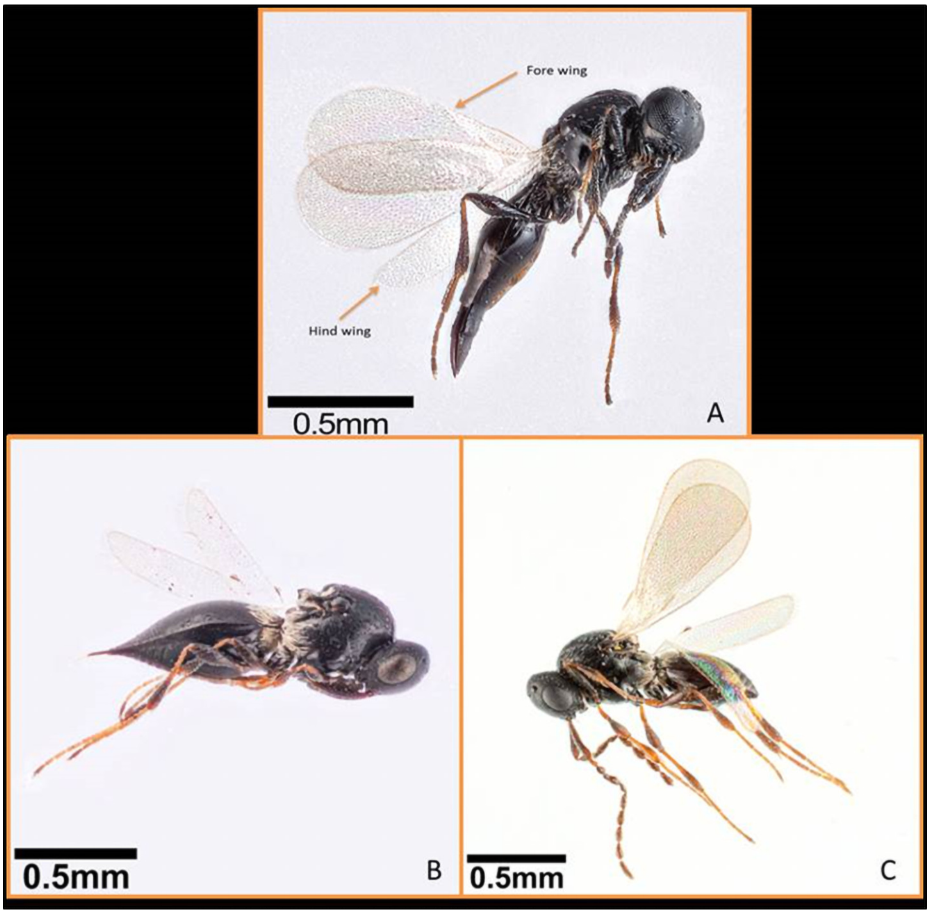

FIGURE 8. Lateral view of female *Ceratacis cochleata* (A), and *Synopeas gibberosus*: female (B) and male (C).

FIGURE 9. Lateral view of female *Gryon* sp. (A), female *Scelio simoni* (B) and male *Scelio striatus* (C).

The registered species are:

Suborder: Apocrita
Superfamily 1: Ceraphronoidea
Family: Megaspilidae
Subfamily: Megaspilinae
Genus: *Dendroccerus* Ratzeburg, 1852
Species: *Dendrocerus aphidum Rondani, 1877**

Superfamily 2: Chalcidoidea
Family: Chalcididae
Subfamily: Haltichellinae
Genus: *Antrocephalus* Kirby, 1883
Species: *Antrocephalus hypsopygiae Masi, 1928**
Species: *Antrocephalus sepyra Walker, 1846**
Subfamily: Brachymemriinae
Genus: *Brachymeria* Westwood, 1829
Species: *Brachymeria excarinata Gahan, 1925**
Subfamily: Chalcidinae
Genus: *Chalcis* Fabricius, 1787
Species: *Chalcis biguttata Spinola, 1808**
Family: Eulophidae
Subfamily: Eulophinae
Genus: *Pnigalio* Schrank, 1802
Species: *Pnigalio epilobii Bouček, 1966**
Genus: *Sympiesis** Förster, 1856
Species: *Sympiesis gregori Bouček, 1959**
Family: Torymidae
Subfamily: Toryminae
Genus: *Podagrion* Spinola, 1811
Species: *Podagrion pachymerum Walker, 1833**

Superfamily 3: Cynipoidea
Family: Figitidae
Subfamily: Eucoilinae
Genus: *Gronotoma* Förster, 1869
Species: *Gronotoma micromorpha (Perkins, 1910)**
Genus: *Kleidotoma** Westwood, 1833
Species: *Kleidotoma kraussi Yoshimoto, 1963**
Family: Figitidae
Subfamily: Pycnostigminae
Genus: *Pycnostigmus* Cameron, 1905
Species: *Pycnostigmus incognito Buffington & van Noort, 2007**

Superfamily 4: Diaprioidea
Family: Diapriidae
Subfamily: Diapriinae
Genus: *Basalys* Westwood, 1883
Species: *Basalys exigua (Marshal, 1868)**
Genus: *Coptera* Say, 1836
Soecies: *Coptera occidentalis Muesebeck, 1980**
Genus: *Trichopria* Ashmead, 1893

Species: *Trichopria aequata Thomson, 1859**

Superfamily 5: Platygastroidea
Family: Platygastridae
Subfamily: Platygastrinae
Genus: Platygaster Latreille 1809
***Species: Platygaster filicornis* Walker , 1836**
Genus: Synopeas Förster, 1856
Species: *Synopeas gibberosus* Buhl, 1997
Family: Selionidae
Subfamily: Scelioninae
Genus: *Gryon* Haliday, 1833
Species: *Gryon* sp.*
Genus: *Scelio* Latreilla, 1805
Species: *Scelio simoni Yoderi, 2014**
Species*: Scelio striatus* Priesner, 1951

New records are marked with asterisk.

Relative abundance (%)

The relative abundance of the species was calculated in this study, and the results show that *G. micromorpha* recorded the highest annual relative abundance value of 26.5%, while *Chalcis biguttata* recorded the lowest relative abundance of 0.89%.

The highest recorded value of *G. micromorpha* is consistent with that of Van den Berg *et al.* (1995), indicating that species of the genus *Gronotoma* are the most prevalent among the hymenopterous parasitoids of agromyzid pests. Some species of this genus have been known to parasitize serious pests of Agromyzidae in the subtropics (Buffington, 2002). *Gronotoma micromorpha* is an egg- and larval-pupal parasitoid (Abe, 2001), and this species reproduces thelytokously (Abe & Tahara, 2003). Many studies indicate that *G. micromorpha* is amenable to mass production and can be used as a biological control agent for *L. trifolii* (Abe & Tahara, 2003; Abe & Konishi, 2004) (Table 2, Figure 10).

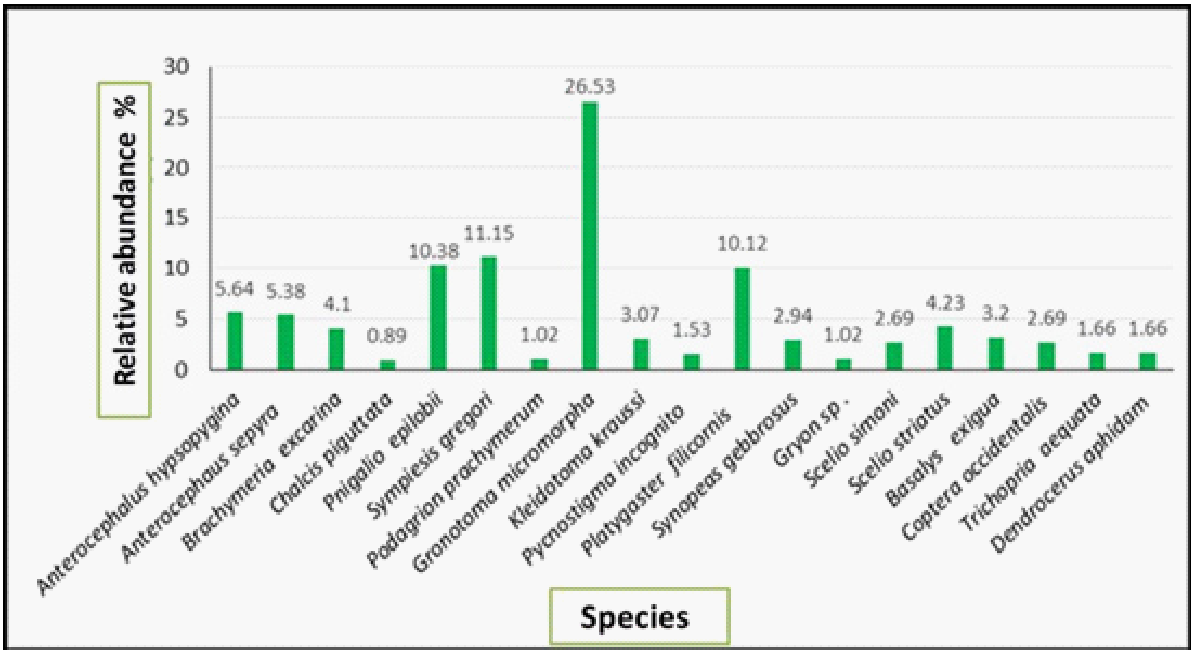

FIGURE 10. Relative abundance of wasp species at each of the four sampling locations.

TABLE 2. Relative abundance of wasps species collected from each station during the study.

#	Relative abundance	Total	Zubair	Shatt Al-Arab	Abo Al-Khaseeb	Hartha	Species
1	5.64	44	0	11	13	20	*Antrocephalus hypsopygiae*
2	3.07	42	0	8	17	17	*Antrocephalus sepyra*
3	2.94	32	2	5	9	16	*Brachymeria excarinata*
4	0.89	7	2	0	2	3	*Chalcis biguttata*
5	10.38	81	4	30	31	16	*Pnigalio epilobii*
6	11.15	87	0	20	42	25	*Sympiesis gregori*
7	1.02	8	0	0	0	8	*Podagrion pachymerum*
8	26.53	205	15	102	60	30	*Gronotoma micromorpha*
9	3.07	24	7	0	9	8	*Kleidotoma kraussi*
10	1.53	12	0	0	12	0	*Pycnostigmus incognito*
11	10.12	79	0	14	33	32	*Platygaster filicornis*
12	42.94	23	0	0	9	14	*Synopeas gibberosus*
13	1.02	8	0	0	8	0	*Gryon sp.*
14	2.69	21	0	7	6	8	*Scelio simony*
15	4.23	33	0	7	15	11	*Scelio striatus*
16	3.20	25	7	3	7	8	*Basalys exigua*
17	2.69	21	0	0	0	21	*Coptera occidentalis*
18	1.66	13	0	0	9	4	*Trichopria aequata*
19	1.66	13	0	7	6	0	*Dendrocerus aphidum*
	100	780	37	214	288	241	Individual
	-	19	6	11	17	16	Taxa–S

Temporal relative abundance

The highest relative abundance of wasps was recorded in April (23.8%), while the lowest abundance was recorded in November (1.2%) (Table 3). The highest relative abundance in April can be attributed to the blooming of flowers and the combination of sugars in nectar, which affects the diversity of insects. In addition to pollen and nectar, flower morphology also influences the diversity of resident and visitor insects (Triat & Marisa, 2019), in addition to environmental factors, such as temperature, humidity, and light intensity.

TABLE 3. Relative abundance of wasps by month.

Month	February	March	April	May	June	July	August	September	October	November
Individual	45	174	186	118	77	29	25	94	22	10
Relative abundance (%)	5.76	22.3	23.84	15.1	9.87	3.71	3.2	12.1	2.82	1.28

Spatial diversity

The greatest wasp biodiversity was found at Abo Al-Khaseeb station, where 18 taxa and 288 specimens were collected. In contrast, the Zubair station had the lowest biodiversity of 6 taxa and the lowest count of specimens at 37. Differences between the numbers of individuals and species of wasps across the four stations are shown in Table 2.

The results of the statistical analyses according to Duncan's test indicate a significant difference between the averages of the group individuals across all study stations under the probability level of 0.05 (Table 4).

TABLE 4. Spatial diversity of wasps at each study location.

Station	Hartha	Abo Al-Khaseeb	Shatt Al-Arab	Zubair
Individual	241	288	214	37
Taxa–S	16	17	11	6
Average	6.69b	8.00a	5.97c	1.02d

Note: Different letters following averages indicate significant differences

Temporal diversity

The greatest number of individual wasps (N = 186) was recorded in April, while no wasps were collected in December and January at any of the stations. The results of the statistical analysis according to Duncan's test indicate a significant difference between some months and no significant difference between others (Table 5).

TABLE 5. Temporal diversity and the average number of individuals collected during the study.

Month	January	February	March	April	May	June
Individual	0	43	174	186	118	77
Taxa–S	0	10	18	19	17	13
Average	0.00i	3.66f	16.9a	13.2b	9.83c	6.41e
Month	July	Augusts	September	October	November	December
Individual	29	27	94	22	10	0
Taxa–S	7	5	5	3	3	0
Average	2.41g	2.08g	7.83d	1.83g	0.83i	0.00i

Note: Different letters following averages indicate significant differences

Diversity Indices

Despite the important ecological roles of wasps, taxonomical and environmental studies of this group in Iraq have not been published. Furthermore, wasp surveys in agroecosystems are lacking, especially in Basrah, making this paper a pioneer study in this field. The biodiversity index aims to characterize the diversity of a community by a single number (Magurran, 2004). The impression of "species diversity" involves two items: the first is richness, which expresses the number of species, and the second is the distribution of individuals among other species. Many environmental factors affect the species diversity of wasps, such as spatial heterogeneity, seasonality, habitat type, competition, productivity, and predation (Rosenzweig, 1995).

The Shannon-Wiener diversity index reflects the richness and proportion of each species, while the evenness and dominance indices represent the relative number of individuals in the sample and the portion of common species, respectively. The spatial pattern of diversity of the wasp species in Basrah was explored using the most important indices of diversity (Table 6).

TABLE 6. Ecological indices of wasps collected from stations during the study.

Diversity Indices	Zubair	Shatt Al-Arab	Abo Al-Khaseeb	Hartha
Simpson index	0.74	0.73	0.89	0.91
Shannon-Wiener index	1.55	1.78	2.5	2.61
Margalef index	1.38	1.86	2.82	2.73
Equitability	0.86	0.74	0.88	0.94
Berger-Parker index	0.40	0.47	0.2	0.13

Simpson index

The diversity values of wasps were estimated by the Simpson index, and the highest values of diversity of up to 0.91 were obtained in Hartha, while the lowest value of 0.73 was recorded in Shatt Al Arab.

Shannon-Wiener index

The Shannon-Wiener diversity index shows that Hartha has the highest diversity index (H' = 2.61), while Zubair has the lowest (H' = 1.55).

Richness index for Margalef

The richness value of wasp species was calculated by the Margalef index for richness, and the highest value of 2.82 was recorded in Abo Al-Khaseeb, while the lowest value of richness of 1.38 was recorded in Zubair.

Equitability

The highest value of evenness of 0.94 was recorded in Hartha, while the lowest value of evenness of 0.74 was recorded in Shat Al-Arab.

Berger-Parker index

The value of dominance was calculated using the Berger-Barker index, and the highest value of 0.47 was recorded in Shat Al-Arab, while the lowest value of 0.13 was recorded in Hartha (Table 6).

The result shows differences in diversity indices between the studied stations, which may be due to the difference in natural topography of the areas. The number, abundance, and distribution of insects respond to multiple stresses as a result of organismal interactions, habitat, and climate change (Wilson & Fox, 2021). No one community has the same biodiversity as the other, even if both have the same characteristics, such as topography, vegetation, and weather (Kim 2017); moreover, the geographical distance influences the community dissimilarity (Perillo, 2017). Some cases include studies of animals, tropical plants (Swenson *et al*., 2011), insect pollinators (Cuartas *et al*., 2015), and ants (Longino *et al*., 2002; Bishop *et al*., 2015), all of these cases show significant diversity.

The neighboring farms and the edge of cultures are equally important in preserving the biological diversity in agroecosystems. The diversity and richness of wasps depend on the diversity of flora in the area, the presence of one or more cultures, the availability of food, and the extent of natural vegetation (Schoeninger *et al*., 2016; Perillo, 2017). Wasps directly use vegetation to search for food and build their nests, thus vegetation enhances the survival chances of wasps (Somavilla *et al*., 2016).

Insect biodiversity is an important tool for assessing the response of species to expected environmental changes (Mason & Bello, 2013; Raven & Wagner, 2016). The similarity of species, and their relative abundance, and the richness of two regions provide evidence of the climate of the two regions (Venette, 2017).

Temporal Diversity

Climate has a significant impact on the diversity of insects through its direct impact on environmental factors. Insects have a positive, inherent ability to adapt to environmental changes and climatic fluctuations (Robinet & Rogues, 2010). The climate and agriculture of the area had a great effect on diversity and species richness (Klein *et al*., 2015). The temporal pattern of wasp species diversity throughout the study months was explored using the most important diversity indices (Table 7).

TABLE 7. Temporal ecological indices of wasps collected during the study.

Diversity Indices	February	March	April	May	June	July	August	September	October	November
Simpson index	0.86	0.89	0.92	0.91	0.87	0.76	0.54	0.24	0.47	0.64
Shannon-Wiener index	2.09	2.56	2.67	2.6	2.28	1.69	1.09	0.53	0.81	1.05
Margalef index	2.3	3.29	3.44	3.35	2.76	1.78	1.24	0.88	0.64	0.86
Equitability index	0.9	0.88	0.9	0.91	0.89	0.86	0.67	0.33	0.74	0.96
Berger-Parker index	0.2	0.18	0.13	0.14	0.18	0.41	0.64	0.86	0.68	0.4

Simpson index

The diversity values of wasps were calculated by the Simpson index; the highest value of diversity of 0.92 was recorded in April, while the lowest value of 0.24 was recorded in September.

Shannon-Wiener index

The highest value of diversity of 2.68 was recorded in April, while the lowest value of 0.53 was recorded in September. The high value in April can be attributed to the high number of species because the concept of species diversity includes species richness. The highest species number was recorded in April. According to Wratten *et al*. (2012) and Nursal (2014), the high level of bee and wasp diversity as pollinators could be impacted by flower color, the number of flowers, and environmental conditions, such as temperature factors. Winfree *et al*. (2008) also reported that the presence of flowers affects the density stability of the population and improves the value of insect diversity.

Margalef richness index

The richness value of wasp species was calculated by the Margalef index for richness, and the highest value of 3.44 was recorded in April, and the lowest value of 0.33 was recorded in September. According to Syamsuardi (2013) and Yuliani et al (2013), the richness of insects depends on the abundance of plant resources, mainly pollen and nectar. Insects use pollen as a source of protein and nectar as a source of sugar, which is essential for their survival. The difference between sugar components in nectar determines the diversity of insects. In addition, flower colors, shapes, and morphologies also influence the diversity of insects. Insect diversity and richness are also influenced by environmental factors such as temperature, humidity, and light intensity in those seasons.

Equitability

The highest value of evenness of 0.96 was recorded in November, indicating that the distribution of wasp individuals by the number of species is uneven in this month, while the lowest value of 0.33 was recorded in September.

Berger-Parker index

The value of dominance was calculated by the Berger-Barker indices, and the highest value of 0.86 was recorded in September, and the lowest value of 0.13 was recorded in April (Table 7).

The opposite relationship between the Berger-Parker and evenness indices was observed in each month due to the uneven distribution of individuals among the species. Clear differences in temporal diversity existed, and these differences are correlated to the climatic changes that occurred through the different seasons of the study period. The results show monthly drifts in the number of individuals and species of wasps. A sharp decrease was observed from

July to December, with population peaks in March and April, and most of the species were low in number during the hot and dry seasons.

Environmental factors

Various insects respond to abiotic factors, such as temperature, humidity, thermal effects, light, and food, in different ways. These abiotic factors not only affect the behavior of insects but also disturb their physiological mechanisms (Karl *et al*., 2011; Khaliq *et al*., 2014).

Some traditional environmental conditions were noted during the study period, with average temperatures ranging from 14.25 °C to 44 °C. The wind speed ranged from 6.50 km/h to 18.75 km/h, and the relative humidity ranged from 8.50% to 15.25%. Few studies have evaluated the influence of environmental factors on wasps in Iraq. The ecological study involved measuring some factors at all stations during the months of the study, which are: air temperature, wind speed, and relative humidity. The temperature ranged between 14–46 °C, and while the results of the statistical analysis showed that there were no significant differences ($P = 0.05$) between the stations, there were significant differences between the months of the study. The wind speed ranged between 8–18 km/h, and the results showed that there were significant differences between the study stations and between months. The relative humidity ranged between 5–21%, and the results of the statistical analysis indicated that there were significant differences between stations and months.

Mansowr *et al*., (2023b) reported that bees and wasps are active in collecting nectar at approximately 24.5–34.5 °C. Insects are poikilothermic organisms; thus, temperature is probably the most important environmental factor affecting their behavior, development, distribution, and reproduction (Koemankova *et al*., 2009). According to Trianto and Marisa (2019), the effective temperatures for insect survival are a minimum temperature of 15 °C, an optimum temperature of 25 °C, and a maximum temperature of 45 °C. Furthermore, Trianto and Purwannto (2020) also explained that wasps and bees could have normal activities around 18–35 °C.

Temperature, precipitation, water vapor pressure, and wind speed influence species richness and abundance (Perillo *et al.*, 2017). Humidity exerts a great effect on insects at extreme temperatures, and vice versa. The same temperature has different effects at different humidity levels. Temperature and humidity are ecologically interlinked. Environmental moisture is a variable factor. Therefore, an insect must resist the extremes of these changes. The moisture factor also changes from time to time. The other environmental factors are relevant to moisture and humidity in the air, for example, temperature, condensation, and surface water. This depends on air movement and the topography of the area. These factors saturate the atmosphere with water vapor, which results in condensation through dew and fog. Humidity is the measure of the amount of water vapor present in the air. For example, the relative humidity fluctuates depending on topographical conditions, time of day or year, and location. Moisture affects a number of insect survival variables (Overgaard and Sorenson, 2008; Karl *et al*., 2011).

Conclusions

Nineteen species of parasitic Hymenoptera were collected and determined from four stations in Basrah, Iraq, during 2020. These species certainly represent a small portion of the wasp diversity in the area, which varies in time and space due to biotic and abiotic factors such as flora, temperature, humidity, and climate. Recognition of wasp diversity and the impacting factors is required for the practical and economic use of wasps, especially in pest control programs. The most abundant wasp species was *Gronotoma micromorpha*, which is a natural enemy that can be used as a biological control agent for *Liriomyza trifolii.*

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Conflict of Interest

The authors declare no conflict of interest.

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