Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(3): 381-386

Received: 16-03-2020
Accepted: 18-04-2020

Diksha Kumari
M.Sc Student, Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

SC Verma
Principal Scientist, Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

PL Sharma
Principal Scientist, Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Sarswati Negi
Ph.D. Student, Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Corresponding Author:
Diksha Kumari
M.Sc Student, Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Biology, feeding potential and functional response of *Chrysoperla zastrowisillemi* to cotton aphid, *Aphis gossypii* glover

Diksha Kumari, SC Verma, PL Sharma and Sarswati Negi

Abstract
Biology, feeding potential and functional response of *Chrysoperla zastrowisillemi* to cotton aphid, *Aphis gossypii* Glover was studied in the laboratory at 25 ± 0.5 °C, 70 ± 5% RH and 12L:12D photoperiod. The study reveal that the incubation, total larval, pre pupal and pupal period of *C. zastrowisillemi* was 2.60, 11.62, 1.10 and 8.30 days, respectively. Pre oviposition, oviposition and post oviposition period of *C. zastrowisillemi* was 3.60, 24.70 and 7.80 days, respectively and each female laid an average of 398.9 eggs. On an average 1st, 2nd and 3rd instars of *C. zastrowisillemi* consumed 30.46,98.7 and 301.7 aphids and total consumption during life cycle was 431.06 aphids/ predator. All the three larval stages of the predator exhibited Type II functional response to the aphid. Based on Rogers's random predator equation the predator's attack rate was lowest (0.089) in the firstinstar and highest (0.140) in the 3rd instar. Handling times of 1st, 2nd and 3rd instar was 1.767, 0.367 and 0.269h, respectively. Functional response parameters indicate that attack rate increased and handling time decreased with the advancement of the predator stage. Third instar larvae were the most voracious feeders and could be crucial for the biological control of the cotton aphid.

Keywords: Biology, feeding potential, attack rate, *Chrysoperla zastrowisillemi*, handling time, predator, functional response

Introduction
Cucumber, *Cucumis sativus* L. is one of the most important commercial vegetables grown throughout the world [1]. It is a warm season crop mainly grown in tropical and subtropical areas in open fields, whereas, in temperate countries it is grown under glasshouses. Among different insect-pests attacking cucumber,cotton aphid, *Aphis gossypii*Glover (Homoptera: Aphididae) is the important one causingsevere damage to the cucumber crop. The cottonaphid, *A. gossypii* is a cosmopolitan, polyphagous species infesting 569 host plants belonging to 80 families [2, 3]. Both nymphs and adults damage the crop by sucking the cell sap, resulting in curling of leaves or appearance of discoloured spots on the foliage. As the aphid become more abundant in juvenile stage, the plants gradually wilt, become yellowish to brownish and ultimately die. Heavy infestation of the aphid, results inreduction of the yield and quality of fruit by contaminating with honeydew which encourages sooty mould that disturbs the normal physiology of the leaves and also act as vector of 76 plant viruses [4-6]. The indiscriminate use of synthetic pesticides for the control of this pest leads to the development of insecticide resistance [7-12], pest resurgence, insecticide residue, environment pollution besides and killing of natural enemies. Insecticide resistance forces the farmers to increase the dose and/or frequency of pesticide application which further aggravates the problem [9]. Therefore, there is a need to find out some alternatives of chemical pesticides to protect cucumber against cotton aphid. Under such circumstances, biological control can be a viable, ecofriendly and sustainable option to control this pest [13]. Green lace wing, *C. zastrowisillemi* (Chrysopidae: Neuroptera) has been reported to naturally suppress the aphid populations in different cropping systems [14, 15]. Before using *C. zastrowisillemi* in a biological control programme, it is essential to evaluate its predatory efficiency against the target species. Thus, it is necessary to know the biology, feeding potential and functional response of *C. zastrowisellimi* on *A. gossypii* on cucumber for its possible utilization in biological control of the pest. The literature on biology and predatory potential of *C. zastrowisellimi* against *A. gossypii* on different in India is scanty [16-18]. However, the information on the biology and feeding potential of *C. zastrowisellimi* of *A. gossypii* on cucumber is lacking. Information on these variables could

lead to the development of a better strategy for the biological control of *A. gossypii* using the predator.

Materials and Methods

Rearing of cotton aphid, *A. gossypii*

The cotton aphid, *A. gossypii* was collected from cucumber field and was maintained in the polyhouse throughout the year on cucumber plants in the Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh, India. Cucumber leaves having nymphs were brought to laboratory for the further experiments. Before maturity of the old plants new plants were planted to maintain the culture of cotton aphid throughout the year.

Developmental biology of *C. z. sillemi*

Developmental biology of the chrysopid was studied on *A. gossypii* at 25± 1^0C, and 70± 5 per cent RH and 12:12 h photoperiod. One pair of newly emerged adults of *Chrysoperla zastrowisillemi* was released in the chrysoperla rearing cage covered with the piece of black cloth. Five per cent mixture of honey, protein X and yeast in a cotton ball was provided as food to the adults. The food was changed twice a day. The data on pre-oviposition period, oviposition period, post-oviposition and fecundity, were recorded. The freshly emerged larvae were taken out from cage and released individually in the Petri plates containing moist blotting paper and cucumber leaves (6×6 cm) infested with mixed population of second and third instar of *A. gossypii*. The incubation period, duration of each larval instar, total larval duration, pre pupal, pupal and total duration from egg to adult emergence was recorded.

Feeding Potential

Feeding potential of different developmental stages of *C. zastrowisellimi* was studied against *A. gossypii*. Newly hatched larvae of the same stage were confined individually to a single Petri plate having counted number of cotton aphids of 2nd or 3rd instar nymphs. The cotton aphids of 2nd or 3rd stage were selected by careful examination of the cucumber leaves under the stereo zoom binocular microscope. The unwanted stages of cotton aphids were removed with the help of camel hair brush. The base of the Petri plate was covered with the wet blotting paper. The experiment was carried out at the same environmental conditions mentioned above. The data on aphid consumption by the chrysopid was recorded after every 24 h till they enter the next stage and the food was changed daily. The experiment was replicated ten times. The number of aphids consumed per day by each larval instar of the chrysopid was also calculated.

Data analysis: The data obtained were subjected to one way analysis of variance through online statistical software OPSTAT [19].

Functional response of Chrysopids

Functional responses of each larval stage of *C. zastrowisillemi* were studied to the second or third nymphal stage of cotton aphid in a Petri plateon 6 cm cucumber leaf disk at the same environmental conditions mentioned above. Seven prey densities (each replicated 10 times) were provided to the individuals of different stages of predators on cucumber leaves in petri plates separately. Prey densities used in the study were 5, 10, 15, 20, 25, 30 and 35 for first larval instar; 10, 20, 30, 40, 50, 60 and 70 for second instar and 20, 40, 60, 80, 100 and 120 for third instar of the chrysopid. After 24 h, the number of aphids consumed by the larva was recorded by counting the aphids remaining on the petri-plate.

Data analysis of functional response

A logistic regression between proportion of prey consumed and prey density offered were fitted to determine the shape (type II or type III) of functional response:

$$N_e/N_0 = \frac{\exp(p_0 + p_1N_0 + p_2N_0^2 + p_3N_0^3)}{1+\exp(p_0 + p_1N_0 + p_2N_0^2 + p_3N_0^3)}$$

Where N_e is the number of prey eaten; N_0 is the initial number of preys, p_0 is intercept, p_1 is linear coefficient, p_2 is quadratic coefficient and p_3 is cubic coefficient. A true type I functional response is possible only when handling time is equal to zero and predators do not reach satiation point which seems to be an unrealistic situation. Significant negative and positive linear coefficients (p_1) from the regression indicate type II or type III functional response, respectively[20]. The random predator equation[21] was used to describe the functional responses because it allows for prey depletion during the course of the experiment. The form of the equation is as follows: $N_e = N_0\,[1- \exp(aT_hN_e – aT)]$.

Where N_e is the number of prey eaten per predator, N_0 is the prey density offered, T is the duration of the experiment (24h), T_h is the handling time i.e. time required by the predator to pursue, kill and digest the prey and a is the predation coefficient or predators attack rate. The value a/ T_h indicates the effectiveness of predator which was calculated by dividing a by T_h and maximum theoretical predation rate K = T/ T_h was also calculated.

Results and Discussion

Developmental biology of *C. zastrowisillemi*

Mean duration of egg, larva, prepupa and pupa of *C. zastrowisillemi* was 2.60, 11.62, 1.10 and 8.30 days, respectively. The predator took 23.56 days to complete the development from egg to adult emergence (Table 1). The female and male longevity of *C. zastrowisillemi* on *A. gossypii* was recorded as 37.60 and 26.80 days, respectively. Each female on an average laid 398.9 eggs. The mean duration of pre-oviposition, oviposition and post-oviposition periods of *C. zastrowisillemi* was 3.6, 24.7 and 7.8 days, respectively.

Feeding potential of *C. zastrowisillemi*

Data presented in Table 2 reveal that 1st, 2nd and 3rdinstarsof *C. zastrowisillemi* consumed on an average 30.66, 98.7 and 301.7 nymphs of 2nd/3rd stage of *A. gossypii*. The total consumption during the entire life cycle was 431.06 aphids. Number of aphids consumed per day by the respective instar was 10.96, 31.84 and 62.86. The feeding potential of the lace wing larvae increased with age. As the larva grew from 1st instar to 3rd instar, the number of aphids consumed per day increased from 10.96 to 62.86.

Functional response of *C. zastrowisillemi*

Cubic polynomial fit between prey density offered (N) and proportion of prey consumed (N_a/N) by all the larval stages of the chrysopid resulted significantly negative linear coefficient thereby confirming a Type II functional response (Table 3).

The mean number of aphids consumed by 1st instar of *C. zastrowisillemi* at the prey densities of 5, 10, 15, 20, 25, 30 and 35 was 3.9, 6.5, 8.3, 9.5, 10.5, 10.6 and 10.9 aphids, respectively (Table 4). The maximum number of aphids consumed at the prey density of 35 (10.90) was statistically on par with the prey density of 30 (10.60 aphids) and 25 (10.50 aphids). The highest proportion of aphids consumed was at the prey density of 5 (78.00%) and lowest at the prey density 30 (35.33%).

The mean number of aphids consumed by the 2nd instar of *C. zastrowisillemi* was 8.9, 17, 24.2, 31.4, 37.7, 38.3 and 38.5 aphids at the prey densities of 10, 20, 30, 40, 50, 60 and 70, respectively. The number of aphids consumed at the prey densities of 50, 60 and 70 were significantly on par with each other (Table 5). The maximum proportion of the aphids consumed was at the prey density of 10 (89%) and minimum at the prey density of 70 (55%).

Data presented in Table 6 reveal that the mean number of aphids consumed by 3rd instar of *C. zastrowisillemi* at prey densities of 20, 40, 60, 80, 100, 120 and 140 was 18.80, 32.8, 47.2, 61.9, 63.5, 64.3 and 64.6 aphids, respectively. The number of aphids consumed was maximum at the prey density of 140 which was statistically on par with at prey densities of 120 and 100. Highest proportion of aphids consumed was at the prey density of 20 (94%) and lowest at the prey density of 140 (46.14%).

The predation efficiency of *C. zastrowisillemi* against *A. gossypii* increased with the advancement of the developmental stage of the predator which is numerically illustrated by parameters of attack rate (a) and handling time (T_h) (Table 7). The attack rates for 1st, 2nd and 3rd instars were 0.089, 0.111 and 0.140, respectively. These findings show that the attack rate of different instars of *C. zastrowisillemi* increased with the gradual increase in larval stages. The time of handling for 1st, 2nd and 3rd instar was 1.767, 0.367 and 0.269 h, respectively. Time of handling of different instars decreased with the advancement in growing stages. The minimum handling time was recorded for3rd instar larva followed by 2nd and 1st instar larvae which may be due to higher movement of larger instars that lead to high attack rate. Maximum theoretical predation rate (K) estimated for 1st, 2nd and 3rd instars were 13.6, 82.8 and 88.9 aphids, respectively.

Discussion

The cotton aphid, *A. gossypii* is an important pest of many host plants belonging to over 80 families [2, 3] and is a vector of more than 30 plant viruses [15]. In the present study, incubation period was 2.6 days which is nearly same (2.25 days) to that recorded by [22]. The study also showed that larval duration of *C. zastrowisillemi* was 11.62 days, whereas, pre pupal and pupal period was 1.10 and 8.30 days, respectively. Similar to present study [23]. recorded total larval duration of 9.65 days and pupal period of 9.43 days of *C. carnea* on *A. gossypii.* The present study also finds support of[18] who recorded total larval and pupal periods of 11.38 and 9.64 days, respectively of *Chrysoperla zastrowi arabica* on *A. gossypii*. Total duration from egg to adult emergence of *C. zastrowisillemi* was 23.56 days. The female and male longevity of *C. zastrowisillemi* on *A. gossypii* was 37.60 and 26.80 days, respectively. These findings were similar to the findings of [18] which showed that female longevity of *C. zastrowi arabica* with *A. gossypii* was 38.93 days and male longevity was 28.59 days. Adult females on an average laid 398.9 eggs/female. In present study, the mean duration of pre-oviposition, oviposition and post-oviposition periods of *C. zastrowisillemi* was 3.6, 24.7 and 7.8 days, respectively. Similar to present results[18] also recorded pre-oviposition, oviposition and post-oviposition periods of *C. zastrowi arabica*as 3.72, 25.54 and 8.47 days, respectively. The 1st, 2nd and 3rd instars of *C. zastrowisillemi* consumed 30.66, 98.7 and 301.7 aphids of *A. gossypii*. The feeding potential of the lace wing larvae increased with age, as the larva grew from 1st instar to 3rd instar, the number of aphids consumed per day increased from 10.96 to 62.86. This is because the larger size of larvae requires more food to satisfy hunger level and reach satiation. This is in accordance to earlier studies of [24] who observed that the daily feeding of *C. carnea* increased slowly during the first two instars and reached peak in the third larval instar. Similarly [25] recorded that larva of *C. carnea* consumed on an average 419.8 nymphs of *A. gossypii*. Khan *et al*. (2013) reported that 1st, 2nd and 3rd instar larvae of *C. carnea* consumed 61 ± 1.97, 113.6 ± 2.42 and 239.2 ± 6.87 aphids, respectively. The present findings were in line with the findings of [26] who recorded that mean consumption rate of 1st, 2nd and 3rd instar larvae of *C. carnea* with *A. gossypii* was 23, 122 and 205.6 aphids, respectively. Host plants on which the aphids fed might affect the quality of the aphids, which in turn, may affect the development, survival and predation of the predator. In this study, *C. zastrowisellemi* presented type-II functional response which is similar to several reports on the functional response in *C. carnea, C. rufilabris, C. externa* and *C. congrua* [27-31]. Although thetype-III functional response represents the only response with regulating possibilities [32], in biological control programmes of ephemeral crops with augmentative release, regulating possibilities are not as important as in inoculative releases[28]. The proportion of aphids eaten increased at decreasing rate in higher aphid densities and the proportion of aphid eaten was not constant.In the present study, as the prey density increased, the number of aphids consumed by different instars of *C. zastrowisillemi* also increased (Table 4-6). Whereas, the proportion of the aphids consumed decreased with the increase in the prey density, which may be due to satiation levels of the predators. The results of present study were supported by the previous studies of [33, 34] who reported that as the prey density offered increased the proportion of aphids consumed decreased. The handling time is a feature of predatory behaviour and influences the functional response by decreasing the search and attack rates as prey density increases [28]. These findings show that the attack rate of different instars of *C. zastrowisillemi* increased with the gradual increase in larval stages. The time of handling for 1st, 2nd and 3rd instar was 1.767, 0.367 and 0.269 h, respectively. Time of handling of different instars decreased with the advancement in growing stages. Similar to present studies many workers have reported that attack rate coefficient (a) increased and handling time (T_h) decreased during the development of the green lacewing (*C. carnea*) larvae against different species of aphids [33-35]. In the present findings, the advancement of growing stages caused higher attack rate and lower handling time which may be due to the increase in size, voracity, hunger level and walking speed of the predator.The handling time decreased over time and the attack coefficient increased which might be due to the larvae take time to acclimate to the new experimental arena and to a new type of prey. The results suggest that *C. zastrowisellemi* could be considered as a candidate for use in a commercial biological control agent for cotton aphid, *A. gossypii* from the view point of environmental safety and non- target effects could be avoided.

Table 1: Duration of developmental stages (days ± SE) of *C. zastrowisillemi* reared on *A. gossypii*

Development Stage	*C. zastrowisillemi*(Days ± SE)
Incubation period	2.60 ± 0.16
1st instar	2.80 ± 0.15
2nd instar	3.10 ± 0.13
3rd instar	4.80 ± 0.12
Total larval period	11.62 ± 0.26
Pre-pupa	1.10 ± 0.10
Pupa	8.30 ± 0.24
Egg-adult emergence	23.56 ± 0.25
Female longevity	37.60 ± 1.71
Male longevity	26.80 ± 0.95
Pre oviposition period	3.60 ± 0.39
Oviposition period	24.70 ± 1.69
Post oviposition period	7.80 ± 0.34
Fecundity (Eggs/female)	398.90 ± 10.58

Table 2: Feeding potential of different developmental stages of *C. Zastrowisillemi* against *A. gossypii*

Stage	Mean number of aphids Consumed		Mean number of aphids consumed/ day	
	Mean ± SE	Range	Mean ± SE	Range
1st instar	30.66 ± 3.35	20-37	10.96 ± 0.48	10-13
2nd instar	98.7 ± 3.73	85-106	31.84 ± 0.86	29-35
3rd instar	301.7 ± 4.59	289-315	62.86 ± 0.90	61-68
Total consumption	431.06 ± 5.99	415-450	37.1 ± 2.36	29-43

Table 3: Parameters of polynomial regression between proportions of prey consumed (Na/N) and initial prey density (N) of *C. zastrowisillemi*

Predator stage	Parameter	Coefficient Mean ± S E	t- value	p
1st instar	P0	0.98 ± 0.02	42.59	< 0.001
	P1	-0.07 ± 0.006	-6.72	< 0.001
	P2	0.001 ± 0.0003	2.90	< 0.001
	P3	-0.000009 ± 5.6E-06	-1.69	< 0.001
2nd instar	P0	0.98 ± 0.01	74.36	0.0012
	P1	-0.01 ± 0.002	-5.80	< 0.001
	P2	0.0002 ± 4.9E-05	4.35	< 0.001
	P3	-0.000002 ± 3.9E-07	-5.66	< 0.001
3rd instar	P0	1.01 ± 0.019	51.75	< 0.001
	P1	-0.07 ± 0.0006	-7.63	< 0.001
	P2	0.00003 ± 5.6E-06	4.49	< 0.001
	P3	-0.0000001 ± 1.5E-08	-8.51	< 0.001

P0= Constant, P1= Linear coefficient, P2= Quadratic coefficient, P3= Cubic coefficient

Table 4: Functional response of 1st instar of *C. zastrowisillemi* to different densities of *A. gossypii*

Prey density	Mean number of aphids consumed (Mean ± SE)	Proportion of aphids consumed (%)
5	3.90 ± 0.10f	78.00
10	6.50 ± 0.17e	65.00
15	8.30 ± 0.26d	55.33
20	9.50 ± 0.17c	47.50
25	10.50 ± 0.17ab	42.00
30	10.60 ± 0.16ab	35.33
35	10.90 ± 0.10a	31.14
CD (p=0.05)	0.48	

Table 5: Functional response of 2nd instar of *C. zastrowisillemi* to different densities of *A. gossypii*

Prey density	Mean number of aphids consumed (Mean ± SE)	Proportion of aphids consumed (%)
10	8.90 ± 0.10f	89.00
20	17.00 ± 0.15e	85.00
30	24.20 ± 0.25d	80.66
40	31.40 ± 0.37c	78.50
50	37.70 ± 0.21ab	75.40
60	38.30 ± 0.21ab	63.83
70	38.50 ± 0.22a	55.00
CD (p= 0.05)	0.65	

Table 6: Functional response of 3rd instar of *C. zastrowisillemi* to different densities of *A. gossypii*

Prey density	Mean number of aphids consumed (Mean ± SE)	Proportion of aphids consumed (%)
20	18.80 ± 0.20^{f}	94.00
40	32.80 ± 0.49^{e}	82.00
60	47.20 ± 1.01^{d}	78.67
80	61.90 ± 0.23^{c}	77.38
100	63.50 ± 0.22^{ab}	63.50
120	64.30 ± 0.26^{ab}	53.58
140	64.60 ± 0.22^{a}	46.14
CD (p= 0.05)	1.32	

Table 7: Parameters of functional response of *C. zastrowisillemi* to *A. gossypii* over 24 h period

Predator stage	Parameter				
	a ± SE	T_h ± SE	a/T_h	K	R^2
1st instar	0.089 ±0.002	1.767 ± 0.035	0.05	13.60	0.957
2nd instar	0.111 ±0.002	0.367 ± 0.011	0.38	82.80	0.983
3rd instar	0.140 ±0.005	0.269 ± 0.007	0.52	88.90	0.981
CD (p= 0.05)	0.010	0.063			

a= Coefficient of attack rate, T_h= Handling time, K= maximum theoretical predation rate, R^2= Coefficient of determination

Acknowledgement

Authors are thankful to the Professor and Head, Department of Entomology, Dr YS Parmar University of Horticultureand Forestry, Nauni, Solan Himachal Pradesh, India for providing necessary facilities for carrying out this research.

Reference

1. Sanjeev K, Patel NB, Saravaiya SN, Desai KD. Economic viability of cucumber cultivation under NVPH. African J Agric Res. 2015; 10:742-747.
2. Singh G, Singh NP, Singh R. Food plants of a major agricultural pest, *Aphis gossypii* Glover (Homoptera: Aphididae) from India: An updated checklist. Intl J Life Scis Biotechnol Pharma Res. 2014; 3:1-28.
3. Tazerouni Z, Talebi AA, Fathipour Y, Soufbaf M. Bottom-up effect of two host plants on life table parameters of *Aphis gossypii* (Hemiptera: Aphididae). J Agric Sci Technol. 2016; 18:179-90.
4. Escriu F, Perry KL, Garcia-Arenal F. Transmissibility of cucumber mosaic virus by *Aphis gossypii* correlates with viral accumulation. Virology. 2000; 90:1069-1072.
5. Pinto ZV, Rezende JAM, Valdir AYVA, Piedade SMS. Ability of *Aphis gossypii* and *Myzus persicae* to transmit cucumber mosaic virus in single and mixed infection with two poty viruses to zucchini squash. Summa Phytopatho. 2008; l34:183-185.
6. Srinivasulu M, Sarovar B, Anthony Jhonson AM, Sai Gopal DVR. Association of poty virus with mosaic virus disease of gherkin (*Cucumis anguira* L.) in India. Indian J Microbiol 2010; 50:221-224.
7. Tomquelski GV, Martins GLM, Papa G. Efeitos dos indutores de resistênciaacibenzolar-smetilesilícionabiologia de *Alabama argilacea* (Lepidoptera: Noctuidae) emalgodoeiro. Rev de Agric. 2007; 82:170-175.
8. Herron GA, Wilson LJ. Neonicotinoid resistance in *Aphis gossypii* Glover (Aphididae: Hemiptera) from Australian cotton. Australian J Entomol. 2010; 50:93-98.
9. Denholm I, Devine G. Insecticide resistance. Encyclopedia of Biodiversity. 2nd ed. Academic Press, Waltham. 2013, 298-307.
10. Sarwar MK, Azam I, Iram N, Iqbal W, Rashda A, Anwer F *et al*. Cotton aphid, *Aphis gossypii* L. (Homoptera; Aphididae); A challenging pest; biology and control strategies: A review. Intl J Appl Biol Pharmatl Techno 2014; l5:288-294.
11. Seyedebrahimi SS, Jahromi KT, Imani S, Naveh VH, Hesami S. Characterization of imidacloprid resistance in *Aphis gossypii* Glover (Hemiptera: Aphididae) in Southern Iran. Turkish J Entomol. 2015; 39:413-23.
12. Pan Y, Tian F, Wei X, Wu Y, Gao X, Xi J, Shang Q. Thiamethoxam Resistance in *Aphis gossypi* Glover Relies on Multiple UDP-Glucuronosyltransferases. Front Physio. 2018; l9:322-327.
13. Joshi S, Rabindra RJ, Rajendran TP. Biological control of aphids. J Biol Contl. 2010; 24:185-202.
14. Tulisalo U, Tuovinen T. The green lacewing, *Chrysopa carnea* Steph. (Neuroptera: Chrysopidae), used to control the green peach aphid, *Myzus persicae* Sulz. And the potato aphid, *Macrosiphum euphorbiae* Thomas (Homoptera: Aphididae) on greenhouse green peppers. Ann. Entomol Fenn. 1975; 41:94-102.
15. Ebert TA, Cartwright B. Biology and ecology of *Aphis gossypii* Glover (Homoptera: Aphididae). Southwestern Entomol. 1997; 22:115-153.
16. Nehare SK, Deotale VY, Deotale RO, Dawane PN. Biology and predatory potential of *Mallada boninensis* (Okamoto) against sucking pests. J Soils Crops. 2004; 14:427-32.
17. Nagamallikadevi M, Undirwade DB, Reddy NB, Ramadevi A, Srasvankumar G. Biology of *Mallada boninensis* (Okamoto) [Chrysopidae: Neuroptera] on Aphids and Neonate Noctuids. Biosci Trends. 2012; 6:827-830.
18. Naruka P, Meena A, Meena BM. Feeding potential of *Chrysoperla zastrowi* arabica on different prey hosts. J Entomol Zool Stud. 2017; 5:608-12.
19. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC, Pannu RS. Statistical Software Package for Agricultural Research Workers. Department of Mathematics Statistics, CCS HAU, Hisar, 1998.
20. Juliano SA. Non-linear curve fitting: Predation and functional response curves. In: Design and analysis of ecological experiments (Scheiner SM and Gurevitch J, eds). Chapman and Hall, New York. 2001, 178-196.
21. Rogers D. Random search and insect population models. J Animal Ecol. 1972; 41:369-383.
22. Shaukat MA. Feeding behaviour and life durations of

Chrysoperla carnea (Stephens) (Neuroptera: Chrysopidae) feeding on a variety of hosts. J Entomol Zool Stud. 2018; 6:691-97.
23. Mannan VD, Varma GC, Barar KS. Biology of *Chrysoperla carnea* (Stephens) on *Aphis gossypii* (Glover) and *Myzus perisicae* (Sulzer). J Insect Sci. 1997; 10:143-45.
24. Batool A, Abdullah K, Rashid M, Khattak MK, Abbas SS. Effect of prey density on biology and functional response of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Pakistan J Zool. 2014; 46:129-37.
25. Balasubramani V, Swamiappan M. Development and feeding potential of the green lacewing, *Chrysoperla carnea* Steph. (Neuroptera: Chrysopidae) on different insect pests of cotton. J Pest Sci. 1994; 67:165-167.
26. Khanzada KK, Shaikh HM, Mastoi SM, Rajput Z, Jat MI, Mastoi PM *et al*. Some parameters of *Chrysoperla carnea* on floral feeds of castor and feeding potential on selective aphid species. J Entomol Zool Stud. 2018; 6:860-863.
27. Stark SB, Whitford. Functional response of *Chrysopa carnea* (Neuroptera: Chrysopidae) larvae feeding on *Heliothis virescens* (Lepidoptera: Noctuidae) eggs on cotton in fields cages. Entomophaga. 1987; 32:521-527.
28. Nordlund DA, Morrison RK. Handling time, prey preference and functional response of *Chrysoperla rufilabris* in the laboratory. Entomology Exp Appl. 1990; 57:237-242.
29. Kabissa JCB, Yaro JG, Kayumbo HY, Julio SA. Functional response of two chrysopid predators feeding on *Helicoverpa armigera* (Lepidoptera: Noctuidae) and *Aphis gossypii* (Homoptera: Aphididae). Entomophaga. 1996; 41:141-15.
30. Fonseca AR, Carvalho CF, Souza EB. Functional response of *Chrysoperla externa* (Hagen) (Neuroptera: Chrysopidae) fed on *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae). Anais da Soci Entomol Brasil 2000; 29:309-317.
31. Stewart CD, Braman DK, Pendley AF. Functional response of the azalea plant bug (Heteroptera: Miridae) and green lacewing, *Chrysoperla rufilabris* (Neuroptera: Chrysopidae), two predators of the azalea lace bug (Heteroptera: Tingidae). Environ Entomol. 2002; 31:1184-1190.
32. Huffaker CB, Messenger PS, De Bach P. The natural enemy component in natural control and the theory of biological control. In: Biological Control (CB Huffaker, ed). Plenum, New York, 1971, 16-67.
33. Alvarez AFM, Lto K, Nakahira K, Arakawa R. Functional response of *Chrysoperla nipponensis* and *C. carnea* (Neuroptera: Chrysopidae) to the cotton aphid *Aphis gossypii* Glover (Homoptera: Aphididae) under laboratory conditions. Appl Entomol Zool. 2010; 45:201-206.
34. Alhamawandy SA. Functional response of common green lacewing, *Chrysoperla carnea* (Stephens) on black bean aphid, *Aphis fabae* (Scopoli). J Agric Vet. Sci. 2017; 10:9-13.
35. Saljoqi AR, Asad N, Khan J, Haq E, Nasir M, Zada H, *et al*. Functional response of *Chrysoperla carnea* Stephen (Neuroptera: Chrysopidae) fed on cabbage aphid, *Brevicoryne brassicae* (Linnaeus) under laboratory conditions. Pakistan J Zool. 2015; 48:165-169.