

Research Article

Effect of different prey species on the biological parameters of *Chrysoperla carnea* (Neuroptera: Chrysopidae) in laboratory conditions

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Abstract: The prey suitability for generalist predators is an important feature for efficient mass rearing and IPM. The green lacewing, *Chrysoperla carnea* (Stephens) is a polyphagous predator attacking several pests on various crops. This experiment was conducted under laboratory conditions at 25 ± 2 °C, $60 \pm 5\%$ R. H. and a photoperiod of 16L: 8D h. The effects of different prey species were investigated on the pre-imaginal development, survival, adult longevity and fecundity of the green lacewing. The results indicated that duration of each pre-imaginal stage development and total development time in *C. carnea* were significantly affected by species of prey tested. The total developmental period was 19.63 ± 0.125 , 20.63 ± 0.180 , 22.06 ± 0.183 , 22.35 ± 0.120 , and 23.81 ± 0.356 days on *Aphis gossypii* (Glover), *Myzus persicae* (Sulzer), *Aphis punicae* (Passerini), *Aphis fabae* (Scopoli) and *Aphis craccivora* (Koch), respectively. The maximum mean fecundity per female of *C. carnea* was 478.50 ± 8.38 eggs recorded when fed as larvae on *M. persicae* followed by 409.33 ± 8.16 eggs on *A. gossypii*, whereas, the minimum of 242.78 ± 7.37 eggs was recorded when fed on *A. craccivora* nymphs. The longest female longevity was recorded for *C. carnea* fed on *M. persicae*. There was significant difference in adult longevity due to feeding on different preys. However, nymphs of *M. persicae* and *A. gossypii* were the best of the prey species tested, in that when fed on these species the pre-imaginal developmental period of *C. carnea* was shorter and its adult longevity, fecundity and percentage survival was greater than those fed on the other preys. These findings could be useful in defining more optimum conditions for the mass rearing of *C. carnea* in IPM programs.

Keywords: *Chrysoperla carnea*, green lacewing, development, fecundity, longevity

Introduction

Chrysopidae has been amongst the useful insects of agricultural ecosystems which is very effective and applicable in biological control

programs against agricultural pests (Canard *et al.*, 1984). This family includes more than 1800 well-known species which their predatory behavior always attracted the entomologists' intention in biological control programs (Brook and Barnard, 1990). So far, 193 lacewings species have been reported in Iran of which 46 species are members of Chrysopidae family (Farahi *et al.*, 2009). The green lacewing *Chrysoperla carnea* is one of the predators of

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aphids, mealy bugs and some other pest species (Hesami *et al.*, 2011). The green lacewing is a cosmopolitan polyphagous predator, commonly found in agricultural systems.

It is estimated that possibly up to one third of the successful biological insect pest control programs are attributable to the introduction of *C. carnea* and release of insect predators (Williamson and Smith, 1994). Larvae of *C. carnea* are voracious and efficient biological control agents for various phytophagous arthropods (McEwen *et al.*, 2001).

For the successful development of pest management programs that utilize *C. carnea* as a biocontrol agent, it is important to identify alternative high quality prey/food. There are not many studies on the effect of different prey species on the biology, life table parameters, fecundity and adult longevity of *C. carnea*, despite its importance as a predator of aphid pests. The importance of the nutritional quality of the prey for this predator is also unknown. Fathipour *et al.* (2004) have studied the population growth parameters of green lacewing on *creontiades pallidus* Rambur.

The aim of the present study was to evaluate five species of aphid (*Aphis fabae*, *Aphis gossypii*, *Myzus persicae*, *Aphis punicae*, and *Aphis craccivora*) as food for *C. carnea* in terms of survival, development and reproduction of the predator under laboratory conditions. Such information would be helpful for optimizing the mass rearing of *C. carnea*. The results may also help in designing integrated pest management (IPM) programs involving the use of *C. carnea* as a biocontrol agent of pests on various crops.

Materials and Methods

Adults of *C. carnea* were collected from alfalfa field at Shahid Bahonar University of Kerman and maintained in laboratory condition (25 ± 2 °C, $60 \pm 5\%$ R. H. and a photoperiod of 16L: 8D). Before the experiment four generations of *C. carnea* were reared in the laboratory. The *C. carnea* adults for experiment were obtained

from this colony. Adults were maintained in cylindrical glass jars (18 cm in diameter and 25 cm high). They had access to water and were fed a 1:1:1 artificial diet of honey, yeast and distilled water that was provided twice daily in droplet on paper strips. Larvae were reared in Petri dishes (9 cm diameter, 1 cm high) on *A. fabae*, which were reared on soybean plants (steel variety) grown hydroponically. Rearing conditions for stock cultures of chrysopids were 25 ± 2 °C, $60 \pm 5\%$ R. H. and a photoperiod of 16 L: 8D.

Five aphid species (*A. fabae*, *A. gossypii*, *A. punicae*, *M. persicae* and *A. craccivora*) were provided as prey for *C. carnea*. In this experiment, the 3rd and 4th instars of aphids were used and mature aphids were removed. All biological parameters including egg incubation, larval and pupal period (days), pupal and adult survival, longevity of female (days), and fecundity per female with hatch rate were recorded daily. To avoid cannibalism, newly hatched (2 h old) larva was kept individually in Petri dishes.

To calculate the hatch rate, eggs on cylindrical jars and lace cloth of caps were harvested by a razor from pike place and separated along with black muslin cloth, counted and kept for hatching.

To investigate the suitability of prey as food for the pre-imaginal development of *C. carnea*, approximately 400 eggs were collected from the mass-reared laboratory culture and kept in small tubes (1 cm diameter and 4 cm long). Eggs were checked every 3–4 h and also the time from egg laying to hatching was recorded in order to determine the incubation period, the newly emerged larvae were transferred singly with a camel hair brush to a plastic Petri dish (9 cm diameter, 1.5 cm high ventilated through a 3-cm-diameter hole in the lid that was covered with soft netting). To determine the larval development time and pupal period, 16 newly emerged larvae were allowed to feed on any of the prey species (total 80 larvae) and to determine the pre-imaginal survival rate, 50 larvae that fed on any of the preys (total 250

larvae) were selected and examined. Third and fourth instar nymphs of each aphid species were supplied daily to the chrysopid larvae (ad libitum 20-150 aphids according to larval age) throughout their larval development. The larvae were fed with nymphs in Petri dishes till pupation and emergence of adults. The survival and development of the lacewing larvae were recorded twice a day at 09:00 and 18:00. All the experiments were conducted at 25 ± 2 °C, relative humidity (RH) of $65 \pm 5\%$ and a photoperiod of 16L: 8D. In each treatment, 50 newly hatched larvae were tested.

A total 90 Adults of *C. carnea* (18 female obtained from each of pupa that had fed on different preys) were examined under a binocular on the day of emergence and sorted according to sex. Single pairs were confined in cylindrical glass jars (18 cm in diameter and 25 cm high) and supplied with the artificial diet for colony maintenance. One end of the cylindrical glass jar was covered with absorbent cloth. Due to the height of the glass jars, cotton wool wrapped in absorbent cloth was placed at the bottom of each of the jars in order to facilitate the collection of eggs from the bottom of the jar. In case of death of male insects in jars they were immediately replaced from colony. The number of eggs laid during their oviposition period and longevity was recorded daily.

Egg viability was monitored by collecting 10 eggs per female per day throughout a female's life and keeping them in a tube (1 cm diameter, 4 cm long) the ends of which were closed with cotton wool. These eggs were kept at the same temperature and photoperiod as the adults. The number of hatched and unhatched eggs was recorded every day.

Data collected on fecundity, fertility, incubation, larval instars, pupal period and other aspects of predator biology were subjected to analysis of variance (ANOVA) and the treatment means were compared using Duncan's Multiple Range Test (DMRT) with the help of SAS computer software as analyzing tool (SAS Institute, 2003).

Results

Larval and pupal period

The effects of feeding on different prey by *C. carnea* on its development time are shown in Table 1. The results indicated that duration of each larval development and total duration in *C. carnea* was significantly affected by species of prey tested (1st instar larva: $F = 10.51$; $df = 4, 75$; $P < 0.001$; 2nd instar larva: $F = 6.38$; $df = 4, 75$; $P < 0.001$; 3rd instar larva: $F = 6.10$; $df = 4, 75$; $P < 0.001$; respectively). But duration of pupal development period was not significantly different between the various preys ($F = 2.15$; $df = 4, 75$; $P < 0.08$).

The shortest and the longest larval development time of *C. carnea* were recorded at 1st instar on *A. gossypii* and *A. craccivora*, and at 2nd instar on *A. gossypii* and *A. craccivora* and at 3rd instar on *A. gossypii* and *A. craccivora*, respectively.

The minimum to the maximum complete larval developmental period on different insect prey species was in the order of *A. gossypii* < *M. persicae* < *A. fabae* < *A. punicae* < *A. craccivora*.

The pupal developmental period was not significantly different among the various preys.

The total developmental period of pre-imaginal stages was 19.63, 20.63, 22.06, 22.35, and 23.81 days on *A. gossypii*, *M. persicae*, *A. punicae*, *A. fabae* and *A. craccivora* respectively and was significantly different on various preys ($F = 58.42$; $df = 4, 75$; $P < 0.001$).

The incubation period of eggs of *C. carnea* feeding on different preys was 2.23, 2.29, 2.34, 2.26 and 2.38 days on *A. gossypii*, *A. craccivora*, *A. faba*, *M. persicae* and *A. punicae* respectively. There were no significant differences between treatments.

Pre-imaginal survival

The results showed (Table 2) that the maximum survival rate of pre-imaginal was recorded when *C. carnea* was feeding on nymphs of *A. gossypii* (78%) followed by nymphs of *M. persicae* (76%) and the minimum survival was

recorded when *C. carnea* was feeding on nymphs of *A. craccivora* (62%).

Fecundity and longevity

Feeding of different prey to larvae of *C. carnea* (Table 2), significantly affected their fecundity ($F = 118.75$; $df = 4, 85$; $P < 0.001$). The maximum mean fecundity per female of *C. carnea* was recorded when fed as larvae on *M. persicae* followed by *A. gossypii*, whereas, the minimum number of eggs was recorded when fed on *A. craccivora* nymphs.

The percentage of eggs hatched was high and in the range of approximately 88–95% and

the maximum mean hatchability was 95.12% on *A. gossypii* and minimum mean hatchability was 88.95% on *A. fabae*.

There was significant ($F = 54.31$; $df = 4, 85$; $P < 0.001$) variation in adult longevity due to feeding on different preys. The maximum female longevity of *C. carnea* feeding on *M. persicae* was 52.78 days and followed by *A. gossypii* that was 52.61 days and the minimum was 45.94 days feeding on *A. craccivora*. The maximum to the minimum longevity was in the order of *M. persicae* > *A. gossypii* > *A. panicum* > *A. fabae* > *A. craccivora*.

Table 1 Mean developmental time of pre-imaginal developmental stages of *Chrysoperla carnea* reared on different prey species.

Prey	Developmental times (days) ¹					
	N ₀ ²	1 st	2 nd	3 rd	pupa	Total
<i>A. panicum</i>	16	5.06 ± 0.193 a	3.32 ± 0.12 bc	3.62 ± 0.125 ab	10.06 ± 0.193 ab	22.06 ± 0.183 b
<i>M. persicae</i>	16	4.13 ± 0.18 b	3.00 ± 0.183 c	3.19 ± 0.12 b	10.19 ± 0.164 ab	20.63 ± 0.180 c
<i>A. craccivora</i>	16	5.25 ± 0.194 a	4.06 ± 0.224 a	4.13 ± 0.202 a	10.44 ± 0.182 a	23.81 ± 0.356 a
<i>A. gossypii</i>	16	3.85 ± 0.171 b	2.94 ± 0.213 c	3.13 ± 0.202 b	9.75 ± 0.194 b	19.63 ± 0.125 d
<i>A. fabae</i>	16	4.31 ± 0.198 b	3.75 ± 0.194 ab	3.94 ± 0.193 a	10.31 ± 0.198 ab	22.35 ± 0.120 b

¹ Means in each column followed by different letters are significantly different (Duncan's multiple range test, $P < 0.05$); ² N₀: number of individuals tested. The values are means ± SE.

Table 2 Larval survival, female longevity and mean total fecundity of *Chrysoperla carnea* reared on different prey species.

prey	N ¹	pre-imaginal survival (%) ²	No. of female ³	Female longevity (days) ⁴	Fecundity (egg/female) ⁴	Hatchability (%)
<i>A. panicum</i>	50	68	18	51.67 ± 0.380 a	312.89 ± 9.66 c	89.15
<i>M. persicae</i>	50	76	18	52.78 ± 0.263 a	478.50 ± 8.38 a	91.22
<i>A. craccivora</i>	50	62	18	45.95 ± 0.501 c	242.78 ± 7.73 d	90.65
<i>A. gossypii</i>	50	78	18	52.61 ± 0.244 a	409.33 ± 8.16 b	95.12
<i>A. fabae</i>	50	64	18	49.89 ± 0.301 b	294.06 ± 9.44 c	88.95

¹n: initial number of newly hatched larvae tested; ² pre-imaginal survival: $100 \times (\text{total number of emerging adults}) / (\text{initial number of newly hatched larvae tested})$; ³ number of females tested; ⁴ means in a column followed by different letters are significantly different (Duncan's multiple range test, $P < 0.05$). The values are means ± SE.

Discussion

It is widely reported that unsuitable food can extend the pre-imaginal development of chrysopids and decrease the survival, fecundity and longevity of the adults (Principi and Canard, 1984; Obrycki *et al.*, 1989; Zheng *et al.*, 1993). In this study we evaluated the pre-imaginal developmental period as well as adult longevity and fecundity of *C. carnea* provided with different species of prey. Generally, the *C. carnea* larvae that were reared on various aphids had different pre-imaginal developmental periods, longevity and fecundity per female. This indicates that the species of prey is of paramount importance as part of a balanced source of food (Evans *et al.*, 1999).

Larval food significantly affected the length of development time. The shortest development time was recorded on *A. gossypii* nymphs (19.63 days), while the longest on *A. craccivora* nymphs (23.81 days). Mannan *et al.* (1997) studied biology of *C. carnea* on *A. gossypii* and *M. persicae* and observed that larval duration was long when fed on *M. persicae*. Saminathan *et al.* (1999) and Bansod and Sarode (2000) studied biology and feeding potential of *C. carnea* on different preys and noted developmental period of *C. carnea* ranged from 18.6 days on *Aphis craccivora* to 22.7 days on *Helicoverpa armigera* (Hb.) neonate larvae. Balasubramani and Swamiappan (1994) studied the development of *C. carnea* on different preys in laboratory and found that larval development was rapid on eggs of *Corcyra cephalonica* (8.20 days) and was the longest on neonates of *H. armigera* (11.10 days). Fathipour and Jafari (2004) studied biology of *C. carnea* on *Creontiades pallidus* and observed that the incubation period was 4.15, the larval period 8.25, and the pupal period 8.10 days. Sattar *et al.* (2011) studied the effect of different preys on biology of *C. carnea* in laboratory and observed that larval duration was long when fed on *Helicoverpa armigera* eggs. The duration of development of *C. carnea* was significantly different on three aphid species. It was the shortest when larvae fed on *A. gossypii*

followed by *M. persicae* and *Lipaphis erysimi* Kalt. (Liu and Chen, 2001). Khuhro *et al.* (2012) investigated effect of different prey species on life history parameters of *C. sinica* and observed that the eggs of *Coreyra cephalonica* and nymphs of *M. persicae* and *A. glycines* were the best of the prey species tested, in that when fed on these species the pre-imaginal developmental period of *C. sinica* was shorter and its adult longevity, fecundity and percentage survival greater than when fed on the other species of prey. In contrast, when fed on nymphs of *A. craccivora* the pre-imaginal development period was longer, adult longevity shorter and fecundity lower than when fed on the other species of prey.

Percentage of pre-imaginal survival to adult stage of *C. carnea* was affected due to feeding on different preys. The maximum survival to adult stage was recorded when *C. carnea* were reared on *A. gossypii* nymphs (78%), while minimum survival to adult stage was found for insects feeding on *A. craccivora* nymphs (62%). The survival rate of *C. carnea* larvae feeding on *A. craccivora*, the larvae of *Drosophila melanogaster* and *C. cephalonica* were 51.8, 80.9 and 86.7%, respectively (Tsfaye and Gautam, 2002).

The maximum female longevity of *C. carnea* feeding on *M. persicae* was 52.78 days and the minimum 45.95 days after feeding on *A. craccivora*. The female longevity of *C. carnea* on *C. pallidus* was found to be 47.32 days (Fathipour and Jafari, 2004).

The maximum fecundity per female of *C. carnea* was 478.50 eggs/female recorded when fed as larvae on *M. persicae*, whereas, the minimum of 242.78 eggs/female was recorded when fed on *A. craccivora* nymphs. While, Tsfaye and Gautam, (2002) observed that *C. carnea* laid 1079, 582 and 172.8 eggs/female when reared on *C. cephalonica*, *D. melanogaster* and *A. craccivora*, respectively.

Liu and Chen (2001) determined the development, survival and predation of *C. carnea* on three aphid species, *A. gossypii*, *M. persicae* and *L. erysimi*. Survival was significantly different on aphid species; when

larvae were fed on *A. gossypii* and *M. persicae*, 94.4 and 87.6% individuals developed to adult stage, respectively; whereas, only 14.9% when fed *L. erysimi*. Duration of development was significantly short (19.8 days) when fed on *A. gossypii* followed by *M. persicae* (22.8 days) and *L. erysimi* (25.5 days).

Osman and Selman (1993) investigated the influence of different aphid species on larval development and fecundity of *C. carnea*. *M. persicae* and *A. pisum* were suitable, while *A. fabae* was most unsuitable prey causing high juvenile mortality. *C. carnea* larvae fed on this aphid and *Macrosiphum albifrons* showed reduced fecundity. Finally this study indicated that among the 5 aphids tested, *A. gossypii* and *M. persicae* were more suitable food sources for mass rearing of *C. carnea* than the other 3 species.

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تأثیر طعمه‌های مختلف روی پارامترهای بیولوژیکی *Chrysoperla carnea* (Neuroptera: Chrysopidae) در شرایط آزمایشگاهی

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چکیده: مناسب بودن طعمه برای شکارچی‌های عمومی، یکی از ویژگی‌های مهم برای پرورش انبوه کارآمد و مدیریت تلفیقی آفات است. بالتوری سبز (*Chrysoperla carnea* (Stephens) یکی از شکارچی‌های چندخوار است که به میزبان‌های متعددی روی گیاهان مختلف حمله می‌کند. این آزمایش در شرایط آزمایشگاهی در دمای 25 ± 2 درجه سانتی‌گراد، رطوبت نسبی 60 ± 5 درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی در دانشگاه شهید باهنر کرمان انجام شد. اثرات گونه‌های مختلف طعمه بر روی رشد و نمو مرحله نابالغ، بقا، طول عمر حشرات کامل و میزان باروری بالتوری سبز مورد بررسی قرار گرفت. نتایج نشان داد که طول دوره رشد و نمو هر کدام از مراحل نابالغ و مجموع کل دوره رشد و نمو در بالتوری *C. carnea* به‌طور معنی‌داری تحت تأثیر گونه‌های طعمه مورد آزمایش قرار داشت. مجموع دوره رشد و نمو به‌ترتیب $0/125 \pm 0/180$ ، $19/63 \pm 0/180$ ، $20/63 \pm 0/183$ ، $22/06 \pm 0/120$ ، $22/35 \pm 0/365$ و $23/81 \pm 23/81$ روز روی طعمه‌های *Aphis gossypii* (Glover)، *Aphis punicae* Myzidae، *Myzus persicae* (Sulzer)، *Aphis craccivora* (Koch) و *Aphis fabae* (Scopoli) (Passerini) بود. بیشترین میانگین باروری در هر حشره ماده با $8/38 \pm 478/50$ تخم، زمانی که لاروهای بالتوری سبز از شته *M. persicae* تغذیه شدند، ثبت شد و در پی آن با $8/16 \pm 409/33$ تخم روی *A. gossypii* دیده شد. بیشترین طول عمر حشرات ماده *C. carnea* زمان تغذیه روی *M. persicae* ثبت گردید. بین طول عمر حشرات ماده به‌خاطر تغذیه روی طعمه‌های مختلف اختلاف معنی‌دار مشاهده گردید. به هر حال پوره‌های *M. persicae* و *A. gossypii* به‌عنوان بهترین گونه‌های طعمه مشخص شدند، چرا که با پرورش و تغذیه *C. carnea* روی این گونه‌ها، دوره رشد و نمو مراحل نابالغ آن کوتاهتر، عمر حشرات بالغ طولانی‌تر، میزان باروری و درصد بقا، بیشتر از زمانی بود که با سایر گونه‌های طعمه مورد آزمایش تغذیه می‌شدند. این یافته‌ها می‌توانند جهت تعیین شرایط بهینه پرورش انبوه *C. carnea* در برنامه‌های مدیریت تلفیقی آفات مفید باشند.

واژگان کلیدی: *Chrysoperla carnea*، بالتوری سبز، رشد و نمو، باروری، طول عمر