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Biological Characteristics of Indigenous *Chrysoperla carnea* (Neuroptera: Chrysopidae) Fed on a Natural and an Alternative Prey

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Authors' contributions

This work was carried out in collaboration between the two authors. Author AA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author SS managed the analyses of the study, performed the statistical analysis, managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Studying of prey suitability for indigenous insect predators is very important factor for their mass rearing in the future. We tested the effects of two different prey species on the preimaginal stages parameters and adult bionomics of the indigenous predator, *Chrysoperla carnea* under laboratory conditions. These prey species are the aphid; *Aphis fabae* as a natural prey and *Ephestia kuehniella* (Zeller) as a factitious prey. The results showed that prey species had a significant effect on preimaginal development times, survival and fecundity. In contrast, adult longevity, egg hatchability and egg duration were not significantly affected by prey species. Eggs of *E. kuehniella* led to high survival rates, short development times for the preimaginal stages and high fecundity. These results would be helpful for mass rearing of *C. carnea* as an indigenous predator in Saudi Arabia and help in designing integrated pest management programs involving its use as a biocontrol agent of aphids on various crops.

Keywords: Bionomics; lacewings; Ephestia eggs; Aphis fabae.

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1. INTRODUCTION

The green lacewings, *Chrysoperla carnea* (Stephens, 1836) (Neuroptera: Chrysopidae) is a cosmopolitan polyphagous predator, commonly found in agricultural systems. It is considered as an effective generalist predator of aphids, thrips, coccids, mealy bugs and mites [1-4]. Moreover, *C. carnea* have a compatibility with different environmental conditions, food diversity, its high searching, its ability to predate about 80 species of pests [5,6,7]. *C. carnea* has been widely used for biological control of aphids and other insect pests because of its polyphagous habits and compatibility with selected chemical insecticides, microbial agents and amenability to mass rearing [8,9]. It has been mass-reared and marketed commercially in the world specially in North America and Europe [5,6].

C. carnea is not a single species; rather, the "*carnea*-group" is a complex of several cryptic species. Cryptic *Chrysoperla* species can only be identified by analyzing duetting courtship songs from live, sexually receptive males and females. Therefore, references to *C. carnea* are qualified by sensu lato or sensu strict [10]. *C. carnea* was recorded in different regions of Saudi Arabia and it was molecularly identified with different mitochondrial genes [11,12].

Indigenous species of natural enemies eventually emerged as the key biocontrol agents [13]. Consequently, local populations of beneficial arthropods may require a period of adaptation to respond maximally to a newly invasive aphid, although this natural process can be impeded or delayed by inherent characteristics of the cropping system and cultural practices, especially the use of broad-spectrum insecticides [14].

The black bean aphid, *Aphis fabae* (Scopoli, 1763) (Hemiptera: Aphididae), is a polyphagous cosmopolitan pest [15]. It is considered as the most important pests of different crops throughout the world such as broad bean and sugar beet in addition to other crops such as cowpea [16]. Eggs of the Mediterranean flour moth, *Ephestia kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) are considered as one of the most factitious prey for mass production coccinellids species because they ensure rapid growth and development, high survival rates and high fecundity [17]. It is very important to identify alternative high quality prey for the successful development of pest management programs that utilize *C. carnea* as a biocontrol agent [18].

The present study aimed to evaluate the developmental and reproductive performance of *C. carnea* when preying on *A. fabae* as a natural prey in comparison to alternative diet, eggs of *E. kuehniella* as a factitious prey under controlled laboratory conditions.

2. MATERIALS AND METHODS

2.1 *C. carnea* Samples

Specimens of the predator, *C. carnea* were obtained from Taif [21° 25' 42" N and 40° 29' 41" E], Saudi Arabia during June 2016 in an area cultivated with clover plants. Each collected male and female pair was maintained in a plastic container (10 cm diameter × 8 cm height) with a hole of 4 cm diameter in the lid and covered by gauze. These adults were fed on an artificial diet [19].

2.2 Prey Species

E. kuehniella eggs were UV sterilized and maintained from a Chrysopa mass production laboratory (Faculty of Agriculture, Cairo University, Egypt). The bean aphid, *A. fabae* nymphs used in this experiments were collected from broad beans (*Vicia faba* L.) plants and reared in the laboratory on *V. faba*.

2.3 Experimental Design

The experiments were carried out in the laboratory at 26±2°C, 16 L: 8 D photoperiods and 65±10% humidity. Each treatment was started with 22 newly hatched larvae as replicates. The newly hatched larvae were transferred individually with a fine hair brush into a plastic petri dishes (5.5 cm diameter and 1.5 cm depth). A piece of filter paper was placed at the bottom of the petri dishes, and a few drops of water were added to maintain humidity [20]. Larvae were fed with sufficient numbers of *A. fabae* instars or *E. kuehniella* eggs until the larvae pupated. The experiments were controlled daily to observe the development periods of eggs, first larvae, second larvae, third larvae and pupae. Females and males fed throughout their larval development on the tested prey species were transferred in pairs on the same day of emergence and maintained in plastic containers as described above. The adult stage was observed daily to investigate the total longevity of males and females. The number of eggs laid by each female was recorded daily.

Thirteen randomly chosen eggs laid by each female were collected in plastic Petri dishes under the same controlled conditions to record the hatching rates and egg duration.

2.4 Statistics

The t-test was used to compare all characters for male and female *C. carnea* between both prey. The analyses were conducted using SPSS version 23 [21].

3. RESULTS

3.1 Effect of Prey Species on Preimaginal Development Time and Survival

The effect of feeding on two different prey by *C. carnea* on its development time is shown in Table 1. The results indicated that the duration of both male and female larval development in *C. carnea* was significantly affected by species of prey tested. The fastest total larval development was obtained on the *E. kuehniella* eggs (13.6 days for females and 13.88 days for males) while these periods on *A. fabae* were 15.13 days for females and 14.75 days for males.

The pupal duration of both males and females were not significantly different when larvae were reared on *E. kuehniella* and *A. fabae*. It was ranged from 10.1 to 10.63 days, respectively (Table 1).

The presented results in Table 2 indicated that the total duration (from larva to adult) in *C. carnea* females was significantly affected by species of prey tested (25.75 and 23.70 days on *A. fabae* and *E. kuehniella* eggs, respectively) but it was not significantly different for males (25.37 and 24.0 days on *A. fabae* and *E. kuehniella* eggs, respectively).

The higher survival rate of pre-imaginal was recorded when *C. carnea* larvae was feeding on *E. kuehniella* eggs (81.8%) while it was 72.7% with feeding on *A. fabae*.

Table 1. Mean of preimaginal developmental stages time (± SE) (days) of *C. carnea* fed on *A. fabae* and *E. kuehniella* eggs at 26±2°C, 16:8 LD and 65±10% RH

Prey species	Developmental time in days ± SE					
	1st larval instar	2nd larval instar	3rd larval instar	Total larva	Pupa	Total (larva-adult)
Females						
A. fabae	3.50±0.19	5.00±0.27	6.63±0.26	15.13±0.35	10.63±0.46	25.75±0.73
E. kuehniella	3.30±0.15	4.60±0.22	5.70±0.21	13.60±0.31	10.10±0.38	23.70±0.45
T values	0.833	1.164	2.762	3.290	0.889	2.506
P	0.417	0.262	0.014	0.005	0.387	0.023
Males						
A. fabae	3.37±0.18	4.88±0.30	6.50±0.19	14.75±0.31	10.63±0.42	25.37±0.50
E. kuehniella eggs	3.25±0.16	4.75±0.31	5.88±0.30	13.88±0.35	10.13±0.40	24.00±0.57
T values	0.509	0.290	1.784	1.861	0.864	1.823
P	0.619	0.776	0.096	0.048	0.402	0.090

Table 2. Adult bionomics of *C. carnea* fed on *A. fabae* and *E. kuehniella* eggs at 26±2°C, 16:8 LD and 65±10% RH

Prey species	Male longevity (days±SE)	Female longevity (days±SE)	Fecundity (eggs/female ± SE)
A. fabae	19.63±1.15	31.00±1.42	373.75±20.71
E. kuehniella eggs	21.13±0.90	32.50±1.60	481.75±29.13
T values	1.030	0.704	3.021
P	0.320	0.493	0.009

3.2 Effect of Prey Species on Adult Longevity and Fecundity

Feeding of different prey to larvae of *C. carnea* (Table 2), significantly affected their fecundity. The mean fecundity per female of *C. carnea* was 373.75 eggs when the larvae was fed on *A. fabae,* whereas it was 481.75 eggs per female when larvae fed on *E. kuehniella* eggs.

There was no significant variation in adult longevity of the same sex due to feeding on different preys although it was higher with feeding on *E. kuehniella* eggs. Female longevity was longer (31.0 and 32.5 days on *A. fabae* and *E. kuehniella* eggs, respectively) than male longevity (19.63 and 21.13 days on *A. fabae* and *E. kuehniella* eggs, respectively) on the same prey (Table 2).

3.3 Effect of Prey Species on Egg Duration and Hatchability

The incubation periods of eggs of *C. carnea* feeding on different prey were 3.43 and 3.4 days on *A. fabae* and *E. kuehniella* eggs, respectively (Table 3). There was no significant difference between both treatments. Also, no significant difference was recorded for the percentage of eggs hatched with feeding larvae on *A. fabae* (83.12%) and *E. kuehniella* eggs (81.25%) (Table 3).

Table 3. Effect of two different prey on progeny of *C. carnea* at 26±2°C, 16:8 LD and 65±10% RH

Prey species	Hatchability %	Egg duration
A. fabae	83.12±2.49	3.43±0.09
E. kuehniella eggs	81.25±2.95	3.40±0.09
T values	0.486	0.258
P	0.635	0.798

4. DISCUSSION

Our experiments indicated that the total larval development of *C. carnea* was shorter on *E. kuehniella* eggs than on *A. fabae*. A previous study stated that the development of *C. carnea* was faster on *E. kuehniella* eggs than on different two aphid species [14]. Larva diets of *Chrysoperla rufilabris* (Burmeister, 1839) that contain proteins can promote fast growth and completion of the larval and pupal period [22]. Other species of chrysopidae have the same character such as *Dichochrysa tacta* (Navás, 1921) larvae which develops faster on *E. kuehniella* than that of three different aphis species [20]. Moreover, various insect predators belong to other orders achieved faster development when *E. kuehniella* eggs as food for their preimaginal stages such as *Hippodamia variegata* (Goeze, 1777) (Cooccinellidae: Coleoptera) [23] and two species of genus *Orius* (Heteroptera, Anthocoridae) [24].

In the present study, the highest survival rate was recorded when *C. carnea* larvae was fed on *E. kuehniella* eggs. Other investigation for *C. carnea* recorded that *A. fabae* was the least suitable prey, causing low survival rate and low fecundity [25].Other study showed that the juvenile survival of *C. carnea* was higher on *E. kuehniella* eggs than the other two different aphid species [14].

The current study recorded higher fecundity of *C. carnea* with larvae feeding on *E. kuehniella* eggs than that of *A. fabae*. Similar findings were recorded for *C. carnea* [26] whereas lower fecundity was achieved for the same predator with feeding on *E. kuehniella* eggs [14]. Moreover, the number of eggs produced (336.4 per female) by *C. carnea* fed with *Rhopalosiphum maidis* (Fitch, 1856) [27], was near to that observed in the present study on *A. fabae*.

Generally, our experiments have shown that *E. kuehniella* eggs were more suitable than *A. fabae* for the development and reproduction of *C. carnea*, resulting in high preimaginal survival rates, short preimaginal development times and increased fecundity. Similar findings have been reported for *Chrysoperla sinica* (= *C. nipponensis* (Okamoto, 1914) [26], *Chrysoperla carnea* [28] and *D. tacta* [22].

5. CONCLUSION

The results showed that prey species had a significant effect on preimaginal development times, survival and fecundity of *C. carnea* while adult longevity, egg hatchability and egg duration were not significantly affected by prey species. Eggs of *E. kuehniella* led to high survival rates, short development times for the preimaginal stages and high fecundity of the predator. These results would be helpful for mass rearing of *C. carnea* as an indigenous predator in Saudi Arabia and help in designing integrated pest management programs involving its use as a biocontrol agent of aphids on various crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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