International Journal of Agriculture, Environment and Food Sciences

JAEFS

e-ISSN : 2618-5946

DOI: 10.31015/jaefs.2020.4.18

www.jaefs.com

Research Article

Int J Agric Environ Food Sci 4 (4): 528-536 (2020)

Numerical response of green lacewing *Chrysoperla carnea* on different preys (*Aphis fabae* and *Acyrthosiphon pisum*)

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Abstract

Aphids can caused significant economic losses in agricultural productions because they have the ability of fast reproduction. In other hand, they are vector of several plant diseases and viruses. Therefore, in the scope of biological control studies, it is important to reveal the numerical responses of the species to determine the effect of green lacewing predator acting on aphids. In this study, the numerical response of *Chrysoperla carnea* on two aphids (*Aphis fabae* and *Acyrthosiphon pisum*) was tested, and the reproductive abilities of the green lacewing were determined. In the experiments, aphids at different densities (5, 10, 20, 40, 80 and 160) were offered to the development periods of the predator insect separately, and their development was recorded. The experiments were carried out in the laboratory at 26±1°C and 60±5% Relative Humidity (RH). The development of predator, fecundity and numerical response parameters (Efficiency of Conversion of Ingested Food (ECI), Prey Usage Efficiency) were significant differences according to prey density. Finally, the ECI values were 142.15, 160.58, 184.99, 213.91, 229.48 and 199.44 for *C. carnea* fed on *A. fabae*, respectively; and 146.43, 173.09, 200.05, 214.04, 226.01 and 205.26 for *C. carnea* fed on *A. pisum*, respectively.

Keywords: *Chrysoperla carnea,* Green lacewing, *Acyrthosiphon pisum, Aphis fabae*, Numerical response

Introduction

The family of Chrysopidae, which are distributed worldwide, is predator of aphids, thrips, and whiteflies (Ridgway and Jones, 1968; McMurtry et al., 1970; Jeppson et al., 1975; Mansell, 1983; Stark and Whitford, 1987). The Chrysopidae family is important in all and biological control studies because their presence in the natural ecosystem, ease of production in the laboratories and the field for scientific studies, and they have high search and consumption power to the pests mentioned above (Jeppson et al., 1975; Obrycki et al., 1989; Bozsik, 1995). *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) is a very common polyphagous species and observed in field and agricultural areas (McMurty et al., 1970; Jeppson et al., 1975; Varma and Shenhmar, 1983; Stark and Whitford, 1987; Jokar and Zarabi, 2012). Green lacewing plays an important role as a biological control agent in greenhouses and the fields (Venkatesan et al., 1997). The larvae of *C. carnea* start feeding after hatching immediately on a wide range of pests. *C. carnea* has fed on lepidopteran larvae, mites, mealybugs, crustaceans, thrips, aphids and whiteflies mature and nymph stages (Lingren et al., 1968; Ridgway and Jones, 1968; Lingren and Green, 1984; Hagley and Miles, 1987; Syed et al., 2005; Sattar et al., 2007; Sattar, 2010; Jokar and Zarabi, 2012; Batool et al., 2014).

From the literature, aphids cause economic losses on the different plant families in the field and need to be controlled. They cause damage to plants into two directions, first, the direct damage by feeding on host plants and the second by indirect damage transmission of plant viruses. The aphid can produce high reproduction in short time and chemical pesticides are

Cite this article as:
Kayahan, A. (2020). Numerical response of green lacewing *Chrysoperla carnea* on different preys (*Aphis fabae* and *Acyrthosiphon pisum*). Int. J. Agric. Environ. Food Sci., 4(4), 528-536.
DOI: https://doi.org/10.31015/jaefs.2020.4.18
ORCID: Ali Kayahan: 0000-0002-3671-254X
Received: 03 July 2020 **Accepted:** 18 November 2020 **Published Online:** 22 December 2020
Year: 2020 **Volume:** 4 **Issue:** 4 (December) **Pages:** 528-536
Available online at : http://www.jaefs.com - http://dergipark.gov.tr/jaefs

intensively used to control (Lodos, 1982; Catherall et al., 1987; Kovalev et al., 1991; Elmalı and Toros, 1994). Some control methods have not negative effects on nature and human health should be emphasized to avoid the negative effects of these chemicals. For this reason, it is very important to find alternative way to control aphids, the numerical response of the species to determine the potency of green lacewing *C. carnea*, for the effective way against aphids and also subjected of this study.

Materials and Methods

Production of Broad Bean (*Vicia faba*)

The Broad beans were used as host plants in the experiment. The plants were grown in the production room under controlled conditions 26±1ºC and 60±5% Relative Humidity (RH) at the Plant Protection Department, Agriculture Faculty, Yozgat Bozok University. For this purpose, broad bean seeds were planted to in the small plastic pots (1 liter) and paper cups filled with soil mixture (1:1:1 ratio of soil: peat: perlite mixture) and seedlings were left under the light conditions (16L: 8D) after grown. When the height of the cultivated plants became suitable (4-6 leaves) for the infestation of aphid and left to let the aphid reproduction for two days, they which were used in this experiment. The experiment was repeated periodically as long as the experiments continued. The aphid cultures were weekly maintenance on the plants.

The Culture of Aphids (*Aphis fabae* and *Acyrthosiphon pisum*)

In this study, *Aphis fabae* and *Acyrthosiphon pisum* individuals were used as food for *Chrysoperla carnea* predator that were obtained from Biological Control Research and Application Center, Faculty of Agriculture, Isparta University of Applied Sciences and mass production was carried out at the Plant Protection Department, Agriculture Faculty, Yozgat Bozok University. The broad beans were reared in cages (50x50x50 cm) in the controlled environment 26±1ºC and 60±5% Relative Humidity at the Plant Protection Department, Agriculture Faculty, Yozgat Bozok University. The host plants were infested with both species of aphid *A. fabae* and *A. pisum*.

The Culture of *Chrysoperla carnea*

The predator green lacewing *Chrysoperla carnea* that used in the study were collected from clover fields around Isparta and Yozgat in Turkey by using net and mouth aspirator. The collected predator were brought to the laboratory and then placed in plastic containers covered with tulle cloth. The predator was feed on yeast extract + honey + water mixture and was placed in containers (Kişmir and Şengonca, 1981; Tireng et al., 1999). The tulle cloths were replaced with strips cloth piece to let *C. carnea*'s females laying eggs. All experiments were carried out in cages at laboratory conditions 26±1ºC and 60±5% Relative Humidity.

Numerical Response Trials

The experiment was conducted in the laboratory after the predator was laid eggs in mass-produced. The larvae of green lacewing were located into separate petri dish (one larva per petri-dish) after emerged. A number of aphids (5, 10, 20, 40, 80, and 160) at 2nd and 3rd nymph's stage were given to each larva in per petri dish. The number of aphids were consumed by the larva and recorded every day and the missing of aphid number was added. The experiment was continued until the predator became pupa, and then emerged to the adult. The male and female of predators were marked separately by using the paint that does not damage the insect body according to the number of preys given per petri-dish. Marked predators were mating in petri-dish and after one day were placed into separate petri dish. The new predator was feed on the different number of aphids according to the literature; while the number of eggs that laid by predator was recorded. Numerical response trials were arranged separately for each period and consist of 50 repetitions. The experiments were carried out at the laboratory conditions which were 26±1ºC and 60±5% Relative Humidity.

Numerical response data were calculated using depends on the equation of Holling (1959) and graphics were arranged. In addition, the relationship between the number of eggs left by the predator and different prey densities were described on graphics. The experiment was conducted in a completely randomized design (CRD). The numerical response of predatory larvae of green lacewing to various prey densities of two species of aphids was express by fitting the data to the Omkar and Pervez (2004) and Omkar and Kumar (2013) equations.

ECI (Efficiency of Conversion of Ingested Food) =(Number of eggs laid)/(Number of consumed food) ×100 (Omkar and Pervez, 2004).

Prey Usage Efficiency(%)=(Number of consumed food)/(Number of preys given) ×100 (Omkar and Kumar, 2013).

Statistical Analysis

SPSS (Ver. 17), Minitab (Ver. 16) programs were used in the statistical analysis of the data that obtained from the numerical response of the predator in laboratory studies. Using the data that obtained to calculate the life table parameters of varying prey densities of the predatory insect were obtained. The age-related life table of the predator on two different foods were created based on the Euler-Lotka equation ($\sum e^{(-rm.x)}.lx.mx=1$) (Birch, 1948). All parameters were calculated using the RmStat-3 (Özgökçe ve Karaca, 2010). The data were subjected to the Tukey multiple comparison test in order to compare the results of the trials.

Results and Discussion

The results indicated that the numerical response values of *Chrysoperla carnea*, increased on two different aphid species (*A. fabae* and *A. pisum*) with different densities (5, 10, 20, 40, 80 and 160) that given to each development instar of *C. carnea*. It was observed that the amount of consumption increased as the density of aphids increased in all larval periods of *C. carnea* feed on *A. fabae*. Similarly, the results showed that increased in consumption of aphids by green lacewing between different instars feeding at the same number of aphids that given to the green lacewing. Moreover, the total of consumption number of aphids decreases when the number of prey density was low ($F_{Instar1}$:841.98; $P_{Instar1}$:0.001 / $F_{Instar2}$:1931.32; $P_{Instar2}$:0.001 / $F_{Instar3}$:3311.71; $P_{Instar3}$:0.001 / F_{Total}:174.02; P_{Total}:0.001). From

the results obtained from this study observed that the amount of consumption was increased as the aphids density increased in all larval instars of *C. carnea* feeding on *A. pisum*. The prey consumption rate increased with rise of aphids number such as the 1st instar of green lacewing consumption rate 14.89 while the 3rd instar consumption was 52.85 when gave 160 aphids per instar. The predicted number of aphids eaten when 80 were given was 12.63 for the 1st instar of green lacewing and 44.39 for the initial 80 aphids for the 3rd instar of the predator, while, the lowest initial prey density 5 and 10 aphids the 1st instar of *C. carnea* was 4.70 and 4.99 respectively of offered 5 aphids and 8.53 and 9.99 respectively of offered 10 aphids from the species *A. fabae*. The results showed the cumulative consumption of green lacewing feeding on *A. pisum* density at different number of aphids that no significant consumption rate between 1st, 2nd and the 3rd instars 4.70 when offered 5 aphids while there was a significant consumption rate when offered 80 and 160 prey number (Table 1). When the total consumption rate determined the consumption was the highest prey density, while consumption decreases when the prey density decreases. In addition, a statistical similarity was observed between 80 and 160 preys in the second larval period and total consumption ($F_{Instar1}$: 1222.81; $P_{Instar1}$: 0.001 / $F_{Instar2}$: 2657.66; $P_{Instar2}$: 0.001 / $F_{Instar3}$: 5453.36; $P_{Instar3}$: 0.001 / F_{Total}: 183.69; P_{Total}: 0.001) (Table 1).

Table 1. Daily consumption amounts of different biological periods of Chrysoperla carnea on Aphis fabae and Acyrthosiphon pisum

Biological stages	Prey Densities (*Aphis fabae*)					
	5	10	20	40	80	160
Instar1	4.70±0.037 f	8.53±0.077 e	11.70±0.104 d	14.07±0.200 b	12.63±0.112 c	14.89±0.203 a
Instar2	5.00±0.000 f	9.79±0.42 e	16.34±0.131 d	21.76±,0.221 c	29.68±0.253 b	33.09±0.439 a
Instar3	4.99±0.007 f	9.99±0.011 e	19.26±0.060 d	33.33±0.310 c	44.39±0.387 b	52.85±0.557 a
Total	52.76±3.22 f	102.44±6.43 e	169.70±11.00 d	291.00±10.30 c	379.80±12.70 b	435.50±19.60 a
Biological stages	Prey Densities (*Acyrthosiphon pisum*)					
	5	10	20	40	80	160
Instar1	4.54±0.039 e	8.62±0.058 d	11.16±0.094 c	13.06±0.154 b	12.75±0.126 b	14.35±0.116 a
Instar2	5.00±0.000 e	9.73±0.034 d	15.38±0.133 c	22.39±0.189 b	30.38±0.309 a	31.04±0.294 a
Instar3	5.00±0.005 f	10.00±0.005 e	19.16±0.075 d	36.60±0.205 c	44.93±0.358 b	50.38±0.412 a
Total	54.12±3.01 e	106.42±5.56 d	167.20±10.30 c	303.60±10.10 b	378.60±13.70 a	410.10±16.80 a

Different letters on the same line show that there is a statistically differences between the averages according to the Tukey test ($p<0.05$).

In this study, the prey was used to determine the efficiency of *C. carnea* on two different aphids and according to the calculation made in the equation of Omkar and Kumar (2013), the low-density preys were consumed all by different stages of predator instars, while high-density preys were consumed less because they were high number than the predator can eat (Figure 1).

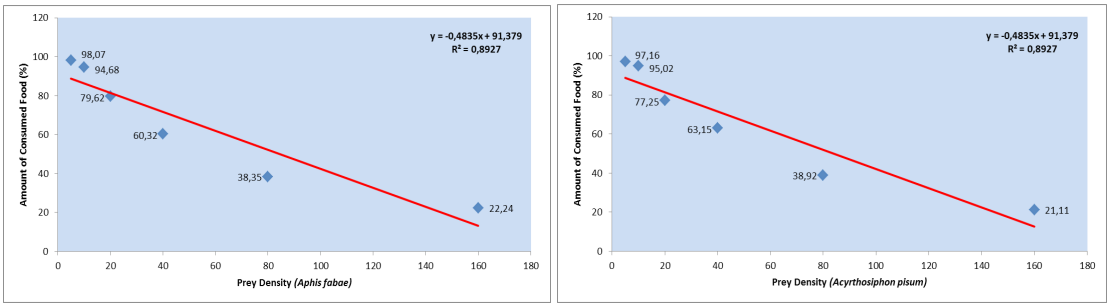

Figure 1. Amount of consumed food on different prey at different prey densities

Atlıhan et al. (2004) indicated that offered different number of prey which were 5, 10, 20, 40, 80, 180 and 250 of *Hyalopterus pruni* (Hemiptera: Aphididae) as food; the amount of consumed rate were calculated as 55.8, 92.7, 134.6, 215.9, 341.6, 411.3 and 404.9 respectively in the pre-adult periods according to prey densities. Similar to our results that were obtained for both preys and their densities. Batool et al. (2014) provided *Citotroga cerealella* (Lepidoptera: Gelechiidae) eggs to *C. carnea* in different densities which were 20, 30, 40, 50, 60, 70, 80, 90 and 100 to determine the consumption rate that increased with increasing prey density. Although the preys given to the predator were different in our study, it has the same results compared with the literature. El Zahi (2017) was used *Aphis gossypii* as a food for *C. carnea* regardless of prey density and determined the prey consumption amounts of the predator. According to our data that obtained from the

experiment, showed that the amount of consumption rate increased as the periods of larvae developed (Table 1). In our study, a similar result is noticeable at the highest density of both preys (*A. fabae* and *A. pisum*) compared with other studies. Rana et al. (2017) were used different preys (*Aphis craccivora*, *Myzus persicae* and *Aphis fabae*) as food for *C. carnea* regardless of prey density and calculated the average number of preys consumed in pre-adult periods. And their data that obtained from their study similar results with our study.

On the other hand, the eggs that given by the female of predator *C. carnea* fed on different preys at different prey densities were recorded. Accordingly, the number of eggs that given by the predator increased when feed on both of aphid species and the number of eggs depending on the prey density; it was shown that egg number decreased slightly when offer 160 prey density. The results indicated that the number of eggs laid by the predator fed on *A. fabae* was calculated and recorded 75, 164.5, 314, 622.6, 871.5 and 868.5, respectively depended on the prey density; and also the number of egg laid by predator were counted when *C. carnea* fed on *A. pisum* and the number of eggs were 79.3, 184.2, 334.4, 649.9, 855.7 and 841.8, respectively (Figure 2).

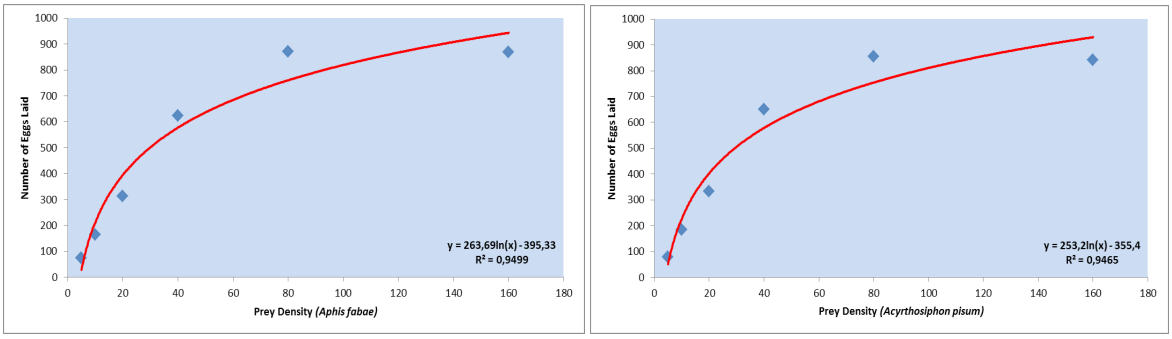

Figure 2. Number of eggs laid by *Chrysoperla carnea* on different preys at different prey densities

ECI (Efficiency of Conversion of Ingested Food) rate were determined based on the data obtained after calculated the number of eggs that laid by the predator fed on different preys at different densities depended on the number of preys that consumed. Omkar and Pervez (2004) equation was used to calculate the number of eggs that laid by *C. carnea* after offered different number of aphids from both species (R^2= 0.8486 for *A. fabae* and R^2= 0.7321 for *A. pisum*). According to the statistical analyzes, the results determined that ECI rate increased depending on the increasing of prey density (Figure 3). Khan and Zaki (2008) referred to the functional and numerical response of *C. carnea* (Stephens) on *Aphis fabae solanella* and when the numerical response data were analyzed, it was determined that there was a linear rised in the graph that created based on the density of the aphid. However, our data which obtained were agreed with Khan and Zaki (2008) results.

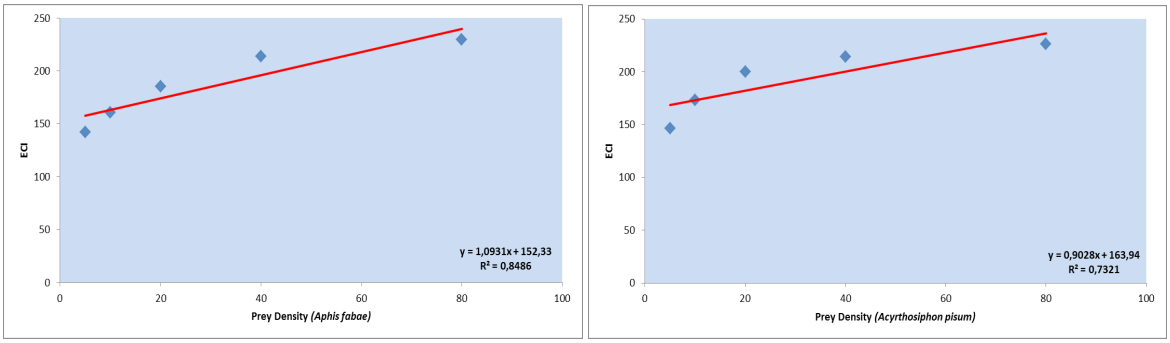

Figure 3. Values of ECI of *Chrysoperla carnea* on different preys at different prey densities

Whereas, the immature stages of adult development times and life table parameters of *C. carnea* were calculated depending on the prey and their density. The results indicated that the pre-adult development times of the predator fed on *A. fabae,* the total development time decreased with the increase significantly in prey density (F_{Total}: 6.40; P_{Total}: 0.001). There is no statistical difference among the development periods of predator (eggs, instar1, instar 2, instar3 and pupa), while a difference significant was observed in the second instar depending on the aphids density of *A. fabae* (F_{Egg}: 0.21; P_{Egg}: 0.960) ($F_{Instar1}$: 0.35; $P_{Instar1}$: 0.879) ($F_{Instar2}$: 3.30; $P_{Instar2}$: 0.007) ($F_{Instar3}$: 2.13; $P_{Instar3}$: 0.063) (F_{Pupa}: 3.17; P_{Pupa}: 0.015) (Table 2). The results determined that the total development time for *A. pisum* decreased with the increase statistically significantly in prey density (F_{Total}: 5.52; P_{Total}: 0.001). Besides, the values obtained from development periods were shown in Table 2 (F_{Egg}: 0.22; P_{Egg}: 0.955) ($F_{Instar1}$: 0.28; $P_{Instar1}$: 0.921) ($F_{Instar2}$: 4,97; $P_{Instar2}$: 0.001) ($F_{Instar3}$: 2.57; $P_{Instar3}$: 0.028) (F_{Pupa}: 3.65; P_{Pupa}: 0.007).

Table 2. Development times of immature stages of *Chrysoperla carnea* on different preys and different prey densities

P.D.	Development Times (Day) on *Aphis fabae*											
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Pupa	N	Total
5	45	3.38±0.07 a	45	3.47±0.11 a	35	4.63±0.18 a	34	4.94±0,15 a	3	10.33±0.33 a	3	28.67±0.33 a
10	44	3.34±0.07 a	44	3.39±0.12 a	34	4.44±0.21 ab	33	4.73±0.18 a	4	10.25±0.48 a	4	28.25±0.25 a
20	45	3.33±0.07 a	45	3.31±0.11 a	35	4.29±0.20 ab	34	4.71±0.18 a	5	9.60±0.51 a	5	27.00±0.45 ab
40	39	3.41±0.09 a	39	3.28±0.14 a	39	3.80±0.21 b	39	4.41±0.16 a	9	8.89±0.54 a	9	26.00±0.65 ab
80	37	3.41±0.09 a	37	3.32±0.14 a	37	3.95±0.17 ab	37	4.32±0.21 a	16	8.13±0.36 a	16	24.81±0.43 b
160	36	3.42±0.09 a	36	3.28±0.14 a	36	3.83±0.17 b	36	4.25±0.21 a	15	8.13±0.39 a	15	24.80±0.46 b
P.D.	Development Times (Day) on *Acyrthosiphon pisum*											
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Pupa	N	Total
5	46	3.37±0.07 a	46	3.39±0.11 a	37	4.65±0.78 a	34	4.95±0,14 a	3	9,75±0.25 ab	3	27.50±0.87 ab
10	44	3.34±0.07 a	44	3.23±0.13 a	37	4.49±0.17 ab	33	4.46±0.18 a	4	10.00±0.32 a	4	27.80±0.58 a
20	45	3.36±0.07 a	45	3.24±0.11 a	37	4.24±0.19 abc	34	4.69±0.17 a	5	9.60±0.51 ab	5	27.00±0.45 abc
40	40	3.33±0.08 a	40	3.25±0.14 a	40	3.73±0.19 c	39	4.33±0.20 a	9	8.83±0.44 ab	9	25.75±0.57 abc
80	36	3.42±0.09 a	36	3.22±0.13 a	36	3.86±0.15 bc	37	4.17±0.22 a	16	7.94±0.37 b	16	24.38±0.47 bc
160	36	3.42±0.09 a	36	3.28±0.14 a	36	3.78±0.17 bc	36	4.17±0.22 a	15	8.00±0.35 ab	15	24.67±0.44 c

Different letters in the same column show a statistical difference between the averages according to the Tukey test ($p<0.05$). (N: Number of individuals, P.D.: Prey Densities)

Atlıhan et al. (2004) were offered *Hyalopterus pruni* (Hemiptera: Aphididae) to *C. carnea* at different densities (5, 10, 20, 40, 80, 180 and 250) in their study and the results of development times of immature stages of predator were recorded according to their prey density. There was no significant difference on the 1st instar, 3rd instar and pupa periods in terms of development times according to their data that obtained, and the total of development times were decreased as the prey density increased. Batool et al. (2014) were given *Citotroga cerealella* to *C. carnea* in their study and they determined that the immature stages of development period of *C. carnea* were shortened due to the prey density. Similar results were observed in our experiment for both aphid species compared with the past literature. Alghamdi and Sayed (2017) were calculated the immature stages of development times of *C. carnea* fed on *A. fabae* and *Ephestia kuehniella* depend on prey density. According to the data, the immature stages (1st instar, 2nd instar, 3rd instar and pupa) and the total development times of *C. carnea* fed on *A. fabae* were 3.50, 5.00, 6.63, 10.63 and 25.75 days, respectively. Our results showed that the development times of predator fed on both preys increased according to the periods and the total development times were similar to the past literature. Kasap et al. (2003) were used *Aphis pomi* and *Tetranychus urticae* as preys regardless of prey density, and determined that larvae of predator were fed on *A. pomi* developed faster during the immature of development periods than fed on the mite *T. urticae* and more adult of predator were obtained. The development periods of *C. carnea* pre-adult periods (1st instar, 2nd instar, 3rd instar and pupa) and the total of development times of *C. carnea* fed on *A. pomi* were 3.08, 3.54, 4.72, 10.82 and 25.68 days, respectively. In our study, the results referred to the development times that obtained from fed on both aphid species were close to their finding. Takalloozadeh (2015) calculated the immature stages of development times and adult periods of *C. carnea* that feed on different aphid species (*Aphis gossypii*, *Myzus persicae*, *Aphis punicae*, *Aphis fabae*, and *Aphis craccivora*) based on the prey density. The development times of *C. carnea* larvae fed on *A. fabae* were (1st instar, 2nd instar, 3rd instar and pupa) and total development times were calculated 4.31, 3.75, 3.94, 10.34 and 22.35 days, respectively. This finding was agreed with the data in the previous literature compared with our finding.

The emerging values of *C. carnea* after adult periods were examined, and the duration of preoviposition and postoviposition days were calculated similarly in both preys and their densities. (For *A. fabae*= $F_{Preovipozitioon}$: 2.00; $P_{Preovipozition}$: 0.096 / $F_{Postovipozition}$: 0.07; $P_{Postovipozition}$: 0.996) (For *A. pisum*= $F_{Preovipozition}$: 2.76; $P_{Preovipozition}$: 0.028 / $F_{Postovipozition}$: 0.47; $P_{Postovipozition}$: 0.794). The oviposition times (day) were calculated, and determined that the time was increased with the increase of prey density (For *A. fabae*= $F_{Ovipozition}$: 80.27;

$P_{Ovipozition}$:0.001) (For *A. pisum*= $F_{Ovipozition}$: 94.16; $P_{Ovipozition}$: 0.001). The average daily number of eggs were determined at last two aphids densities (80 and 160) and a statistical difference was found compared to other aphid densities when *C. carnea* fed on *A. fabae* ($F_{D.N.E}$: 155.19; $P_{D.N.E}$: 0.001) (D.N.E: Daily Number of Eggs). The average daily number of eggs was determined in the last three aphid densities (40, 80 and 160) and a statistical difference was found compared to other aphid number that offered to *C. carnea* fed on *A. pisum* ($F_{D.N.E}$: 130.22; $P_{D.N.E}$: 0.001). The total average of eggs was determined at the last two prey denisties (80 and 160) and a significant difference was found compared to other prey densities when *C. carnea* was fed on *A. fabae* ($F_{T.N.E.}$: 261.45; $P_{T.N.E}$: 0.001) (T.N.E: Total Number of Eggs). The total avarage of eggs was determined at most in the last two prey densities (80 and 160) and a statistically significant difference was found compared to other prey densities when *C. carnea* was fed on *A. pisum* ($F_{T.N.E}$: 199.72; $P_{T.N.E}$: 0.001) (Table 3).

Table 3. Development times and number of daily and total eggs of adults of *Chrysoperla carnea* on different preys at prey densities

		Aphis fabae			*Acyrthosiphon pisum*		
	Prey D.	N	Mean±SE		N	Mean±SE	
Preoviposition times	5	3	7.67±0.88	a	4	7.50±0.50	a
	10	4	7.00±0.58	a	5	7.20±0.49	a
	20	5	6.00±0.45	a	5	6.00±0.45	a
	40	9	6.00±0.33	a	12	6.08±0.26	a
	80	16	6.06±0.23	a	16	6.06±0.23	a
	160	15	6.07±0.25	a	15	6.00±0.26	a
Oviposition times	5	3	17.33±0.67	c	4	17.50±0.50	c
	10	4	18.25±0.63	c	5	18.00±0.55	c
	20	5	22.20±0.66	c	5	22.00±0.55	bc
	40	9	26.78±0.55	b	12	25.83±0.64	b
	80	16	35.56±0.70	a	16	32.63±0.71	a
	160	15	35.47±0.74	a	15	35.53±0.74	a
Postoviposition times	5	3	3.00±0.00	a	4	3.25±0.25	a
	10	4	3.00±0.00	a	5	3.00±0.00	a
	20	5	3.00±0.00	a	5	3.00±0.00	a
	40	9	2.89±0.20	a	12	2.92±0.15	a
	80	16	2.94±0.11	a	16	3.00±0.13	a
	160	15	2.93±0.12	a	15	2.87±0.13	a
Daily number of eggs	5	3	2.69±0.32	d	4	2.79±0.27	d
	10	4	5.83±0.31	d	5	6.54±0.30	c
	20	5	10.11±0.41	c	5	10.81±0.37	b
	40	9	17.50±0.40	b	12	18.68±0.51	a
	80	16	19.62±0.41	a	16	19.20±0.44	a
	160	15	19.58±0.40	a	15	19.02±0.46	a
Total number of eggs	5	3	75.00±8.14	d	4	79.25±8.84	d
	10	4	164.50±8.01	d	5	184.20±8.18	d
	20	5	314.00±5.86	c	5	334.40±8.44	c
	40	9	622.56±9.59	b	12	649.90±20.10	b
	80	16	871.50±16.00	a	16	855.70±18.20	a
	160	15	868.50±18.30	a	15	841.80±18.70	a

Different letters in the same column and in the same parameter indicate a statistical difference between the averages according to the Tukey test ($p<0.05$). (D.:Densities; SE: Standart Error)

Atlıhan et al. (2004) stated indicated that different prey densities did not effect of *C. carnea*'s oviposition, postoviposition and total lifespan during feed on *Hyalopterus pruni*, while they calculated the number of eggs that given by adult females of predator increased at the high of prey density. In our study, it was observed that the duration of oviposition was increased when aphid density was increased for both preys, and preoviposition and postoviposition periods did not change. The total number of eggs increased daily depending on prey density. El Zahi (2017) determined that the number of eggs laid by females of *C. carnea* fed on *A. fabae* and *E. kuehniella* were 373.75 and 481.75, respectively; this finding was agreed with our study. It was found that predator fed on *A. fabae* can give more eggs than previous literature. Kasap et al. (2003) showed that calculated preoviposition, oviposition and postoviposition times of *C. carnea* females fed on *A. pomi* were 7.56, 45.22, 2.67 days, respectively. In our study, it was seen that these durations of preoviposition and postoviposition

were close to the both of preys with the highest prey density. The number of eggs left laid by *C. carnea* female was lower than the number of we obtained, but it was observed to be a close value to the finding (Kasap et al., 2003).

Life table parameters were calculated separately for both of preys at different prey densities according to Euler-Lotka equation. Predator fed on *A. fabae*, intrinsic rate of increase (r_m) were calculated and were 0.010, 0.041, 0.067, 0.103, 0.121 and 0.118 females/female/day at different prey densities; whereas, the predator fed on *A. pisum* the intrinsic rate of increase were 0.032, 0.052, 0.069, 0.112, 0.122 and 0.119 females/female/day, respectively (Table 4). The other values that obtained (R_0, T_0, GRR, λ) were increased depending on the increasing of prey density when all the data are examined, but these values decreased at 160 prey density (Table 4). Atlıhan et al. (2004) in their studies on *H. pruni*, it was determined that different prey densities were effective on *C. carnea*'s life table parameters (Reproduction rate, Intrinsic rate of increase). According to the past literature, both r_m and R_0 values were increased by the prey density increased. This finding was similar to the literature when our study is evaluated on this subject.

Table 4. Life table parameters of *Chrysoperla carnea* fed on *Aphis fabae* and *Acyrthosiphon pisum* at different densities

Prey Densities	Life Table Parameters (*Aphis fabae*)					
	r_m	R_0	T_0	GRR	T_2	λ
5	0.010	2.143	78.522	32.143	71.414	1.010
10	0.041	5.982	43.827	65.800	16.983	1.042
20	0.067	17.444	42.551	157.700	10.316	1.069
40	0.103	64.650	40.510	280.400	6.735	1.108
80	0.121	207.929	44.273	482.814	5.750	1.128
160	0.118	187.188	44.165	451.237	5.851	1.126
Prey Densities	Life Table Parameters (*Acyrthosiphon pisum*)					
	r_m	R_0	T_0	GRR	T_2	λ
5	0.032	3.938	43.499	45.619	21.998	1.032
10	0.052	9.514	43.277	83.727	13.316	1.053
20	0.069	18.578	42.458	167.375	10.072	1.071
40	0.112	106.355	41.567	356.591	6.174	1.119
80	0.122	202.838	45.537	458.559	5.681	1.130
160	0.119	181.427	43.855	437.993	5.845	1.126

r_m: Intrinsic rate of increase, R_0: Net reproductive rate, T_0: Mean generation time, GRR: Total productivity rate, T_2: Doubling time, λ: Daily maximum reproductive value.

Conclusion

Aphids are pests that cause economic losses in the worldwide. They reproduce very quickly in their environment and also cause indirect damage on plants because they are a disease vector. For this reason, it is very important to reveal the numerical response of the species in determining the impact power of a predator that has an effect on aphids.

In this research, the numerical response of *C. carnea* on two different aphid species (*A. fabae* and *A. pisum*) was determined. The reproductive abilities of the green lacewing at varying prey densities were also determined. The obtained data were evaluated and it was observed that *C. carnea* was effective on two different aphids (*A. fabae* and *A. pisum*) under laboratory conditions. It has been determined that the aphid population was intensive and the predator is more effective at the high density of aphids than lower aphid densities. It is thought that the data obtained in this study will help the researchers who want to produce mass production of *C. carnea* in the laboratory. However, it was concluded that similar experiments should be carried out in the field conditions in order to determine the information related to the numerical response of the species more clearly.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

Funding

This study was supported by Yozgat Bozok University, Project Coordination Application and Research Center (Project Number: 6602b-ZF/18-232).

Data availability

Not applicable.

Consent for publication

Not applicable.

Acknowledgements

Live aphids were supplied by Prof. Dr. Ismail KARACA (Isparta University of Applied Sciences, Faculty of Agriculture, Biological Control Research and Application Laboratory).

I am grateful to Qasim Hussein Ahmed at University of Baghdad for editing the English version of this manuscript.

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