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Impact of the Parasitoid, *Diaeretiella rapae* (McIntosh) on Crucifers Aphid in Egypt and Iraq.

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ABSTRACT

The present study was conducted to survey and count the population density of parasitoids on crucifers aphid infesting cabbage plants in Egypt and, Iraq during the two seasons 2019-20 and 2020-21.

Three parasitoids, one primary *D. rapae* and two hyperparasitoid, *Pachyneuron* sp. and *Alloxysta* sp., were recorded. *Diaeretiella rapae* was highly dominant (91.37 and 88.39%) in Egypt and (94.00 and 91.03%)in Iraq during the 2019-20 and 2020-21 seasons.

The highest parasitism rate in Egypt was 92.39% recorded in the 2019-20 season and 95.65 % in the 2020-21 season. Meanwhile, in Iraq it was 77.78% recorded in the 2019-20 season while it was 53.33 % in the 2020-21 season. The life cycle of *D. rapae* was 17.43 ± 0.91 days at $18.00^\circ\text{C} \pm 1^\circ\text{C}$ and $65 \pm 5\text{RH}\%$. The sex ratio (Female: Males) was 2.47 :1. By rearing *D rapae* for two generations, the sex ratio was almost 1:1 in two generations.

This investigation may be helpful in implementing the use of parasitoids as biological control agents in integrated pest management programs for aphids on cabbage.

INTRODUCTION

Cruciferous vegetables are increasingly important crops in Egypt and Iraq. A number of insects feed on crucifers, including the cabbage aphid, *B. brassicae*, which is the most serious pest of these plants throughout the world (Ellis *et al.*, 1996 and Jankowski *et al.*, 2007). The cruciferous aphid, *B. brassicae* has been chosen for this study because it has markedly overlapped generations and is convenient to study, in the field, and under laboratory conditions (Chien-Chung Cheng.,1985 and Saleh, 2012). Theoretical ecology has developed over the past half-century to provide a framework for the study of species interactions. Relatively simple mathematical models describing, for example, competition and parasitoids now exist (Chien-Chung Cheng.,1985).

Outbreaks of *B. brassicae* were recorded as a major cause of brassica loss as early as 1931 by Barnes H.F. while it was recorded in Egypt in 2008 by Saleh A.A.). In the field, dense colonies may develop on the leaves, or on the flower of seed crops, causing

considerable damage, particularly in warm dry weather (Zhang and Hassan 2003 and Razaq *et al.*, 2011). The distribution of aphid stages tends to approach a steady state when the density exceeds 40 aphids per plant. It has been observed that the compact aggregations of *B. brassicae* are very significant (Hayamizu, 1982), improving the nutrition on the leaves they colonize and enhancing the growth and reproduction of the aphids up to a certain density level (Way and Cammell, 1970, Nemeć and Stary 1994 and Hossein *et al.*, 2014). A simulation model of the aphid population with the parasitoid was developed and used to study the possible within-season impact that the parasitoid can have on the aphid population growth (Gowling and van Emden 1994 and Kant *et al.*, 2008).

The potential rate of increase was obtained from the relative abundances of the first three instars, and the observed rate of increase was calculated graphically from a series of total population counts ending at the sampling date. The validity of the analysis was confined to occasions when the instar distribution was thought to be stable and the aphid population size increased geometrically (Carter, Aikman and Dixon, 1978). Temperature and other climatic factors are unlikely to be major factors influencing the role of aphid population growth during the summer, with other factors having a strong suppressing role (Saleh 2004). The present study was conducted to survey the parasitoids associated with the crucifers aphid *B. brassicae* and estimate the rates of parasitism in Egypt and Iraq during two seasons 2019-20 and 2020-21 respectively and study some biological aspects of *D. rapae*.

MATERIALS AND METHODS

Ecological Studies:

1. Survey of the Common Parasitoid Species Associated with *B. brassicae* Aphid on Cabbage Plants.

An experimental area of about half feddan of cabbage plants on each of the farms of Kafr Saqr district Sharkia Governorate, Egypt and the farm at Muthanna district, Iraq during the two seasons 2019-20 and 2020-21.

Six leaves of cabbage were chosen weekly. All aphid individuals in an area of 25 inch² / leaf were counted. Aphids were kept in a Petri dish (75 aphids / Petri dish) until the formation of mummies. The mummies of the aphids were separated in small plastic tubes until their emergence. Emerged parasitoids were primarily classified, counted and preserved in 50% ethyl alcohol. Parasitoid specimens were mounted, and confirmation and identification were completed with aid of Prof. Ahmed El-Heneidy, biological control laboratory, Ministry of Agriculture, Egypt. The rates of parasitism caused by different parasitoids were calculated. In the laboratory, aphids were divided into 3 groups; a- aphid mummies, b- living aphids containing parasitoid larvae (those were kept until the formation of mummies) and c- unparasitized aphids and numbers were recorded.

The parasitism rate was estimated according to Farrell and Stufkens's (1990) formula:

$$\text{Percentage of parasitism} = \frac{A + B}{A + B + C} \times 100$$

Biological Studies:

1. Life Cycle:

Brevicoryne brassicae cultures were maintained in the laboratory on cabbage plants at 18±1°C and 60±5% relative humidity. Parasitoids used in the experiments were obtained from the field and allowed female parasitoids to parasitize third instar aphids for 4 hrs. Mummies were checked daily until parasitoid emergence. Emerging parasitoids were put in a Petri dish for 12 hrs for mating. For estimating the durations of egg, larva and pupa of the

parasitoid on the nymphs of *B. brassicae*, nymphs were confined with the parasitoid for 4 hours. Thirty parasitized host aphids were daily dissected to determine the egg, larva and pupa stages.

2. Sex Ratio:

The sex ratio among *D. rapae* adults after rearing on third instar nymphs of *B. brassicae* was calculated. The culture was reared for two generations. The sex ratio of *D. rapae* was calculated depending on the ratio between the total number of emerged females: males from field-collected mummies (in the two generations). Also, the percentage of adults' emergence was calculated.

Statistical Analysis:

Data were analyzed using SAS package 8.2 v (SAS Institute 2003). Obtained data were analyzed using one-way ANOVA. When F values were significant, means were compared using Tukey' HSD at a 0.05 level of significance.

RESULTS AND DISCUSSION

Ecological Studies:

1.1. Survey of the Common Parasitoid Species Associated with *B. brassicae* Aphid on Cabbage Plants.

Three parasitoids, one primary parasitoid *Diaeretiella rapae*, and two hyperparasitoid, *Pachyneuron* sp. and *Alloxysta* sp. (Hymenoptera: Aphididae), were recorded. (Table 1).

In Egypt:

Population Density of *B. brassicae* and Its Parasitoids:

Throughout the period from October, 26th 2019 to February, 22th 2020, the counted number of *B. brassicae* ranged from 351 to 252 aphid individuals/sample (Table 1). In the subsequent season (2020/21) this number ranged from 450 to 281 individuals Throughout the period from November, 3rd 2020 to February 23rd 2021 (Table 2).

The highest population of *B. brassicae* reached (599 individuals/sample) in the 2nd week of November and December 2019 at 23.70 °C & 58.82% RH 2019-20 season and (591 individuals/sample) in the last week of December 19.80 °C & 73.3 % RH in the second season. Two peaks in the first season reached (599 individuals/ sample) in the second week of November at 23.7°C and 58.82 % RH. and (637 individuals/ sample) were found in the second week of December at 18.60 °C and 67.00 % RH (Table 1).

Two peaks in the 2020-21 season reached (589 individuals/ sample) in the fourth week of November 2020 at 21.25°C and 68.57 % RH. and (591 individuals/ sample) found in the last week of December at 19.80 °C and 73.30 % RH (Table 2).

Parasitoids:

1- *Diaeretiella rapae*:

Three peaks were recorded in the first season of 2019-20 (89 individuals) in the 4th week of November at 19.80°C & 60.70 % RH, (149 individuals) in the 2nd week of December at 18.60 °C & 67.0 % RH, and (221 individuals) in the first week of February at 14.60 °C & 60.0 % RH In the 1st season (Table 1), *D. rapae* was found in high percent (100 %) from 1st week of November to 1st week of January. The lowest percent of the parasitoid (84.14%) was recorded in the 4th week of January (Table 1).

Meanwhile, two peaks were found in the second season in the 4th week of November (72 individuals) at 21.25 °C & 68.57 % RH and in the 1st week of February (315 individuals) at 16.60 °C & 63.30 % RH during 2020-21 (Table 2).

D. rapae was found in a high percentage (100 %) during the period from the 1st week of November to the 3rd week of December. The lowest density of the parasitoid

(79.03 %) was found in the 2nd week of November. The mean percentage of the parasitoid in that season was 89.25 % in the 2019-20 season and 92.16 % during 2020-21 season.

2. *Pachyneuron* sp.:

Pachyneuron sp. appeared in the 2nd week of January, rate of parasitism was (7.65 %). A high percentage of the parasitoid (10.13 %) was found in the 4th week of January in 2019-20 and (13.48%) was recorded in the 2nd week of February in the 2020-21 season. Meanwhile, the low percent (7.62 %) was recorded in the 3rd week of February in the 2019-20 season and the low density of the parasitoid (5.76 %) was recorded in the 1st week of February in 2020-21. The means of the parasitoid percent was 3.29% during the first season 2019-205.61% and 5.61% in the season 2020-21 (Table 2).

3- *Alloxysta* sp.:

Alloxysta sp. Appeared on the 4th week of January, Percentage parasitism was (4.11 %). The high percent of the parasitoid (6.29 %) was found on the 4th week of February in 2019-20 and (7.49%) was recorded on the 2nd week of February and the low percentage of the parasitoid (1.93 %) was recorded in 4th week of January in 2020-21 season. The mean percentage of the parasitoid in the whole season was 1.89% In 2019 and 2.23% in the season 2020-21 (Table 2).

From Table (1), it could be noted that the maximum number of mummies was recorded in the 1st week of February (271 mummies), when the temperature and relative humidities were 14.60 °C and % 60.00 RH in 019-20 season and (374 mummies) in 2020/21 season during 1st week of February, at 16.60 °C and 63.30 % RH.

Percentage of Parasitism:

Results in Tables (1 and 2) showed that the parasitism percentage was 3.46 % in 1st week of November and it reached its maximum (92.39%) in the third week of February in the 2019-20 season at 15.20 °C and 59.60 % RH (Table 1), while it was 95.65 % on the first week of February in the second season at 16.60 °C & 63.30 % RH. (Table 2).

In Iraq:

The highest number of *B. brassicae* was (667 individuals /sample) during the 1st week of January 2020 in the first season, but in the 2020-21 season, it reached (610 individuals /sample) in the 3rd week of December. Meanwhile, the lowest number (319 individuals /sample) occurred on the 3rd week of November in the 2019-20 season, while in the 2020/2021 season, it reached 291 individuals/ sample during the 1st week of November.

Three peaks in the 2020-2021 season reached (567 individuals/ sample) in the fourth week of November 2019 at 19.71 °C, 60.85% RH., (667 individuals/ sample) found in the first week of January at 15.57°C, 49.42 % RH and (601 individuals/ sample) occurred in the last week of January at 15.00 °C 64.71 % RH in 2019-20 season (Table3). While two peaks were found in the second once in the third week of November (542 individuals) at 22.35 °C & 66.30 % RH and in the third week of December (610 individuals) at 12.00 °C & 48.90 % RH during 2020-21 (Table 4).

From Table (3), the highest number of mummies was recorded in the 4th week of January (378 mummies/sample), in season 2019-20 and (188 mummies/sample) in 2020-21 season during the 4th week of December (Table 4).

The parasitism percentage of 4.52% took place in the 4th week of November and it increased to reach its maximum of 77.78 % on the 4th week of January in the 2019-20 season at 16.14 °C and 55.28 % RH (Table 3), while it was 53.33 % in the mid of February in 2020-21 season at 12.9 °C, 58.93 % RH. (Table 4).

Parasitoids:

1- *Diaeretiella rapae*:

In the first season (Table 3), *D. rapae* was found in a very high percentage (100 % parasitism) from the last week of November to the third week of January. During the

following period, until the 2nd week of February the parasitoid, *D. rapae* remained at a high relative density (85.29 – 93.13). *D. rapae* was the most dominant species representing 100 – 78.15 % of the total parasitoids during the period from the 2nd week of November to 3rd of February (Table 4). The mean percentage of the parasitoid was 89.56 % in 2019-20 season and 87.07 % in 2020-21 season.

2. *Pachyneuron* sp.:

Pachyneuron sp. appeared in the 4th week of January, parasitism rate was (6.87 %). The high percentage of the parasitoid (11.43 %) was recorded in the 1st week of February and the low percentage of the parasitoid (5.34 %) was recorded in the 4th week of January. (Table 3). From table (4), The high percentage of *Pachyneuron* sp. (16.53%) was recorded in the 2nd week of February and the low percentage (11.92 %) was found in the 3rd week of February (Table 4). The means of the parasitoid percentage was 2.28% during season 2019-20 and 4.47% in 2020-21 season.

3- *Alloxysta* sp.:

For *Alloxysta* sp., the high percentage of the parasitoid was (6.47 %) on the 2nd week of February 2019-20 and (11.64%) on 1st the week of February 2020-21. The mean density of the parasitoid during the whole season was 1.03% for the first season (2019-20) and 2.21% for the second season 2020-21 (Table 4).

Percentage of Parasitism:

Results in Tables (3 and 4) showed that the highest parasitism percentage was 77.78% in the 4th week of January in 2019-20 season at 16.14 °C and 55.28 % RH (Table 3), while it was 53.33 % in the 3rd week of February in 2020-21 season at 12.9°C & 58.93 % RH. (Table 4).

Table (5) shows the intensity and relative densities of parasitoids *D. rapae*, *Pachyneuron* sp. and *Alloxysta* sp. Compared to the total catch of these parasitoids during two years of study in Egypt, those were 91.37, 5.50 and 3.13 % in the 2019/20 season and 88.39, 8.08 and 3.53 % in the second season of study. Meanwhile, in Iraq were 94.00, 4.26 and 1.74% in 2019/20 season and 91.03, 6.02 and 2.95 % in the 2020-21 season.

Biological Studies:

1. Life Cycle of *D. rapae* Reared on *B. brassicae* (at 18±1°C and 60±5% RH):

Diaeretiella rapae is an internal parasitoid that attacks aphids and deposits its eggs into the body of its host. There are four larval instars.

The results are given in Table (6) indicated the egg stage period ranged from 2-4 days with a mean of 4.01±0.35 days. The larval stage duration ranged from 4-to 7 days with a mean of 6.23±0.51 days. The pupal period ranged from 5-to 8 days, with a mean of 7.19±0.24 days. The mean life cycle from egg to adult's emergence ranged from 12-19 days with a mean of 17.43±0.91 days.

2. Sex Ratio of *D. rapae* and Adults' Emergence:

Data presented in Table (7) shows the sex ratio and percentage of adults' emergence of *D. rapae* in the field and of two laboratory generations of *B. brassicae*, in the field, the percentage of parasitoid emergence was 88.99 % with the sex-ratio 2.47 females: 1 male. While, in the laboratory, the percentage of adults' emergence in the first generation was 70.80 % with the sex-ratio 1.48 female: 1 male. while in the second generation, 68.66 % emergence occurred from host mummies with the sex-ratio 1.04 female: 1 male. The highest percentage of emergence was that from field-collected *B. brassicae* mummies. Among the emerged adults, the sex ratio was almost 1: 1 except for those who emerged from field-collected *B. brassicae* mummies among which the sex ratio was in favor of females, being 2.47: 1 (Table 7).

Table 1: Parasitism rate on *B. brassicae* in Kafr Saqr district, Egypt at 2019/2020 season.

Sampling dates	No. of dissected aphid	No. of parasitoid			Parasitism %	Emergent parasitoid						Total	Temp.	R.H %	
		A	B	Total		<i>D. rapae</i>		<i>Pachyneuron</i>		<i>Alloxysta</i> spp.					
						No.	RD%	No.	RD%	No.	RD%				
26/10/2019	351	0	0	0	0	0	0	0	0	0	0	0	22.97	62.28	
2/11	433	7	8	15	3.46	11	100	0	0	0	0	0	11	24.4	61.00
9/11	599	19	24	43	7.18	39	100	0	0	0	0	0	39	23.7	58.82
16/11	475	36	29	65	13.68	54	100	0	0	0	0	0	54	21.0	55.00
23/11	509	51	49	100	19.65	89	100	0	0	0	0	0	89	19.8	60.7
30/11	448	38	32	70	15.63	61	100	0	0	0	0	0	61	20.8	61.6
7/12	505	52	41	93	18.42	80	100	0	0	0	0	0	80	19.0	70.00
14/12	637	89	77	166	26.10	149	100	0	0	0	0	0	149	18.6	67.00
21/12	498	61	54	115	23.09	101	100	0	0	0	0	0	101	17.4	69.1
28/12	547	47	60	107	19.56	96	100	0	0	0	0	0	96	19.7	67.85
4/1/2020	578	95	71	166	28.72	151	100	0	0	0	0	0	151	16.5	70.00
11/1	437	119	65	184	42.11	150	88.24	13	7.65	7	4.11	170	16.9	51.0	
18/1	415	170	79	249	60.00	198	86.46	21	9.17	10	4.37	229	16.08	60.8	
25/1	363	162	87	249	68.59	191	84.14	23	10.13	13	5.73	227	17.6	61.4	
1/2	315	180	91	271	86.03	221	85.99	22	8.56	14	5.45	257	14.6	60.0	
8/2	306	194	161	255	83.33	201	87.39	19	8.26	10	4.35	230	13.9	60.0	
15/2	263	201	42	243	92.39	186	88.57	16	7.62	8	3.81	210	15.2	59.6	
22/2	252	165	53	218	86.51	150	85.71	14	8.00	11	6.29	175	16.8	60.1	
Total	7931	1686	161	2609	694.45	2128	1606.5	128.00	59.39	73.00	34.11	2329			
Mean	440.61±27.00	93.67	93.67	4144.9 20.97±	38.58±7.52	118.22 ±16.18	89.25± 5.48	7.11± 2.22	3.29± 1.01	4.06± 1.28	1.89± 0.59	129.39 ±19.16			

A=No. of mummified host counted at the date of inspection. N-Number RD= Relative density
 B=No. of mummified host appearing during the laboratory rearing.

Table 2: Parasitism rate on *B. brassicae* in Kafr Saqr district, Egypt at 2020/2021 season.

Sampling dates	No. of dissected aphid	No. of parasitoid aphids			Parasitism %	Emergent parasitoid						Total	Temp.	R.H %
		A	B	Total		<i>D. rapae</i>		<i>Pachyneuron</i>		<i>Alloxysta</i>				
						No.	RD	No.	RD%	No.	RD			
3/11/2020	450	9	5	14	3.11	9	100	0	0	0	0	9	20.87	66.07
10/11	483	14	12	26	5.38	20	100	0	0	0	0	20	21.15	65.3
17/11	435	32	21	53	12.18	49	100	0	0	0	0	49	21.05	65.4
24/11	589	49	32	81	13.75	72	100	0	0	0	0	72	21.25	68.57
1/12	421	33	28	61	14.49	50	100	0	0	0	0	50	21.08	70.8
8/12	475	45	39	84	17.68	73	100	0	0	0	0	73	17.00	61.6
15/12	501	62	54	116	23.15	98	100	0	0	0	0	98	16.55	64.8
22/12	445	71	57	128	28.76	100	90.91	10	9.09	0	0	110	14.92	57.0
29/12	591	142	86	228	38.58	180	89.55	21	10.45	0	0	201	19.80	73.3
5/1/2021	446	175	69	244	54.71	190	89.62	15	7.08	7	3.30	212	16.50	71.24
12/1	413	161	96	257	62.23	181	82.27	29	13.18	10	4.55	220	16.90	68.6
19/1	460	198	145	343	74.57	270	85.71	24	7.62	21	6.67	315	15.87	64.6
26/1	400	186	157	343	85.75	278	89.39	27	8.68	6	1.93	311	17.60	65.6
2/2	391	226	148	374	95.65	315	90.78	20	5.76	12	3.46	347	16.60	63.3
9/2	346	173	125	298	86.13	211	79.03	36	13.48	20	7.49	267	16.90	65.07
16/2	304	139	94	233	76.64	176	84.62	19	9.1	13	6.25	208	15.20	63.50
23/2	281	153	85	238	84.69	180	84.91	23	10.85	9	4.24	212	17.30	58.30
Total	7431	1868	1253	3121	777.45	2452	1566.	224.0	95.32	98.00	37.89	2774	15.60	60.8
Mean	437.12± 20.12	109.88± 17.66	73.71± 11.89	183.59 ±29.12	45.73± 8.05	144.24 ±22.74	92.16± 1.79	13.18± 3.06	5.61± 1.26	5.76± 1.77	2.23± 0.67	163.18± 26.76		

A=No. of mummified host counted at the date of inspection. N-Number RD= Relative density
 B=No. of mummified host appearing during the laboratory rearing.

Table 3: Parasitism rate on *B. brassicae* in Muthanna district , Iraq at 2019/2020 season

Sampling dates	No. of dissected aphid	No. of parasitoid aphids			Parasitism %	Emerged parasitoid						Total	Temp.	R.H %
		A	B	Total		<i>D. rapae</i>		<i>Pachyneuron</i> spp.		<i>Alloxysta</i> spp.				
						No.	RD%	No.	RD%	No.	RD%			
15/11/2019	319	0	0	0	0	0	0	0	0	0	0	0	22.14	62.28
22/11	354	5	11	16	4.52	15	100	0	0	0	0	15	21.14	69.85
29/11	567	29	21	50	8.82	41	100	0	0	0	0	41	19.71	60.85
6/12	408	24	28	52	12.75	43	100	0	0	0	0	43	22.42	42.71
13/12	485	44	40	84	17.32	71	100	0	0	0	0	71	20.28	51.14
20/12	501	49	51	100	19.96	89	100	0	0	0	0	89	13.14	58.85
27/12	546	69	67	136	24.91	123	100	0	0	0	0	123	11.57	65.85
3/1/2020	667	94	117	211	31.63	165	100	0	0	0	0	165	15.57	49.42
10/1	493	61	56	117	23.73	101	100	0	0	0	0	101	13.42	52.42
17/1	489	133	99	232	47.44	219	100	0	0	0	0	219	13.71	64.85
24/1	601	185	125	310	51.58	271	93.13	20	6.87	0	0	291	15	64.71
31/1	486	193	185	378	77.78	330	92.69	19	5.34	7	1.97	356	16.14	55.28
7/2	450	101	197	298	66.22	221	82.77	30	11.43	16	5.92	267	16.57	43.85
14/2	369	119	80	199	53.93	145	85.29	14	8.24	11	6.47	170	15.28	60.0
Total	6735	1106	1077	2183	440.59	1834	1253.88	83	31.88	34.00	14.36	1951		
Mean	481.07±25.95	79±16.46	76.93±16.39	155.93±31.47	31.47±6.44	131±26.65	89.65±7.07	5.93±2.74	2.28±1.01	2.43±1.37	1.03±0.60	139.36±29.38		

A=No. of mummified host counted at the date of inspection. N-Number RD= Relative density
 B=No. of mummified host appearing during the laboratory rearing.

Table 4: Parasitism rate on *B. brassicae* in Muthanna district Iraq at 2020/2021 season.

Sampling dates	No. of dissected aphid	No. of parasitoid aphids			Parasitism %	Emerged parasitoid						Total	Temp.	R.H %
		A	B	Total		<i>D. rapae</i>		<i>Pachyneuron</i> spp.		<i>Alloxysta</i> spp.				
						No.	RD%	No.	RD%	No.	RD%			
7/11/2020	291	0	0	0	0	0	0	0	0	0	0	0	18.35	48.9
9/11	307	4	6	10	3.26	7	100	0	0	0	0	7	20.2	55.4
16/11	542	25	24	49	9.04	37	100	0	0	0	0	37	22.35	66.3
23/11	411	19	33	52	12.65	40	100	0	0	0	0	40	18.92	74.5
30/11	509	51	42	93	18.27	81	100	0	0	0	0	81	17.6	67.33
7/12	510	69	54	123	24.12	109	100	0	0	0	0	109	13.75	53.93
14/12	469	76	51	127	27.08	117	100	0	0	0	0	117	11.45	51.8
21/12	610	92	63	155	25.41	151	100	0	0	0	0	151	12.0	48.9
28/12	503	99	89	188	37.38	130	100	0	0	0	0	130	11.65	55.4
4/1/2021	518	88	79	167	32.24	154	100	0	0	0	0	154	11.3	66.3
11/1	432	91	83	174	40.28	149	100	0	0	0	0	149	12.9	74.5
18/1	407	101	86	187	45.95	140	86.96	21	13.04	0	0	161	11.45	67.33
25/1	375	77	84	161	42.93	111	79.29	19	13.57	10	7.14	140	12	53.93
1/2	346	74	105	179	51.73	105	71.92	24	16.44	17	11.64	146	11.65	51.8
8/2	318	69	71	140	44.03	93	76.86	20	16.53	8	6.61	121	11.3	60.33
15/2	345	85	99	184	53.33	118	78.15	18	11.92	15	9.93	151	12.9	58.93
Total	6893	1020	969	1989	467.70	1542	1393.18	102	71.50	50.0	35.32	1694		
Mean	430.81±23.92	63.75±8.42	60.56±8.07	124.31±16.04	29.23±4.26	96.38±12.53	87.07±6.37	6.38±2.46	4.47±1.73	3.13±1.47	2.21±1.02	105.88±13.79		

A=No. of mummified host counted at the date of inspection. N-Number RD= Relative density
 B=No. of mummified host appearing during the laboratory rearing.

Table 5: Survey and relative densities of *B. brassicae* parasitoids on cabbage plants in Iraq and Egypt during two successive seasons.

Species	Iraq				Egypt			
	2019/2020		2020/2021		2019/2020		2020/2021	
	No.	%	No.	%	No.	%	No.	%
Primary parasitoids: <i>Diaeretiella rapae</i> (M'intosh)	1834	94.00	1542	91.03	2128	91.37	2452	88.39
Hyper parasitoids: <i>Pachyneuron</i> sp.	83.00?	4.26	102	6.02	128	5.50	224	8.08
<i>Alloxysta</i> sp.	34.00?	1.74	50	2.95	73	3.13	98	3.53
Total	1951	100	1694	100	2329	100	2774	100

N-Number RD= Relative density

Table 6: life cycle of *D. rapae* on *B. brassicae* at 18.00°C ±1°C and 65 ±5RH%

Host aphid	Egg (days)	Larval (days)	Pupal (days)	Life cycle (days)
<i>B. brassicae</i>	4.01±0.35 ^a (2 – 4)	6.23±0.51 ^b (4 - 7)	7.19±0.24 ^c (5 - 8)	17.43±0.91 ^d (12 - 19)
LSD0.05	0.49947	0.79915	0.9989	1.9978

Table 7: Sex ratio of *D. rapae* and adults' emergence

Host aphid	Source parasitoid	Mummies	Adults emerged	% Emergence	Females	Males	Sex ratio (M: F)
<i>B. brassicae</i>	In the field	854 ^a	760 ^a	88.99 ^a	541 ^a	219 ^a	1: 2.47 ^a
	First generation	609 ^b	486 ^b	79.80 ^b	290 ^b	196 ^b	1: 1.48 ^b
	Second generation	434 ^c	298 ^c	68.66 ^c	152 ^c	146 ^c	1: 1.04 ^c
LSD0.05		9.989	7.991	6.352	3.996	1.997	0.6326

DISCUSSION

Our results showed that one primary parasitoid *D. rapae*, and two hyperparasitoid, *Pachyneuron* sp. and *Alloxysta* sp., were found associated with the crucifers aphid *B. brassicae*. Many biocontrol agents (parasitoids, predators and entomopathogens) have been reported to be associated with *B. brassicae* from different parts of the world (Perdikis *et al.*, 2008). *Diaeretiella rapae* is a potential bio-agent for biological control against aphids in different nations (Maghraby 2012). *Diaeretiella rapae* plays an important role in averting aphid outbreaks in oilseed brassicas under field conditions (Blande *et al.*, 2004). Results of the present investigation showed that the highest rate of parasitism, in Egypt, was 92.39% in 2019-20 season and 95.65 % in 2020-21 season meanwhile, in Iraq it was 77.78% recorded in the 2019-20 season while it was 53.33 % in the 2020-21 season.

Data obtained from this manuscript is mentioned percentages of *D. rapae*, *Pachyneuron* sp. and *Alloxysta* sp. during the two seasons of study, it was (91.03, 6.02 and 2.95 % in the first season and 94.00, 4.26 and 1.74 % in the second season of study. A similar trend was obtained by Farouk and Mervat (2019) who showed *D. rapae* ranked the first and presented more than 90% dominance.

In this work, The mean life cycle from egg to adult's emergence ranged from 12-19 days with an average of 17.43±0.91 days on *B. brassicae*. These results are in harmony with those obtained by (Ragab *et al.*, 2002 and Saleh (2008)) who mentioned that *D. rapae* completed its life cycle in a period of 12-18 days at 19.5°C on *B. brassicae*. These results are in agreement with the findings of (Gazmer *et al.*, 2015 and Petchey *et al.*, 2008) who reported that the life cycle of *D. rapae* was completed in 19.3 days, 20.1 days and 17.2 days when reared on 48 h, 72 h, and 96 h old nymphs of *B. brassicae*.

Fecundity and percentage of parasitism of parasitoid were higher on cabbage, thus it represents a good host plant species for mass rearing of *D. rapae*. Analogous to the results of this study, Al-Azawi (1970) in Iraq and Gowling and van Emden (1994) showed dissimilarity in the parasitization of *B. brassicae* by *D. rapae* and concluded that this dissimilarity in Life cycle and longevity may be because of several factors, including nutritional qualities of the host plant. (Bayhan *et al.*, 2007 and Srwa *et al.*, 2021) also mentioned that the host plant could affect the rate of parasitism, development and longevity of *D. rapae* (Hussain *et al.*, 2019 and Soni and Kumar 2020).

Female parasitoids prefer host sizes that yield a higher fitness gain rate to those yielding a higher absolute gain. The size of associated parasitoids and hosts is positively correlated in ecological communities (Gi-Mick Wu 2010). In the present investigation, *D. rapae* cleared a female-biased sex ratio. Our results corroborate the study of Le Guigo *et al.*, 2012 and Soni and Kumar 2020) who also reported a female-biased sex ratio of *D. rapae* parasitizing *M. persicae* feeding on different plant hosts. Sex ratio can have strong effects on classical biological control and population dynamics (Wogin *et al.*, 2013). In this respect, (Saleh *et al.*, 2009 and Verma *et al.*, 2019) mentioned that the sex ratio of *D. rapae* was 1.7: 1(F: M). By rearing the parasitoid sex ratio was almost 1: 1 in the first, second and third generations respectively. This investigation will be helpful in implementing the use of parasitoids as biological control agents in integrated pest management programs (IPM) for *B. brassicae* on cruciferous crops.

Declarations

Author Contributions: Ahmed A.A.Saleh and Ahmed.S.Jabbar put strategy to achieve this work. All authors achieved this investigation. A.A.Saleh, M.F.zawrah, A.S.jabbar and S.A.M.Amer are the contributors to writing the manuscript. AhmedA.A.Saleh and M.F.zawrah revised the manuscript. All authors read and approved the final manuscript.

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