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**Biological Control of Cereal Aphids on Barley Plants By Field
Release of the Predator, *Chrysoperla Carnea* (Stephens) (Neuroptera:
Chrysopidae), In Integration with the Natural Role of the Parasitoid,
Aphidius Matricariae Hal. (Hymenoptera: Aphidiidae) And
Coccinellidae Predators**

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Abstract

Barley plant is considered as one of the most important feeding sources of carbohydrate for man and livestock. Four different aphids' species were recorded attacking barley plants which were; the bird cherry-oat aphid, *Rhopalosiphum padi* (L.) (which was the most abundant aphids' species), the corn leaf aphid, *Rhopalosiphum maidis* (F.), the green bug, *Schizaphis graminum* (R.) and the English grain aphid, *Sitobion avenae* (Fab.) (Homoptera: Aphididae). The parasitoid, *Aphidius matricariae* Hal. (Hymenoptera: Aphidiidae) was the only primary parasitoid species recorded parasitizing the different surveyed cereal aphids' species. Two common predatory species were recorded preying on cereal aphids on barley plants; they were *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) and Coccinellidae predators (including: *Hippodamia convergens* (Geur.) and *Coccinella undecimpunctata* L.). Percentage of aphids' individuals reduction after releasing second instar predatory larvae of *Ch. carnea* per season was estimated as 46.82%, while it was evaluated as 90.01% after 3 weeks from releasing date. Also, releasing second instar larvae of *Ch. carnea* indicating that, predatory larvae were effective as a suitable larval stage to be released. In addition, there were increases in case of: means total length (cm.) per one spike for those spikes of no terminal hairs or with terminal hairs, means total spike weight (gm.), mean total numbers of grains per one spike, total weight of 100 grains and percentages of newly barley grains' germination. Therefore, this study was made to direct the highly efforts towards increasing cultivating barley areas side by side with that of cultivated ones of wheat. The released predator *Ch. carnea* can be mass reared released and integrated with the natural role of both of the parasitoid, *A. matricariae* and predatory species of Coccinellidae, for controlling cereal aphids on barley plants.

Keywords: barley, aphids' infestation, parasitism, predation, releasing *Chrysoperla carnea*, aphids' populations' reduction.

INTRODUCTION

Barley (*Hordeum vulgare* L.) represents one of the most suitable cereal crops which can be cultivated in a wide scale and under many different environmental conditions (El-Bawab, 1994). Farmers cultivated barley for two reasons: for animal feeding and also human food as they have a rich supply of carbohydrates (Neelhirajan *et al.*, 2007), besides its important uses as a common model in many of new genetic researches (Hagberg, 1987). Many aphids species could be found in a mixed populations form as pests of cereal crops including barley where they are strongly suffering from their attack (Bishara & Sourial, 1997). As, aphids are responsible by sucking plants sap, for the occurrence of an obvious decrease in plants viability, which lead to a clear reduction in resulted cereal crop yield (Saleh *et al.*, 2006). They may also transmit many plants pathogens (Mahmoud *et al.*, 2023), such as Barley Yellow Dwarf Virus (BYDV) (El-Heneidy, 1994), that will be responsible for the occurrence of many plants' diseases. Years after years, the repeat intensively use of chemical harmful pesticides had developed many sever problems as a result of their uses (such as; health hazards, reduction in population density of natural enemies and also lead to a disruption in the natural balance that existed between them and their pests, besides the development of pests resistance). As a result, scientists had directed their efforts to search strongly for another safer control methods to face pests including aphids attack (Easterbrook *et al.*, 2006; Arif & Ghaffar, 2009 and Sarwar, 2014). Recently, the aim was concerned on searching of alternative and more safe and friendly methods for pests' control such as using biological control techniques, which now seemed to be the most promising tool and strategy for sustainable agriculture (Hemidi & Laamari, 2020), and is considered as a cornerstone of many Integrated Pest Management programs (Joshi *et al.* 2010). However, biocontrol agents had appeared to be of an important role in the planning and performing of many techniques and methods that can be applied against agricultural pests in different integrated ways (Banken & Stark,

1998). Biocontrol agents such as; firstly, many parasitoids species of order Hymenoptera, are important effective bioagents groups for controlling aphids including cereal aphids, being used in many diverse agricultural crops as a component of many different biological control programs (Pungerl, 1984). For example, the primary parasitoid species *Aphidius matricariae* Hal. (Hymenoptera: Aphidiidae), is considered as one of these major parasitoids species that parasitize many aphids species including cereal aphids (Abdel-Rahman, 2005 and El-Fatih, 2006). Secondly, the use of predatory species by mass rearing and releasing them for insect management in many applied control programs has received the same increased and directed clear attention (Atlihan, 2010). Among these predatory species, adults and larvae of family Coccinellidae (Vo"lkl *et al.*, 2007) and lacewing predatory larvae of family Chrysopidae feed on aphids (Vo"lkl *et al.*, 2007; Yadav & Pathak, 2010 and Saleh *et al.*, 2017). From them, the predatory green lacewing *Chrysoperla carnea* (Steph.) is characterized by possessing a highly searching behavioral ability with a widely geographical distribution and also has the ability to face different changes of environmental factors (Tauber *et al.*, 2000). It was shown to be continually easily mass reared in the laboratory and released as predatory larval instars in many applied biological control programs against aphids (Sarwar, 2013). Thus, present work was conducted during season 2023/2024, at the Plant Protection Research Station in Qaha district, Qalubia Governorate, to study the effect of a field integration biological control experiment including; the release of second instar larvae of the predator, *Ch. carnea*, with recording the natural existed role of the primary aphid parasitoid, *Aphidius matricariae* Hal. (Hymenoptera: Aphidiidae) and predatory species of Coccinellidae, against cereal aphids' attacking barley plants. This study had two aims: the first one was to through light on the ability to cultivate barley in a new area (Delta region) that was not cultivated in it before and the second one was concerning with the following points:

1. Calculating total numbers of aphids' individuals (adults & nymphs) recorded in both unreleased and released areas.
2. Calculating total numbers of aphids' mummies and also percentages of aphids' parasitism and percentages of parasitoid emergence of the parasitoid, *A. matricariae*.
3. Calculating total numbers of aphids' predatory species.
4. The biological control experiment which was performed to study the following points:
 - 4.1- Effect of releasing second instar predatory larvae of *Ch. carnea* on percentages of aphids' individuals reduction and on the occurrence of predatory species in barley field.
 - 4.2- Effect of releasing predatory larvae of *Ch. carnea* on resulted barley crop concerning the following two points (in comparing unreleased and released areas) :
 - 4.2.1- Means' calculations of barley spikes length (with no terminal spikes' hairs and with terminal spikes' hairs (cm.) and also estimation of total spikes weight (gm.).
 - 4.2.2- Means' calculations of total numbers of spikes' grains, besides total weight of grains and also estimating percentages of newly grains' germination of resulted barley crop after 72 hours.

5. Statistical analysis of obtained data:

- 5.1. Correlations recorded in barley field experiment (by comparing means values).
- 5.2. Effect of temperature and relative humidity on some tested ecological factors.

MATERIALS AND METHODS

1. Experimental design.

A total experimental area of 135 m² (9m. × 15m.), was selected and used in the farm at the Plant Protection Research Station in Qaha district, Qalubia Governorate which affiliated to the Plant Protection Research Institute (P.P.R.I.), Agriculture Research Center (A.R.C.), that was located in Qaha district (Qalubia Governorate), during 2023/2024 season. Experimental area was cultivated with barley grains (Balady, variety Giza 123), in the first week of December, 2023 (in 4/12/2023) and it was ended in the second week of April, 2024 (in 10/4/2024). All agricultural practices were made except the use of chemical insecticides which was not allowed to be used. This experimental area was divided into two parts (areas), each one of 59.5 m² (8.5×7m.), i.e., a total area of both of 119m², representing unreleased and released areas that were chosen for experimental purpose. Figure (1) displayed a diagram that shows performed field designed barley experiment. The distance between the two areas (unreleased and released one), was 50

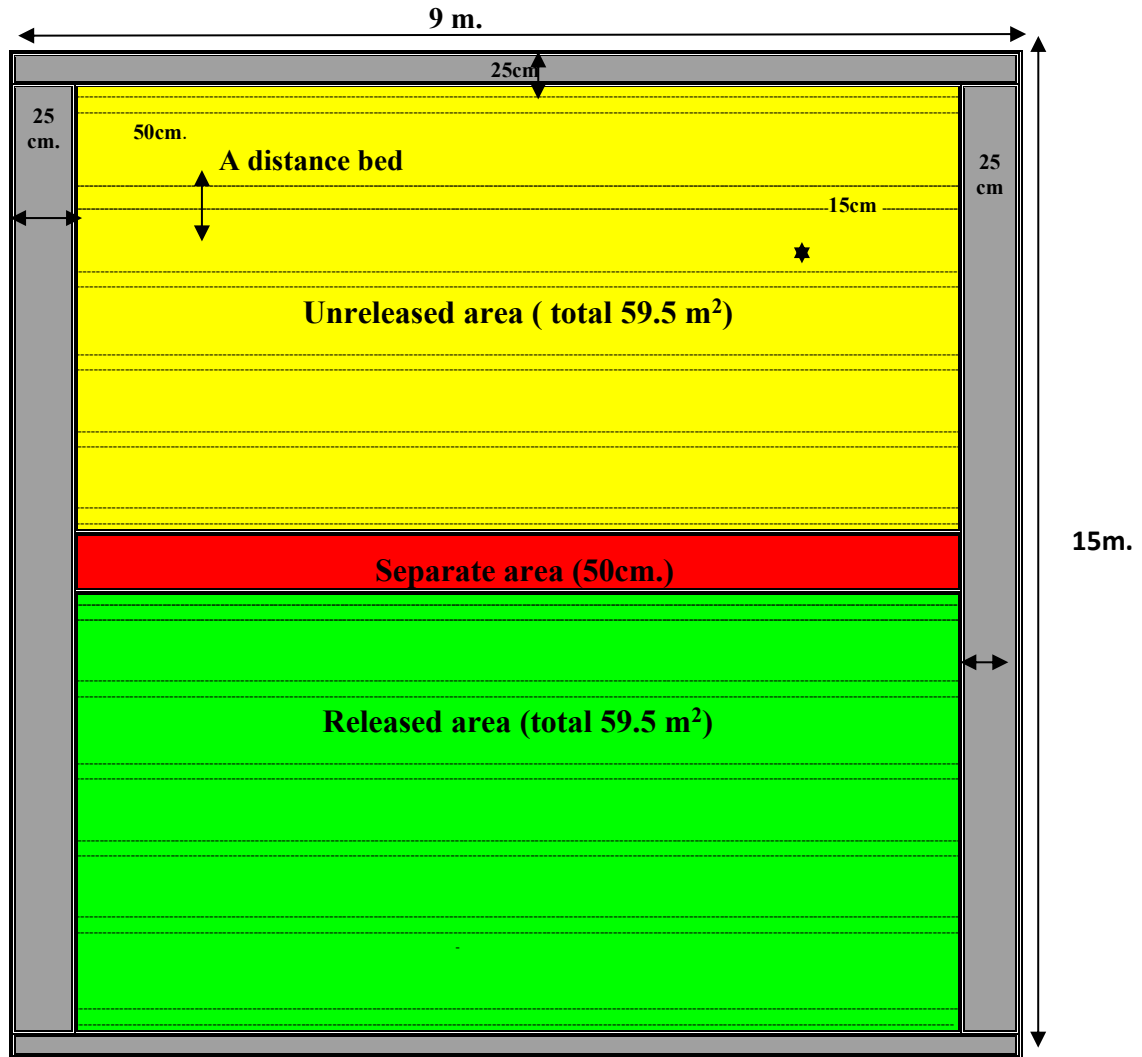


Fig. 1: diagram that showed performed field designed experiment of barley.

cm. (Which representing the separate area) and the outer limit surrounding total experimental area was 25cm. from each side. The two experimental areas (unreleased and released one), were cultivated with barley grains

on beds each of 50 cm. and the distances between these beds were 15cm. The different steps of development of cultivated barley plants in field experimental areas from planting until harvesting time were configured in Figure (2).



A- New planting

B- Development stage

C- Formation of spikes

D- Harvesting of barley

Fig. 2: Different steps concerning development of cultivated barley plants in field experimental areas from planting until harvesting time.

2. Field biological control performed experiment:

2.1. Source and releasing second predatory instar larvae of *Ch. carnea*.

Second instar larvae of lacewing predator, *Ch. carnea* were used against cereal aphids attacking barley, according to the conclusion shown by Younes *et al.* (2013), who demonstrated that, this larval instar was the most suitable larval instars to be used and released. Source of predatory larvae was from "laboratory mass-rearing unit", located at Faculty of Agricultural, Cairo University, Giza. Where, Figure (3a) showed life cycle of lacewing predator, *Ch. carnea* that was used against cereal aphids attacking barley in performed field

experiment (from eggs to adults' stage). While, Figure (3b) showed released area in which five similar squares plots area each one of 4m² (2m.×2m.), representing a total area of 4m²×5=20 m², for these five released plots), in which predatory second instar larvae of *Ch. carnea* were distributed and applied along this area. Therefore, predatory larvae of *Ch. carnea* were distributed and applied along this released area (at a rate of 10 predatory second instar larvae/1m²). Releasing of these predatory larvae was done in third week of February, 2024 (in 21/2/2024), with a rate of 40 second instar larvae of predator/sequare×5squares plots of released area (i.e., a total number of 200 second instar larvae of *Ch. carnea* was released).

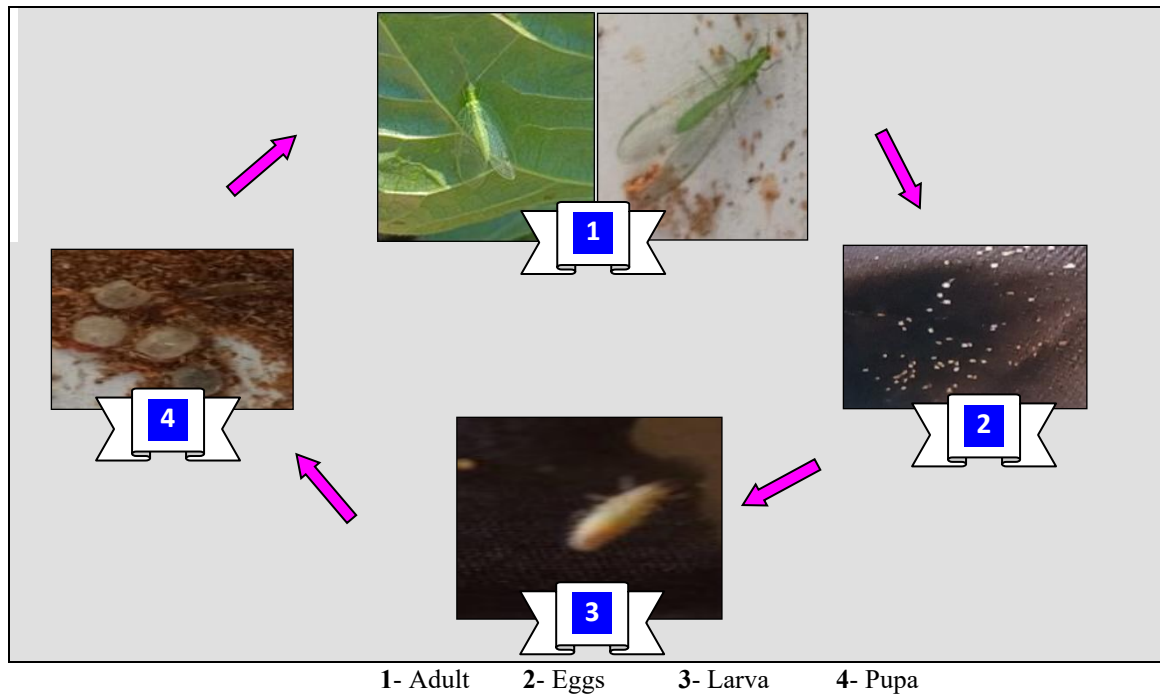


Fig. 3(a): Life cycle of lacewing predator, *Ch. carnea* that was used against cereal aphids attacking barley in performed field experiment.

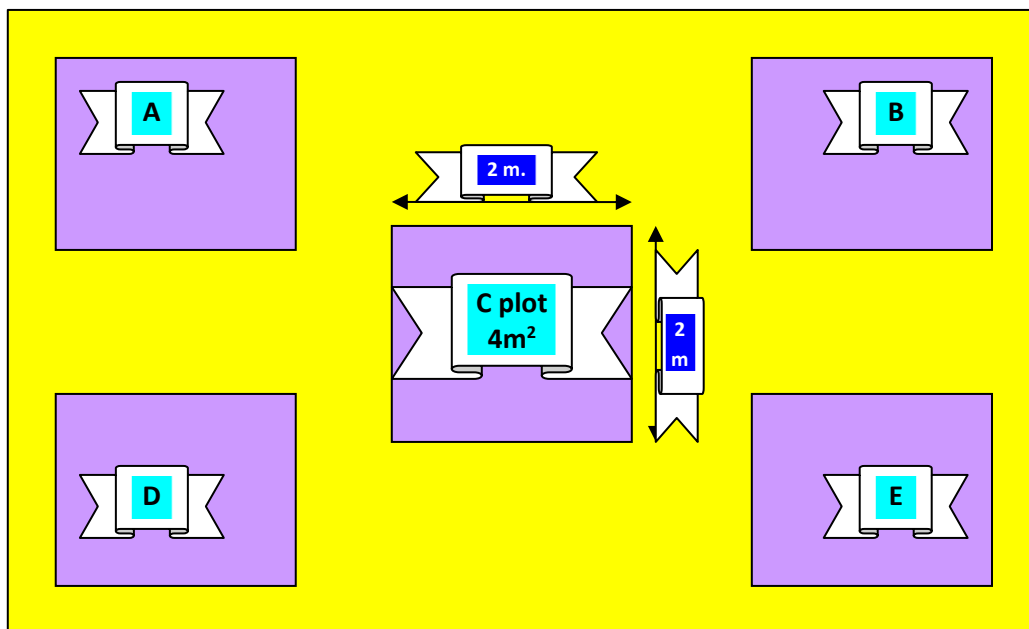


Fig. 3(b): Representing released experimental area in which the five similar squares area (A, B, C, D and E), in which predatory second instar larvae of *Ch. carnea* were distributed and applied along this released area.

2.2. Investigation of field samples and data calculations.

- a- Random weekly barley plants samples representing a total of 10 squares plots each of them was 1m²(1m.×1m.) was investigated early in the morning throughout different barley growth stages. Each barley sample was of 20 plants/one square×10 squares = a total of 200 plants/sample), for either unreleased area or released one.
- b- Total numbers of cereal aphids' individuals (adults & nymphs) were counted and mean total numbers of aphids individuals/one plant were also calculated.

$$\text{Mean no. of aphids individuals/one plant} = \frac{\text{Numbers of individuals (adults \& nymphs)}}{200 \text{ plants sample}}$$

- c- Percentages of reduction in aphids individuals' populations per season and also after three weeks from releasing second instar predatory larvae of *Ch. carnea* in comparing unreleased and released area were also estimated according to the equations described by Bahy El-Din *et al.* (2024) as follow:

$$\text{Reduction (\%)} = 100 - \frac{\text{Total no. of aphids individuals in released area}}{\text{Total no. of aphids individuals in unreleased area}} \times 100$$

- d- At the same time, total numbers of predatory species that were surveyed in both unreleased and released areas were recorded and counted and percentages of increase in their populations per season in released area were also estimated
- e- Then, infested barley plants samples with aphids species were directly taken in paper bags to the laboratory, waiting for a week until formation of any newly aphids' mummies which were counted. Percentages of aphids parasitism were estimated according to the equation described by Bahy El-Din *et al.* (2024) as follow:

$$\text{Parasitism (\%)} = \frac{\text{Total no. of formed aphids mummies}}{\text{Total no. of aphids individuals}} \times 100$$

- f- Afterthat, emerged aphids parasitoids species from both unreleased and released areas was recorded and identified at Department of Biological Control Research, Plant Protection Research Institute, Cairo. Egypt.
- g- The effect of releasing the predatory larvae of *Ch. carnea* on barley crop yield was estimated after 106 days by many obtained features such as: mean total numbers of grains in barley spikes, representing a mean of 5 grains groups where each grain group was represented by 5 barley spikes, mean spikes length (cm.) either with no terminal hairs or with terminal hairs (a mean of 5 groups where each one group was represented by 5 barley spikes) and weights of barley spikes (a mean of 5 groups where each one group was represented 25 barley spikes). Weights of resulted newly crop yield grains were calculated (a mean of 5 groups, each one group was represented by 100 barley grains). Also, mean percentages of newly grains germination were also estimated after 72 hours (a mean of 5 groups, each one group was represented by 20 barley grains). These tested ecological barley crop yield features were all calculated after 106 days post barley planting in last week of March, 2024 (i.e., in 27/3/2024).

2.3. Statistical analysis of obtained data.

Means' values of resulted data (where, the least significant difference was carried out at L.S.D.0.01&0.05 levels of probability) and also r-values (correlation coefficient) were estimated by using SPSS computerized program version14.0. As for means of temperature and relative humidity, they were obtained from Meteorological Station at A.R.C., to calculate the relationships recorded between many tested ecological field factors and means of temperature and relative humidity.

RESULT AND DISCUSSION

1. Total numbers of aphids individuals (adults & nymphs) recorded in both unreleased and released areas.

From Table (1) and Figures (4&7), mean total numbers of aphids individuals (adults & nymphs) recorded in barley field experiment

per season 2023/2024 were; 912.93 ± 235.57 (8-2318) & 485.50 ± 175.57 (8-1856 individuals), while, maximum total numbers of aphids individuals were during last week of February, 2024 (2318 individuals, in 28/2/2024, at means of temperature and relative humidity of 17.07°C & 62.70 R.H.%, respectively) and during third week of February, 2024 (1856, in

21/2/2024, at 16.63°C & 54.80 R.H.%), in unreleased area (with no release of predatory larvae of *Ch. carnea*) and released area (with release of predatory larvae of *Ch. carnea*), respectively. Also, means total numbers of aphids individuals for one plant per season were; 4.57 (0.04-11.59) & 2.43 (0.04-9.28 individuals), respectively.

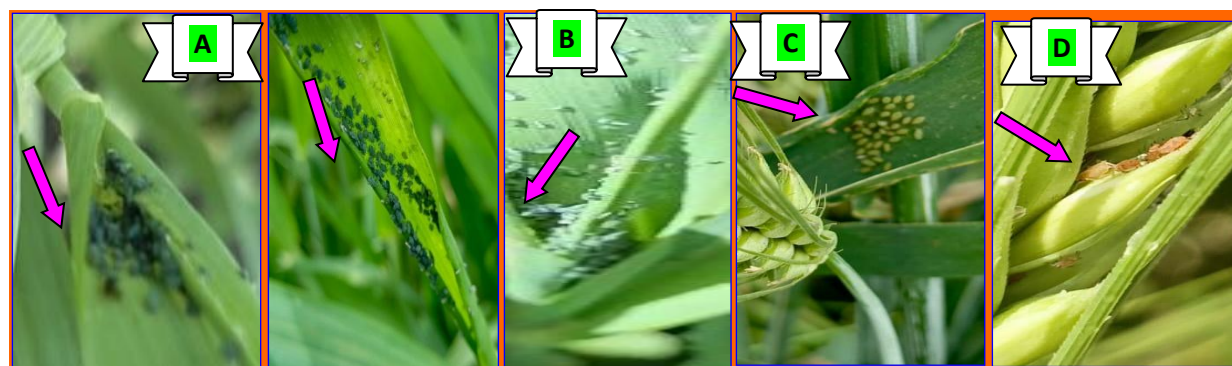
Table 1: Weekly total numbers of aphids individuals (adults & nymphs) recorded in both unreleased and released areas of barley field experiment, during season 2023/2024.

Dates of inspection	Unreleased area		Released area		Mean weather factors	
	Total no. of aphids individuals (A+N)	Mean total no. /one plant	Total no. of aphids individuals (A+N)	Mean total no. /one plant	Temp (C°)	R.H. (%)
10/1/2024	8	0.04	8	0.04	17.90	60.86
17/1	27	0.14	14	0.07	16.09	49.77
24.1	136	0.68	123	0.62	18.09	45.40
31/1	464	2.32	405	2.03	15.43	60.09
7/2	1357	6.79	1258	6.29	13.17	55.91
14/2	1983	9.92	1707	8.54	17.13	60.73
21/2 *	2101	10.51	1856	9.28	16.63	54.80
28/2	2318	11.59	801	4.01	17.07	62.70
6/3	1890	9.45	378	1.89	19.26	48.96
13/3	1402	7.01	126	0.63	18.33	52.64
20/3	550	2.75	53	0.27	18.69	58.81
27/3	322	1.61	37	0.19	17.96	48.24
3/4	154	0.77	21	0.11	23.50	45.07
10/4	69	0.35	10	0.05	17.90	60.86
Total/season	12781		6797			
Mean/season (range)	912.93 ± 235.57 (8-2318)	4.57 (0.04-11.59)	485.50 ± 175.57 (8-1856)	2.43 (0.04-9.28)	17.65 C° (13.17-23.50C°)	54.63% (45.07-62.70%)

Note: A = Adults of aphids. N = Nymphs of aphids. * = Date of releasing predatory second instar larvae of *Ch. carnea*.

Obtained data revealed that, four different aphids' species were recorded attacking barley plants including; the bird cherry-oat aphid, *Rhopalosiphum padi* (L.) (which was the most abundant aphids species), the corn leaf aphid, *Rhopalosiphum maidis* (F.), the green bug, *Schizaphis graminum* (R.) and the English grain aphid, *Sitobion avenae* (F.) (Homoptera: Aphididae). These previous aphids species were surveyed attacking barley fields by many authors such as: (Ahmed *et al.*, 2007); (Slman & Ahmed (2005)); (Abd El-Salam (1999) & Ahmed *et al.* (2007)) and (El-Fatih (2006) &

Ahmed *et al.* (2007)), respectively. In addition, Tantawi (1985) showed that, first and second ones were the most dominant aphids' species in Middle Egypt, but, El-Fatih (2006) indicated that, only first species was the most abundant one in the same area with few recorded numbers of other aphids species. Moreover, Slman and Ahmed (2005) observed that, the bird cherry-oat aphid, *R. padi* was found on barley plants by late February at Middle Egypt and early March at Southern Egypt and the highest recorded total numbers of aphids' individuals was after 70 days post barley planting.



A= the bird cherry-oat aphid, *R. padi*

B= the green bug, *S. graminum*

C= the corn leaf aphid, *R. maidis*

D= the English grain aphid, *S. avenae*

Fig. 4: Different aphids' individuals' species that were recorded in unreleased area attacking barley plants.

2. Total numbers of parasitoid mummies and also percentages of aphids parasitism and percentages of emergence of the parasitoid, *A. matricariae*.

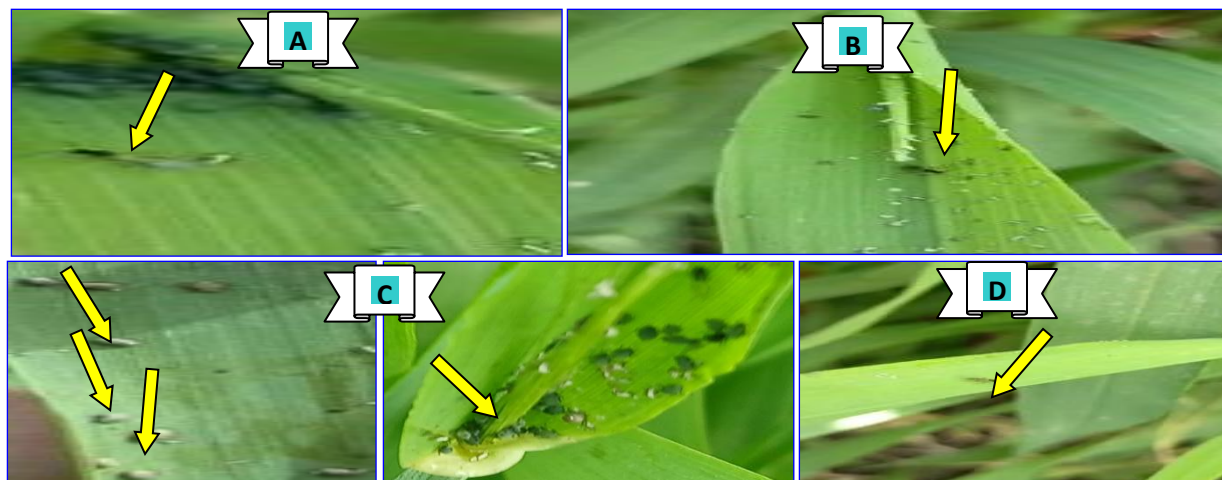
The parasitoid, *Aphidius matricariae* Hal. (Hymenoptera: Aphidiidae) was the only primary parasitoid species recorded parasitizing the different four surveyed cereal aphids species

in barley experimental field, during this study as shown in Table (2) and Figures (5&7). This result was similar to the findings recorded by Abdel-Rahman (2005) and El-Fatih (2006) and also, where family Aphidiidae was shown to form the major part of the primary parasitoid spectrum of aphids (Stary, 1976).

Table 2: Weekly total numbers of parasitoid mummies and also percentages of aphids' parasitism and emergence of the parasitoid, *A. matricariae*, recorded in both unreleased and released areas of barley field experiment, during season 2023/2024.

Dates of inspection	Unreleased area				Released area			
	Total no. of parasitoid mummies	% aphids parasitism	Total no. of emerged <i>A. matricariae</i> parasitoid	% <i>A. matricariae</i> parasitoid emergence	Total no. of parasitoid mummies	% aphids parasitism	Total no. of emerged <i>A. matricariae</i> parasitoid	% <i>A. matricariae</i> parasitoid emergence
10/1/2024	0	0.00	0	0.00	0	0.00	0	0.00
17/1	2	7.41	1	50.00	1	7.14	0	0.00
24/1	15	11.03	13	86.67	13	10.57	10	76.92
31/1	97	20.51	84	86.60	75	18.52	51	68.00
7/2	220	16.21	179	81.36	172	13.67	116	67.44
14/2	267	13.46	223	83.52	183	10.72	124	76.67
21/2 *	245	11.66	205	83.67	156	8.41	135	86.54
28/2	235	10.14	185	78.72	28	3.50	18	64.29
6/3	172	9.10	97	56.40	10	2.65	4	40.00
13/3	101	7.20	69	68.32	2	1.59	1	50.00
20/3	35	6.36	17	48.57	0	0.00	0	0.00
27/3	14	4.35	5	35.71	0	0.00	0	0.00
3/4	6	3.90	2	12.50	0	0.00	0	0.00
10/4	4	2.90	0	0.00	0	0.00	0	0.00
Total/season	1413		1080		640		459	
Mean (range)	100.93±28.05 (0-267)	11.06% (0.00-27.37%)	77.14±23.02 (0-223)	76.43% (0.00-86.67%)	45.71±18.87 (0-183)	9.42% (0.00-18.52%)	32.79±13.88 (0-135)	71.72% (0.00-86.54%)

• = Date of releasing predatory second instar larvae of *Ch. carnea*.



A= the parasitoid begins searching for aphids. **B=** the parasitoid moved towards aphids to begin parasitism process. **C=** Success of parasitism with formation of aphids mummies. **D=** Emergence of newly adult parasitoid species. Fig. 5: Formed parasitoid mummies and adult primary parasitoid, *A. matricariae* that was recorded parasitizing aphids in barley field experiment.

Mean total numbers of parasitoid mummies and also percentages of aphids parasitism and percentages of emergence of the parasitoid, *A. matricariae* per season were; (100.93 ± 28.05 (0-267) & 45.71 ± 18.87 (0-183)), (11.06% (0.00-27.37%) & (9.42% (0.00-18.52%)) and (76.43% (0.00-86.67%) & (71.72% 0.00- 86.54%)). Maximum total numbers of parasitoid mummies and also the highest percentages of aphids parasitism and percentages of emergence of the parasitoid, *A. matricariae* were; (267&183 were during second weeks of February, i.e., in 14/2/2024), (20.51% & 18.52% were during last weeks of January, 2024, i.e., in 31/1/2024) and (86.67% & 86.54% were during (third week of January, 2024, i.e., in 24/1/2024) & (third week of February, 2024, i.e., in 21/2/2024), in case of unreleased and released areas, respectively. Results obtained emphasized strongly the important natural role of the parasitoid as a biocontrol agent against cereal aphids attacking barley plants, which, seemed to be in complete accordance with that detected by Youssif *et al.* (2017). Also, there was an increase in total numbers of parasitoid mummies and percentages of aphids parasitism which were directly related to the increase occurred in the aphids individuals' population. In similar line, during late February-mid. April, highest percentages of aphids parasitism were shown to

be mostly existed with the highest cereal aphids populations found on barley plants (Abdel-Rahman, 2005 & Slman, 2006). Parasitoids were peaked after two weeks following the occurrence of aphids peak (Megahed, 2000).

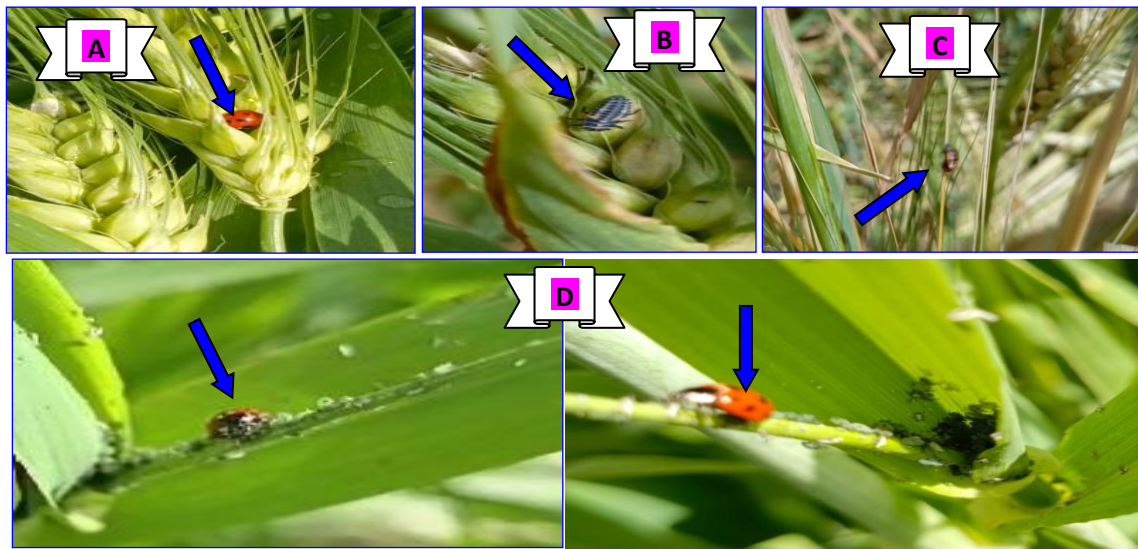
3. Total numbers of aphids' predatory species.

Two common predators were recorded preying on cereal aphids on barley plants; they were *Chrysoperla carnea* (Steph.) (Neuroptera: Chrysopidae) and Coccinellidae predators (including: *Hippodamia convergens* (Geur.) and *Coccinella undecimpunctata* L.). In the same line, El-Gapaly (2007) recorded the same predatory species in association with the four recorded aphids species surveyed in the present study. As demonstrated in Table (3) and illustrated in Figures (6&7), mean total numbers of *Ch. carnea* (adults & larvae) and Coccinellidae (adults & larvae) per season were; (10.29 ± 2.89 (0-29) & 12.57 ± 5.32 (0-67), for *Ch. carnea*) and (4.57 ± 1.46 (0-18) & 3.14 ± 1.05 (0-11), for Coccinellidae). Also, the mean total numbers of both predatory species together were; (14.86 ± 3.72 (0-36) & 15.71 ± 5.90 (0-72). Highest total numbers of predators (36&72) were during second week of March, 2024 (in 13/3/2024) and during last week of February, 2024 (in 28/2/2024), in case of unreleased and released areas, respectively.

Table 3: Weekly total numbers of predatory species of aphids recorded in both unreleased and released areas of barley field experiment, during season 2023/2024.

Dates of inspection	<i>Ch. carnea</i> (A+L)		Coccinellidae (A+L)		Total no. of predatory species	
	Unreleased	Released	Unreleased	Released	Unreleased	Released
10/1/2024	0	0	0	0	0	0
17/1	0	0	0	0	0	0
24.1	0	0	0	0	0	0
31/1	0	0	0	0	0	0
7/2	0	0	0	0	0	0
14/2	9	12	1	1	10	13
21/2 *	18	26	2	3	20	29
28/2	21	67	3	5	24	72
6/3	25	39	5	8	30	47
13/3	29	21	7	11	36	32
20/3	23	9	11	9	34	18
27/3	11	1	18	4	29	5
3/4	6	1	10	2	16	3
10/4	2	0	7	1	9	1
Total/season	144	176	64	44	208	220
Mean/season (range)	10.29±2.89 (0-29)	12.57±5.32 (0-67)	4.57±1.46 (0-18)	3.14±1.05 (0-11)	14.86±3.72 (0-36)	15.71±5.90 (0-72)

Note: A = Adults. L = Larvae. * = Date of releasing predatory second instar larva of *Ch. carnea*.



A= Adult predator begin to search for aphids preys. B= A larva of predator that prey on aphids.

C= A formed predatory pupa.

D= Adult predator that begin to prey on aphids individuals.

Fig. 6: Coccinellidae predatory species that were surveyed in barley field experiment.

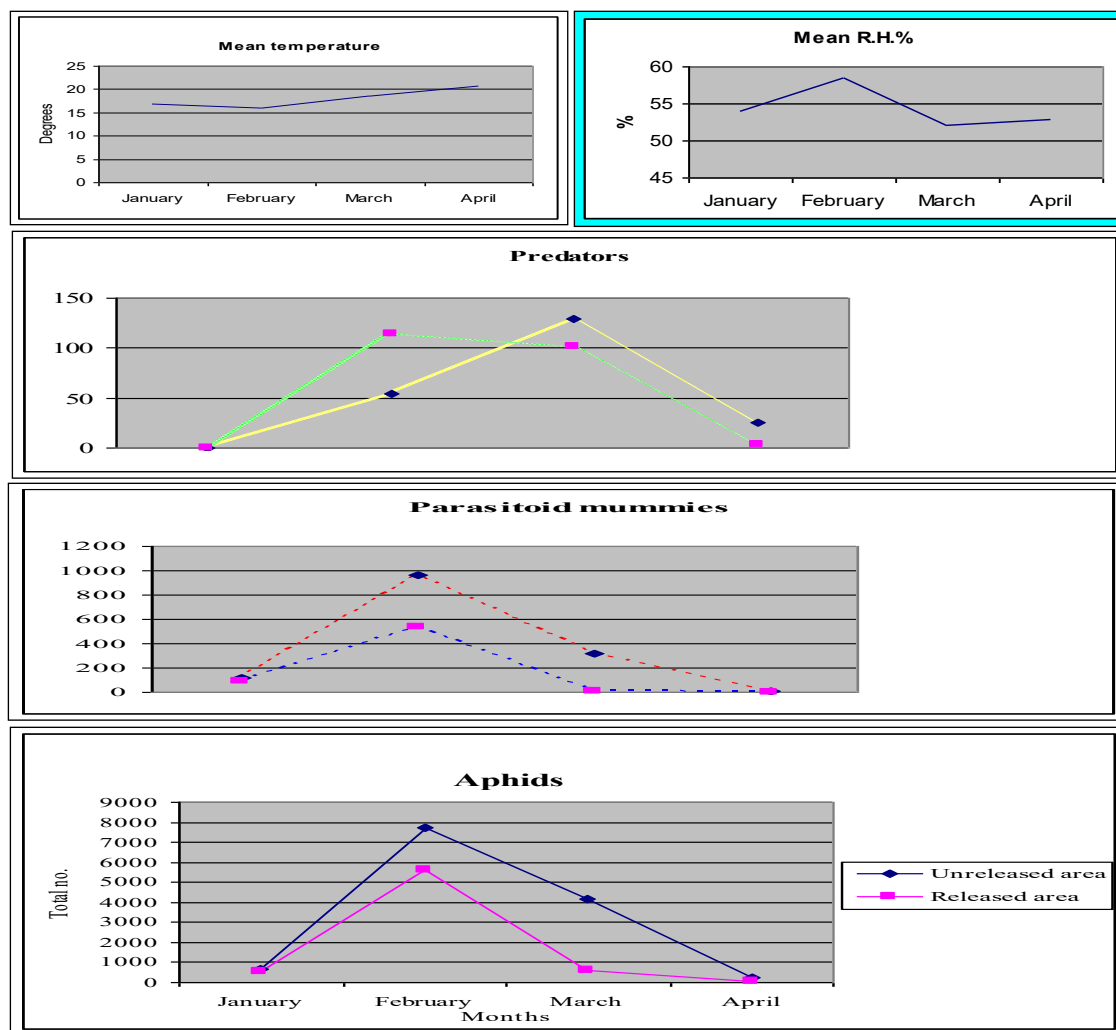


Fig. 7: Monthly total numbers of aphids individuals (nymphs & adults), parasitoid mummies and predatory species, which were recorded in unreleased and released areas, in barley field during season 2023/2024, in Qalubia Governorate.

4. Effect of releasing second instar predatory larvae of *Ch. carnea* on percentages of aphids individuals reduction and also on occurrence of predatory species in barley field.

Table (4) showed that, means total numbers of aphids' individuals before and after releasing process of releasing second instar larvae of *Ch. carnea* were; 868.00 ± 350.12 (8-2101) and 957.86 ± 342.37 (69-2318), respectively. The respective for released area were; 767.29 ± 308.59 (8-1856) and 203.71 ± 110.69 (10-801) individuals. Indicating that, the occurrence of aphids individuals reduction after predatory larvae release per season was 46.82%. The highest mean recorded percentage of aphids individuals reduction was

evaluated as 90.01% after 3 weeks from releasing predatory second instar larvae of *Ch. carnea* (where, total numbers of aphids individuals were, 1402&126, in unreleased and released areas, respectively). Thus, results in this study also demonstrated that, releasing second instar larvae of this predator was effective and maximum percentage of aphids individuals reduction was happened directly after 3 weeks post releasing time (during second week of March, 2024, i.e., in 13/3/2024) (Table, 1). Observation recorded was like that recorded by Younes *et al.* (2013), who showed that, promising and best results was achieved by releasing second instar larvae of *Ch. carnea* against *Aphis gossypii* and *myzus persicae*, on

cantaloupe after 21 days from releasing date. In similar results, percentages of aphids species populations reduction after releasing the predator, *Ch. carnea* were estimated as: 98.50% (Gurbanov, 1982); 84.00% (Messina & Sorenson, 2001) and 73.90% (Younes *et al.*, 2013). Results also showed that, releasing second instar larvae of *Ch. carnea* as an effective larval stage, to be laboratory mass reared and released against aphids' populations in barley field released experimental area. So, they were supported by those of Sarwar (2014), who stated that, first instar followed by second and third instars larvae of *Ch. carnea* were most effective in reducing aphids' population compared with unreleased control. In general, results recorded in this study indicated that, this predator can consider as one of the important predators in controlling cereal aphids on barley plants and its role could be strongly encouraged and can be extensively used as one of the main

components of Integrated Pest Management (I.P.M.) programs. The important role of the green lacewing, *Ch. carnea* as an effective predator against aphids species was confirmed by many authors such as: Driesche *et al.* (1987); Ushchekov (1989) and Gurr *et al.*, (2012), and was considered also as an important component of Integrated Pest Management programs (Rashid *et al.*, 2012). An observed increase was recorded in percentage of surveyed all predatory species (*Ch. carnea* & Coccinellidae) which was evaluated as 5.77% and also an increase in percentage of *Ch. carnea* only per season which was estimated as 22.22%, while this increase was evaluated as 68.83% after 3 weeks from released time (in 21/2/2024) (Tables, 3&4). This increase in total numbers of the predator, *Ch. carnea* was due to releasing process, where it was successively reproduced after its release.

Table 4: Effect of releasing second instar predatory larvae of *Ch. carnea* on percentages of aphids individuals' reduction and on the percentages of occurrence of predatory species, in barley field during season 2023/2024, in Qalubia Governorate.

Period	Unreleased area				Released area			
	Total		Mean total (range)		Total		Mean total (range)	
	Aphids	Predatory species	Aphids	Predatory species	Aphids	Predatory species	Aphids	Predatory species
Before releasing	6076 (0-2101)	27 (0-20)	868.00±350.12 (8-2101)	4.29±2.97 (0-20)	5371 (8-1856)	38 (0-29)	767.29±308.59 (8-1856)	6.00±4.25 (0-29)
After releasing	6705 (69-2138)	117 (9-36)	957.86±342.37 (69-2318)	25.42±3.72 (9-36)	1426 (10-801)	144 (1-72)	203.71±110.69 (10-801)	25.43±10.06 (1-72)
- The mean reduction percentage of aphids' individuals per season was estimated as 46.82% and the mean percentage of reduction was evaluated as 90.01% after 3 weeks from releasing predatory second instar larvae of <i>Ch. carnea</i> . - The increase in percentage of recorded total numbers of surveyed all predatory species (<i>Ch. carnea</i> & coccinellidae) per season was recorded as 5.77% . While, the increase in percentage of recorded total numbers of the predator, <i>Ch. carnea</i> individuals per season was estimated as 22.22% , while this increase was evaluated as 68.83% after 3 weeks from released time (in 21/2/2024).								

5. Effect of releasing predatory larvae of *Ch. carnea* on resulted barley crop.

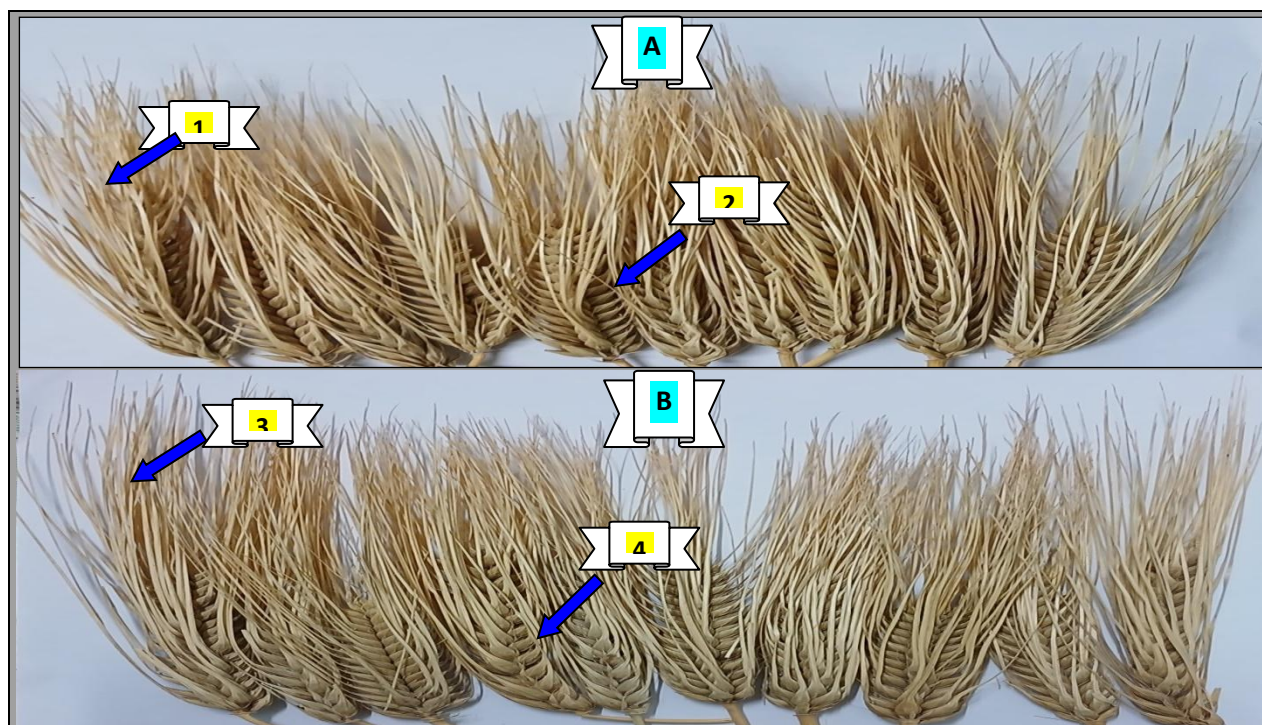
5.1. Means calculations of barley spikes length with no terminal hairs or with terminal hairs (cm.) and also estimation of their total spikes weight (gm.).

Means Calculations of barley spikes length with no terminal hairs or with terminal hairs (cm.) and also estimation of its total spikes weight (gm.), after 106 days post barley planting were shown in Table (5) and Figure (8).

Table 5: Measurements of barley spikes length with no terminal hairs or with terminal hairs (cm.) and also the estimation of their total spikes weight (gm.) after 106 days post barley planting.

Tested groups	Unreleased area			Released area		
	Mean total length (cm.)/spike		Total spikes weight (gm.)	Mean total length (cm.)/spike		Total spikes weight (gm.)
	No terminal hairs	With terminal hairs		No terminal hairs	With terminal hairs	
Group 1	8.34* (7.5-10.2)	19.30 (15-21.5)	338 (13.52**)	9.12 (8.5-9.6)	20.10 (19-22)	498 (19.92)
Group 2	9.14 (8.5-10.5)	21.20 (20-23)	340 (13.60)	9.20 (8.5-10)	20.50 (18.5-23)	380 (15.20)
Group 3	8.10 (7-9.5)	19.50 (16-22)	450 (18.00)	9.60 (9-10)	20.20 (18.5-23)	500 (20.00)
Group 4	8.60 (7-10.5)	19.60 (16.5-23.5)	380 (15.20)	8.90 (8.5-10)	21.60 (20-23)	550 (22.00)
Group 5	7.94 (6.5-9.5)	20.20 (16.5-23)	320 (12.80)	9.10 (8.5-10)	21.90 (19.5-23.5)	450 (18.00)
Means of all groups $\pm$ S.E	8.42 $\pm$ 0.24 (7.94-9.14cm.)	19.96 $\pm$ 0.47 (19.30-21.20cm.)	14.62 $\pm$ 0.93 (12.80-18.00gm.) (mean total 365.60 $\pm$ 23.27 (320-450gm.))	9.18 $\pm$ 0.11 (8.90-9.60cm.)	20.86 $\pm$ 0.32 (20.10-21.90cm.)	19.02 $\pm$ 1.15 (15.20-22.00gm.) (mean total 475.60 $\pm$ 28.66 (380-550gm.))

Note: * = representing a mean total of 5 spikes. ** = representing a mean total of one spike.



A= Spikes with terminal hairs that were formed in unreleased area:

1- Shorter terminal hairs of spikes. 2- Smaller size of barley spikes.

B= Spikes with terminal hairs that were formed in released area:

3- Taller terminal hairs of spikes 4- Larger size of barley spikes.

Fig. 8: Spikes of barley crop yield that was formed after 106 days post barley planting.

Means total length (cm.) per one spike for those of no terminal spikes hairs or with terminal spikes hairs for all five tested groups were; 8.42 $\pm$ 0.24 (7.94-9.14cm.) & 19.96 $\pm$ 0.47

(19.30-21.20cm.), (for unreleased area) and 9.18 $\pm$ 0.11 (8.90-9.60cm.) & 20.86 $\pm$ 0.32 (20.10-21.90cm.), (for released area). Means total spike weight (gm.) for all five tested groups were;

14.62±0.93 (12.80-18.00gm.), with a mean total of 365.60±23.27 (320-450gm.) and 19.02±1.15 (15.20-22.00) gm., with a mean total of 475.60±28.66 (380-550gm.)), respectively. Results obtained revealed that, there were an increase in both means total length (cm.) per one spike for those of no terminal hairs or with terminal hairs and also means total spike weight (gm.) for all five tested groups, indicating that, releasing second instar larvae of *Ch. carnea* has decreased the infestation degree caused by cereal aphids. Therefore, this situation improved barley plants development, which were directly positively reflected by increasing investigated

resulted yield crop cases in released area in comparing with those of unreleased one.

5.2. Means calculations of total numbers of spike's grains, besides total weight of grains and also estimating percentages of newly grains germination of resulted barley crop.

From Table (6) and Figures (9&10), mean total numbers of grains per one spike, total weight of 100 grains and percentages of newly barley grains germination (after 72 hours) for all five tested groups were; 59.04±1.41grains (56.40-62.40 grains) & 5.74gm. (5.00-7.00 gm.) and 76.00% (65.00-90.00%), respectively (for unreleased area).

Table 6: Means calculations of total numbers of barley grains per spike, total weights of them and also the estimation of the percentages of newly grains germination of resulted barley crop after 106 days post barley planting.

Tested groups	Unreleased area			Released area		
	Mean total no. of grains/one spike	Total weight of 100 grains	% newly grains germination	Mean total no. of grains/one spike	Total weight of 100 grains	% newly grains germination
Group 1	62.40* (54-72)	6.00**	65.00***	66.80 (62-74)	6.70	90.00***
Group 2	57.60 (54-66)	5.50	90.00	67.20 (62-78)	6.09	90.00
Group 3	61.20 (54-72)	7.00	80.00	70.80 (66-72)	6.00	85.00
Group 4	58.80 (54-72)	5.18	75.00	64.80 (60-72)	7.00	80.00
Group 5	56.40 (48-66)	5.00	70.00	69.60 (64-78)	6.13	85.00
means of all groups ±S.E	59.04±1.41grains (56.40-62.40)	5.74gm. (5.00-7.00)	76.00% (65.00-90.00%)	67.84±1.01grains (66.80-70.80)	6.38gm. (5.00-7.00)	86.00% (80.00-90.00%)

Note: * = representing a mean total number of grains of each spike. ** = representing a total of 100 grains. *** = representing a percentage of grains germination for 20 grains.

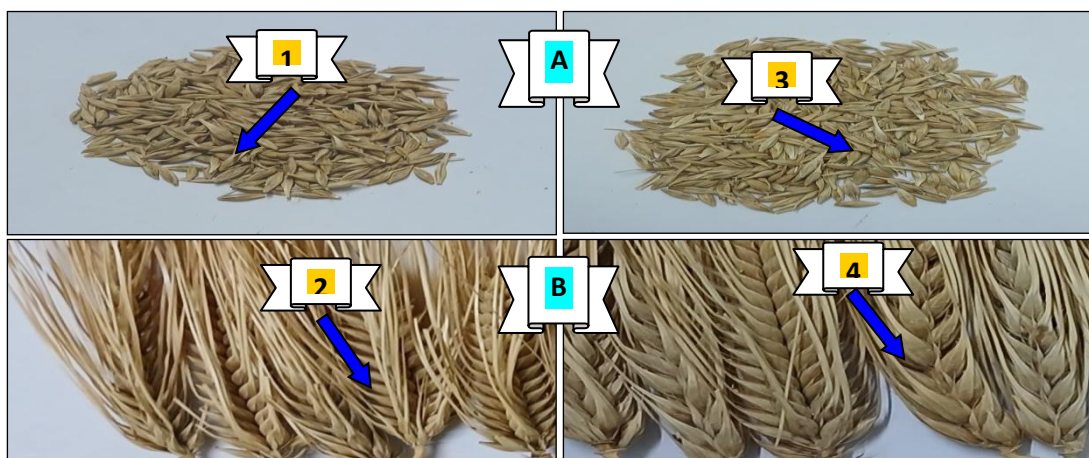


Fig. 9: newly grains of resulted barley crop that was formed in both unreleased and released areas.

A= Grains that were formed in unreleased area.

1- Less total numbers of grains. 2- Smaller size of grains.

B= Grains that were formed in released area.

3- More total numbers of grains. 4- larger size of grains.

The respective for released area were; 67.84 ± 1.01 grains (66.80-70.80 grains) & 6.38gm. (5.00-7.00 gm.) and 86.00% (80.00-90.00%). In comparing unreleased area with released one, an increase in mean total numbers of grains per one spike, total weight of 100 grains and percentages of newly barley grains germination (after 72 hours) for all five tested groups, indicating that, releasing second instar larvae of *Ch. carnea* has been decreased the infestation degree caused by cereal aphids. So,

as a result, an improvement of plant development was happened and achieved, followed by an increase in the three tested factors in released area compared with unreleased one. This finding with in accordance with that found by Sarwar (2014) who demonstrated that, releasing first and second instars larvae of *Ch. carnea* were more effective that increased crop yields compared with unreleased one in Canola field.



A= Unreleased area

B- Released area

Fig. 10: Newly grains of barley crop yield after 106 days post planting that was germinated after 72 hours.

6. Statistical analysis of obtained data:

6.1. Correlations recorded in barley field experiment (by comparing means values).

The data shown in Table (7), after 106 days post planting, in comparing unreleased and released areas, statistical analysis of obtained data revealed positive moderate significant relationships in case of comparing: total numbers of aphids individuals (adults & nymphs), total numbers of parasitoid mummies,

total numbers of total predatory species and total numbers of *Ch. carnea* (adults & larvae) (r-values were; 0.0.767**, 0.792**, 0.638** and 0.708**, respectively). A highly positive significant relationship was obtained only in case of total numbers of emerged *A. matricariae* parasitoid (r-value was 0.841***) and also a positive significant relationship was obtained in case of Coccinellidae predatory species (r-value was 0.508*).

Table 7: Correlations that were existed in barley field experiment (by comparing means).

Tested factors	Correlations (r-values)
A- Aphids individuals (adults & nymphs).	0.0.767**(significant=0.001)
B- Parasitoid mummies.	0.792**(significant=0.001)
C- The parasitoid, <i>A. matricariae</i> .	0.841*** (significant=0.000)
D- Predatory species.	0.638** (significant=0.014)
1- <i>Ch. carnea</i> .	0.708** (significant=0.005)
2- Coccinellidae.	0.508* (significant=0.064)
E- Resulted barley crop yield after 106 days post planting.	
1- Total numbers of barley grains.	0.375 (significant=0.065)
2- Length of spikes with no terminal hairs.	0.298 (significant=0.148)
3- Length of spikes with terminal hairs.	0.010 (significant=0.964)
4- Weight of barley grains.	0.459 (significant=0.436)

• Significant r-values (0.500-0.600) **Moderate significant (0.600-0.800) ***Highly significant (0.800-0.900) ****Very highly significant>0.900.

As for resulted barley crop yield, no relationships were observed in comparing: total numbers of barley grains, length of spikes with no terminal spikes hairs, length of spikes with terminal spikes hairs and weight of barley grains (r-values were; 0.375, 0.298, 0.010 and 0.459, respectively).

6.2. Effect of temperature and relative humidity on some tested ecological factors.

Natural relationships that were existed (in unreleased area of barley experiment), between total numbers of aphids individuals (adults & nymphs), total numbers of parasitoid mummies, total numbers of emerged *A. matricariae* parasitoid, total numbers of predatory species, total numbers of *Ch. carnea*, total numbers of Coccinellidae predators and some weather factors (including; means of temperature and relative humidity), during season, 2023/2024 (in Qalubia Governorate), were shown in Table (8).

Table 8: Natural relationships between aphids individuals, total numbers of aphids mummies, predatory species and weather factors (including temperature and relative humidity), in unreleased area of barley field during season, 2023/2024.

Tested factors	Tested factors × means of temp.(C°)	Tested factors × means of R.H. %
1- Aphids individuals	r = -0.232 (significant=0.425)	r = 0.277 (significant=0.339)
2- Parasitoid mummies.	r = -0.419 (significant=0.136)	r = 0.361 (significant= 0.204)
3 – The parasitoid, <i>A. matricariae</i> .	r = -0.464 (significant=0.095)	r = 0.398 (significant= 0.158)
4 – Predatory species.	r = 0.418 (significant=0.137)	r = -0.110 (significant=0.708)
a- <i>Ch. carnea</i> .	r = 0.271 (significant=0.348)	r = 0.010 (significant=0.973)
b- Coccinellidae.	r = 0.526*(significant=0.053)	r = -0.299 (significant=0.299)

* Significant.

6.2.1. Relationships between many ecological factors and means of temperature.

The relationships between; total numbers of aphids individuals (adults & nymphs), total numbers of parasitoid mummies, total numbers of emerged *A. matricariae* parasitoid, total numbers of total predatory species and total numbers of *Ch. carnea* and means of temperature were insignificant (where, r-values were; -0.232, -0.419, -0.464, 0.418 and 0.271, respectively). But, the relationship was positive in case of Coccinellidae predators (where, r-value was 0.526*).

6.2.2. Relationships between many ecological factors and means of relative humidity.

There were not any significant relationships were obtained between; total numbers of aphids individuals (adults & nymphs), total numbers of parasitoid mummies, total numbers of emerged *A. matricariae* parasitoid, total numbers of total predatory species and total numbers of *Ch. Carnea*, Coccinellidae and means of relative humidity (r-values were; 0.277, 0.361, 0.398, -0.110, 0.010

and -0.299), respectively). Thus, obtained results indicate that, relationships between tested ecological factors and means of temperature and relative humidity may be positively or negatively correlated. However, Nechols *et al.* (1999) revealed that, meteorological conditions significantly affect on insect occurrence and their distribution.

CONCLUSION

In conclusion, from present study, barely was firstly cultivated in these tested experimental Egyptian areas (in Delta region), where it was not cultivated there before. So, it was considered as an attempt that can help to cultivate barley successfully and intensively, which is an important strategy cereal crop, to increase the national Egyptian agricultural carbohydrate food source which will result in reducing the gap between the consumption and production. Where, barley can be cultivated together side by side with wheat (with presented cultivation areas), to decrease the external importation process and also the heavy need to

external demand on wheat with its highly payment costs, In similar findings, Neelhirajan *et al.* (2007) stated that, barley represents the most important source of required carbohydrates. Besides, Mariey *et al.* (2021) revealed that, barley was indicated as a chief cereal crop that has well improved to numerous abiotic stresses in dry areas. It was found to have the ability to tolerant drought stress and restricted irrigation amount of water. Moreover, results also supported the natural role of the parasitoid, *A. matricariae*, where magnifying its role must be taken in consideration and with predatory species recorded of Coccinellidae, in integration with mass laboratory rearing and field release of second instar predatory larvae of *Ch. carnea*, that will be surely important in field of biological control of cereal aphids. Thus, they can be strongly applied in planning effective biological control techniques in frame of Integrated Pest Management programs, to reduce the use of harmful insecticides. Where, Boivin *et al.* (2012) stated that, aphids parasitoids are commonly used in biological control programs in greenhouses and field situations Also, many authors support the role of mass rearing and releasing the predator, *Ch. carnea* such as: Singh & Varma (1986); Burgio *et al.* (1997); El-Arnaouty *et al.* (2000); Medina *et al.* (2002); El-Heneidy *et al.* (2006); Pappas *et al.*, 2007; Turquet *et al.* (2009) and Ragsdale *et al.* (2011).

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