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Research Article

Biology and predatory potential of *Chrysoperla zastrowi sillemi* (Esben-Peterson) (Neuroptera: Chrysopidae) on *Aphis gossypii* Glover and *Phenacoccus solenopsis* Tinsley in laboratory conditions

V. Thandava Moorthy[1*], S. Mohamed Ashick[2], A. Raghavi[3] and B. Ananda Ganesa Raja[3]

[1]*Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia – 741252, West Bengal, India*

[2]*Department of Entomology, Punjab Agricultural University, Ludhiana – 141004, Punjab, India*

[3]*Department of Entomology, Annamalai University, Chidambaram – 608002, Tamil Nadu, India*

**Corresponding author E-mail*: thandavamoorthy2000@gmail.com

ABSTRACT: A research trial was conducted to investigate the significance of the development and predatory potential of *Chrysoperla zastrowi sillemi* (Esben-Peterson) (Neuroptera: Chrysopidae) against sucking pests, *Aphis gossypii* Glover (Aphididae: Hemiptera) and *Phenacoccus solenopsis* Tinsley (Pseudococcidae: Hemiptera) under laboratory conditions during 2023-2024. Among the seven larval diets tested, the shortest larval (8.13 ± 0.29 days) and pupal period (7.73 ± 0.06 days), highest adult longevity (M: 24.26 ± 0.24 days, F: 38.66 ± 0.46 days), and maximum fecundity (447.33 ± 21.71) were observed, when the *C. zastrowi sillemi* larvae fed on eggs of *C. cephalonica* followed by adults of *A. gossypii.* These larval diets proved to be the most suitable regime for supporting the optimal growth and development of *C. zastrowi sillemi*. The predatory potential of *C. zastrowi sillemi* increased with larval stage advancement. Maximum predation rate was observed when *Chrysoperla* larvae fed on the first instars of *P. solenopsis* (893.66 ± 13.73), followed by eggs of *C. cephalonica* (724.33 ± 24.67) and nymphs of *A. gossypii* (495.33 ± 5.81). Results suggested that *C. zastrowi sillemi* could be a potential alternative to conventional insecticides for managing *A. gossypii* and *P. solenopsis*. It can be effectively used as a sustainable and environmentally sound component for integrated pest management strategies.

KEYWORDS: Biology, *C. zastrowi sillemi*, Integrated pest management and predatory potential

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INTRODUCTION

The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), and the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), are the most serious sucking insect pests of economically important agricultural and horticultural crops worldwide (Waqas *et al*., 2021; Zha *et al*., 2024).

Aphis gossypii is a cosmopolitan insect species infesting nearly 900 plant species around the world (Blackman and Eastop, 2000). In India, *A. gossypii* infests 569 species from 103 plant families, including Cucurbitaceae, Fabaceae, Malvaceae, Solanaceae, etc. (Singh *et al.,* 2014). It causes direct damage to the plants by sucking their sap, which causes a loss of vigour, decreased growth rates, yellowing, stunted growth, curled leaves, and death (Singh and Singh,2021). It is also responsible for some indirect damage to the plants by excreting honey dew, which allows the growth of black sooty mould (*Capnodium spp*.) on the leaves. Aphids can transmit various viral diseases, including banana mosaic, papaya mosaic, papaya ring spot, citrus tristeza and passion fruit woody virus.

Phenacoccus solenopsis, an invasive species of mealybug, was reported in India in 2005 and is causing serious damage to cotton (Hodgson *et al.,* 2008). The pest

has been reported in 194 host species from 50 families in India (Vennila *et al.,* 2011). Mealybugs primarily suck the sap from the plant phloem, which causes decreased plant vigour and the excretion of sticky sap and waxy substances, which affect the quality of fruits, especially when the sooty mould grows (Subramanian *et al.,* 2021).

Managing these highly aggressive sucking pests has become increasingly challenging, primarily due to farmers' growing reliance on chemical insecticides as their preferred control strategy. The use of synthetic chemical insecticides poses various environmental risks, including insecticide residue, insect resistance development and resurgence of pests (Maurya *et al*., 2022). The best alternative method to tackle these pest problems is to develop a biocontrol strategy involving potential natural enemies, which could be successfully incorporated into an Integrated Pest Management (IPM) program (Bhatt and Karnatak, 2018). The insect predators are distributed in about 167 families of 14 orders of the class Insecta. Some important predatory insect orders, such as Coleoptera, Neuroptera, Hymenoptera, Diptera and Hemiptera, contain significant predators (Sattar *et al.,* 2011).

Chrysoperla zastrowi sillemi (Esben-Peterson) (Neuroptera: Chrysopidae), a widely distributed generalist larval predator, plays a pivotal role in suppressing populations of soft-bodied pests across diverse cropping systems, thereby contributing to sustainable farming practices (Kalkal *et al*., 2024). It is also regarded as an aphid-lion that has a wide range of larval hosts like mealybugs, aphids and thrips, as well as eggs of different lepidopterans. (Carrillo and Elanov, 2004). Adult *C. zastrowi sillemi* feed primarily on nectar and pollen.

The mass production of natural enemies is essential for augmentative biological control programs. It is necessary to get a large population of predators to release in the field (Sahayaraj, 2001). The growth rate and the development of the predator's life table depend on the quantity and quality of the prey (Awadallah *et al.,*1986). Because the particular prey species observed to be eaten in the field is not necessarily suitable for their survival and development (Balasubramani and Swamiappan, 1994). Therefore, before incorporating *C. zastrowi sillemi* into the Integrated pest management program for *A. gossypii* and *P. solenopsis,* it is essential to evaluate its biological parameters when reared on these sucking pests. Such information will provide valuable insights for the efficient mass rearing of *C. zastrowi sillemi* and assessing its potential as a biological control agent against these economically important pests.

MATERIALS AND METHODS

The experiment was conducted under laboratory conditions at the Department of Entomology, Annamalai University, Cuddalore district, Tamil Nadu, India, to evaluate the biology and predatory potential of the green lacewing (*C. carnea*) against nymphs and adults of *A. gossypii,* first to third instars and adults of *P. solenopsis* and eggs of *C. cephalonica*.

Culture of prey insects

Aphis gossypii

Adult aphids were collected from the cotton field and released on the twenty-day-old cotton plants by using a camel hair brush. Plants were raised in pots and covered with fine mesh to control the movement of aphids from the culture. Aphid populations were monitored regularly, and a new batch of seedlings was raised to ensure the continuous maintenance of the culture.

Phenacoccus solenopsis

Medium-sized potato tubers with well-developed eyes were procured from a local market. These tubers were thoroughly washed and placed in a dark room to initiate sprouting. Once the tubers sprouted, they were arranged in a plastic tray with sand covering half of the tubers to retain moisture. Adult *P. solenopsis* were collected from the cotton field and released onto the tubers. After a week, adults began to lay eggs and the culture was well established. This setup was maintained under laboratory conditions at a temperature of 25°C and a relative humidity of 75%.

Corcyra cephalonica

The nucleus egg culture of *C. cephalonica* was procured from the Agriculture College and Research Institute, Madurai. The eggs were dispersed in the growth medium (sorghum grains + yeast + wettable sulphur) in trays covered with muslin cloth. After 45-60 days, the emerged adults were carefully transferred to an adult oviposition cage. To sustain fecundity and longevity, they were fed a nutritive mixture of honey and a vitamin E capsule. Eggs were collected from the cage daily, sterilised under UV light, and stored in the refrigerator at 10°C.

Culture of predator, *C. carnea*

Eggs of *C. zastrowi sillemi* were procured from the Biocontrol Laboratory, Agriculture College and Research

Institute (AC and RI), Madurai, Tamil Nadu Agricultural University (TNAU) and maintained under laboratory conditions (25 ± 5 ºC, 65± 5 % R.H.). The eggs were kept separately, and hatched neonate larvae were individually transferred to a multi-cavity tray. Sterilised eggs of *C. cephalonica* were provided in sufficient quantities as food for the *C. zastrowi sillemi* larvae to complete their larval stage. The pupae were subsequently transferred to glass jars for adult emergence. Adults were maintained in cylindrical glass jars (height 18 cm, diameter 10 cm) covered with black muslin cloth as a substrate for egg laying. Adults were given an artificial diet consisting of equal parts of proteinex, honey, a vitamin E capsule, and water. The diet was administered once a day in the form of small droplets placed on paper strips. After two generations of laboratory rearing, the newly emerged adults were sexed, and five pairs of adults were introduced into glass jars for oviposition. The newly hatched larvae obtained from these adults were used in the experimental trials.

Experimental techniques

The experiment was laid out in a Completely Randomised Design (CRD) with three replications and seven treatments, *viz*., nymphs and adults of *A. gossypii,* first-, second- and third-instar nymphs and adults of *P. solenopsis* and eggs of *C. cephalonica.* Each replication consisted of five neonate *C. zastrowi sillemi* larvae fed their respective prey species. Thus, 15 predator larvae were evaluated per treatment, with a total of 105 larvae used across all treatments. A sufficient number of fresh prey individuals were provided daily to the *C. zastrowi sillemi* larvae throughout the experimental period.

Developmental stages of prey insects were identified based on morphological characteristics such as body size and appendage structure under stereo microscopy in accordance with Hodgson *et al.,* (2008) for *P. solenopsis* (first, second, third instar and adult) and Vadher and Acharya (2022) for *A. gossypii* (nymph and adult). Individuals were sourced from age-monitored laboratory colonies to ensure stage-specific treatment.

Biology of *C. carnea*

To investigate the larval period and pupal period of *C. carnea,* in each treatment, fifteen neonate larvae were used. Newly hatched larvae obtained from the laboratory culture were transferred individually to the Petri plates lined with moist blotting paper. A predetermined number of respective preys provided daily in sufficient quantities until the larvae pupated. The developing larvae were observed daily for the presence of exuviae to determine the duration of each larval instar. Upon pupation, the pupae were individually transferred to glass jars, where they were maintained until adult emergence to determine the pupal duration.

A total of 105 *C. zastrowi sillemi* adults (15 from each treatment) were examined under a microscope on the day of emergence and sorted according to sex (females have a bulged abdomen). A single pair from the same treatment was confined in a glass jar (12 cm diameter and 20 cm height) and supplied with an artificial diet (water:honey:proteinex:vitamin E). The top of the cylindrical glass jar was covered with black absorbent cloth, which acted as a substrate for egg laying. Adults were monitored twice a day at 10 am and 5 pm to calculate the adult development and reproductive parameters.

To calculate the incubation period of eggs, ten eggs laid by each female were collected daily throughout the female's oviposition period following the method of Takalloozadeh (2015). The eggs were carefully detached using a sharp razor blade and individually transferred to test tubes (1 cm diameter, 5 cm length). Egg hatch was monitored daily, and the incubation period was recorded for each egg. All experiments were conducted under laboratory conditions at 25 ± 5 ºC and RH of 65 ± 5%.

Predatory potential of *C. carnea*

To determine the predatory potential of *C. carnea,* neonate larvae from a laboratory colony were used. Individual larvae were placed in separate Petri dishes and provided with a predetermined number of the respective prey species. The number of prey offered daily was adjusted according to the larval stage of the predator. Before fresh prey were supplied each day, the number of prey consumed (empty chorion, collapsed aphids and mealybugs) on the previous day was recorded. Three replicates were maintained for each prey species. The *C. zastrowi sillemi* larvae were examined daily to record ecdysis and monitor their developmental progress. Observations were made on the number of prey consumed during each larval instar, and the total prey consumption throughout the development period was calculated. All experiments were conducted under laboratory conditions at 25 ± 5°C and RH of 65 ± 5%.

Statistical analysis

The recorded data on the development, reproductive parameters, and predatory potential of *C. zastrowi sillemi*

were subjected to analysis of variance (ANOVA), and the treatment means were compared using Duncan's Multiple Range Test (DMRT) with the help of OPSTAT software as an analysis tool.

RESULTS AND DISCUSSION

The results of the present study demonstrated that different prey diets significantly influenced the developmental biology of *C. zastrowi sillemi* as well as the predatory potential of its larval stages, as reflected by the number of test insects consumed during development.

Biology of *C. zastrowi sillemi*

Optimising larval nutrition plays a crucial role in enhancing biological traits that support large-scale laboratory rearing of this beneficial predator. Larval diet significantly affects the biology of *C. carnea.* The results on the effect of larval diet on developmental and reproductive parameters of *C. zastrowi sillemi* are presented in Tables 1 and 2, respectively.

Chrysoperla zastrowi sillemi completed its life cycle on all the tested prey except the adult stage of *P. solenopsis,* because the first instar larvae of *C. zastrowi sillemi* were unable to feed on adult mealybugs. This limitation is likely attributable to the relatively larger size of the prey, which prevented successful predation by the newly hatched larvae. Consequently, the developmental and reproductive parameters of *C. zastrowi sillemi* could not be evaluated when fed exclusively on adult *P. solenopsis.*

Larval period

The experimental results indicated that the larval duration of *C. zastrowi sillemi* differed significantly among



Figure 1. First instar larva of C. *zastrowi sillemi* feeding on *C. cephalonica* egg.



Figure 2. Third instar larva of C. *zastrowi sillemi* feeding on adult *P. solenopsis.*

individuals reared on different prey species(F = 8.30; P<0.001).

The shortest duration of the first instar of *C. zastrowi sillemi* larvae was observed when reared on eggs of *C. cephalonica* (2.47 ± 0.06 days), followed by adults of *A. gossypii* (2.53 ± 0.06 days) and the longest larval duration was observed in the first and second instars of *P. solenopsis* (2.80 ± 0.11 days). The same trend was followed in the second and third instar larval duration (Table 1). The longest total larval period of *C. zastrowi sillemi* was recorded on the first instar of *P. solenopsis* (9.87 ± 0.17 days) and the lowest total larval period was recorded when the larvae fed on eggs of *C. cephalonica* (8.13 ± 0.29 days) and adults of *A. gossypii* (8.33 ± 0.17 days). The order of complete larval development period on different insect prey was eggs of *C. cephalonica* < adults of *A. gossypii* < nymphs of *A. gossypii* < third instar of *P. solenopsis* < second instar of *P. solenopsis* < first instar of *P. solenopsis* (Table 1). A similar observation was made by Balasubramani and Swamiappan (1994),who found that the larval development was shortest on eggs of *C. cephalonica* (8.20 days) and longest on neonates of *H. armigera* (11.10 days). Similar observations on the suitability of laboratory prey over other natural prey were made by Awadallah *et al*., (1975) and Beglyarov and Ponomoreva (1983).

Pupal period

The pupal period of *C. zastrowi sillemi* differed significantly among the host species, indicating that larval diet had a pronounced effect on pupal development (F = 9.30; P<0.001). The lowest pupal period of 7.73 ± 0.06 days was recorded when the larva fed on eggs of *C. cephalonica,* followed by adults of *A. gossypii* (8.27 ± 0.13 days). These results are similar to those of Sattar *et al.,* (2011), who found

that the pupal period was shortest when *C. zastrowi sillemi* fed on *A. gossypii*. These results were in contrast with the findings of Kumar *et al.,* (2019), who reported that the pupal period was maximum (11.00 days) when *C. zastrowi sillemi* larvae were reared on the eggs of *C. cephalonica*.

Adult period

Adult longevity was significantly affected by larval diet, with significant variation observed among host treatments for both males ($F = 32.98$; $P < 0.001$) and females ($F = 32.34$; $P < 0.001$). The highest male and female longevity was recorded as 24.26 ± 0.24 days and 38.66 ± 0.46 days, respectively, when larvae fed on eggs of *C. cephalonica.* The lowest male and female longevity were noticed on the first instar of *P. solenopsis* as 19.73 ± 0.33 days and 31.07 ± 0.63 days, respectively. Our results corroborate earlier work by Manjunatha (2018), who observed that the male longevity was 21.50 and 24.80 days and female longevity of 35.50 and 38.50 days, when larvae of *C. zastrowi sillemi* were reared on eggs of *C. cephalonica* and *A. gossypii,* respectively.

Egg incubation period

The egg incubation period of *C. zastrowi sillemi* differed significantly across the various host species evaluated ($F = 9.18$; $P < 0.001$). The lowest incubation period of 2.33 ± 0.17 days was recorded when larvae were reared on eggs of *C. cephalonica,* followed by adults of *A. gossypii* (2.53 ± 0.07 days), and the highest incubation period was observed in the first instar of *P. solenopsis* (3.67 ± 0.11 days). This aligns with earlier findings by Nahiyoon *et al.,* (2020), who reported that the incubation period of 3.00 days on *A. gossypii.*

Reproductive parameters

The shortest pre-oviposition period was noticed in predators reared on eggs of *C. cephalonica* (2.87 ± 0.24 days) followed by adults of *A. gossypii* (3.13 ± 0.24 days), whereas the longest oviposition period was noticed on eggs of *C. cephalonica* (29.20 ± 2.65 days) and the shortest post-oviposition period was noticed in adults of *A. gossypii* (6.20 ± 0.69 days) followed by nymphs of *A. gossypii* (6.80 ± 0.80 days). The present findings were comparable

Table 1. Effect of different larval diets on the developmental parameters of *C. zastrowi sillemi*in laboratory conditions (Mean ± SE)

Treatment	Egg incubation period (days)	First instar (days)	Second instar (days)	Third instar (days)	Total larval period (days)	Pupal period (days)	Adult longevity	
							Male (days)	Female (days)
Nymphs of *A. gossypii*	2.73 ± 0.06 ab	2.60 ± 0.11 abc	2.87 ± 0.07 ab	3.20 ± 0.23 bc	8.67 ± 0.24 bc	8.47 ± 0.06 bc	23.20 ± 0.31 b	37.33 ± 0.75 a
Adults of *A. gossypii*	2.53 ± 0.07 a	2.53 ± 0.06 ab	2.73 ± 0.06 ab	3.07 ± 0.24 ab	8.33 ± 0.17 b	8.27 ± 0.13 b	23.67 ± 0.29 ab	37.80 ± 0.57 a
1st instar of *P. solenopsis*	3.67 ± 0.11 c	2.80 ± 0.11 c	3.20 ± 0.12 cd	3.87 ± 0.06 c	9.87 ± 0.17 d	9.33 ± 0.13 d	19.73 ± 0.33 e	31.07 ± 0.63 c
2nd instar of *P. solenopsis*	3.40 ± 0.30 c	2.80 ± 0.11 c	3.33 ± 0.13 d	3.40 ± 0.20 abc	9.53 ± 0.37 d	8.93 ± 0.24 cd	21.13 ± 0.29 d	32.53 ± 0.29 bc
3rd instar of P. solenopsis	3.13 ± 0.13 bc	2.73 ± 0.06 bc	3.00 ± 0.11 bc	3.53 ± 0.17 bc	9.27 ± 0.06 cd	8.60 ± 0.30 bc	22.07 ± 0.43 c	33.60 ± 0.50 b
Adult of *P. solenopsis*	NA	NA	NA	NA	NA	NA	NA	NA
Eggs of *C. cephalonica*	2.33 ± 0.17 a	2.47 ± 0.06 a	2.67 ± 0.13 a	3.00 ± 0.11 a	8.13 ± 0.29 a	7.73 ± 0.06 a	24.26 ± 0.24 a	38.66 ± 0.46 a

In each column, figures followed by the same letter are not significantly different from each other at 5% DMRT.

*NA = Not applicable. First-instar larvae of *Chrysoperla zastrowi sillemi*did not survive when fed adults of *P. solenopsis*; therefore, the subsequent developmental parameters could not be recorded.

with those of Khan *et al.,* (2013), with respect to the post-oviposition period, who reported an oviposition period of 34.6 days when the larvae of *C. zastrowi sillemi* fed on the wheat aphid.

Feeding larvae of *C. zastrowi sillemi* with different host species significantly influenced their fecundity (Shaukat, 2018). The results of the study suggest that prey consumption during the immature stages of *C. zastrowi sillemi* led to enhanced reproductive output. This may be attributed to the higher nutritional value, specifically elevated levels of proteins, lipids, carbohydrates, ash, vitamins, caloric acid, and cholesterol found in the nymphs and adults of *A. gossypii* and the third instar of *P. solenopsis.* Some authors also concluded that high reproduction is closely related to the biochemical composition of the diet (Ulhaq *et al.,* 2006).

In the present study, fecundity of *C. zastrowi sillemi* differed significantly among larvae reared on different host species (F = 7.47; P<0.001). The highest fecundity was recorded when larvae were reared on eggs of *C. cephalonica* (447.33 ± 21.71 eggs), followed by adults of *A. gossypii* (415.73 ± 18.45eggs), and the lowest fecundity (313.4 ± 10.10 eggs) was observed in the first instar of *P. solenopsis.* This is in agreement with the findings of Shaukat (2018), who reported that the highest fecundity was observed when larvae of *C. zastrowi sillemi* fed on *Sitotroga cerealella* (503.30 eggs), followed by nymphs/adults of *Aphis gossypii* (419.80 eggs) and first instar nymphs of *P. solenopsis* (384.00 eggs). In the emerged adults (15 per treatment), the maximum number of females was recorded in adults of *A. gossypii* and eggs of *C. cephalonica,* both registering the same percentage of 53.33%.

Predatory potential of *C. carnea*

The mean prey consumption of *C. zastrowi sillemi* larvae differed significantly among the host diets, indicating that prey species had a significant influence on their feeding capacity (F = 460.43; P < 0.001).

The results on the predatory potential of *C. zastrowi sillemi* against *A. gossypii* and *P. solenopsis* are presented in Table 3. It was found that the first instar of *C. zastrowi sillemi* had the highest predatory potential against the first instar of *P. solenopsis* (133.66 ± 9.77), followed by eggs of *C. cephalonica* (67.66± 5.36). Consequently, first-instar *C. zastrowi sillemi* larvae failed to survive when adult *P. solenopsis* were provided as the sole prey, indicating that adult mealybugs are unsuitable prey for this developmental stage. Variations in the predator's ability to recognise suitable prey may be related to their morphological differences (Dixon, 2000), the changes in the chemical characteristics

Table 2. Effect of Different Larval Diets on the Reproductive Parameters of *C. zastrowi sillemi* in Laboratory Conditions (Mean ± SE)

Prey	Pre-oviposition (days)	Oviposition (days)	Post-oviposition (days)	Fecundity (days)
Nymphs of *A. gossypii*	3.33 ± 0.24 abc	27.40 ± 1.56 ab	6.80 ± 0.80 a	402.2 ± 17.52 ab
Adults of *A. gossypii*	3.13 ± 0.24 ab	28.07 ± 2.52 ab	6.20 ± 0.69 a	415.73 ± 18.45 a
1st instar of *P. solenopsis*	4.27 ± 0.58 c	19.73 ± 2.25 c	7.33 ± 0.88 a	313.4 ± 10.10 c
2nd instar of *P. solenopsis*	4.13 ± 0.29 bc	21.27 ±2.77 bc	7.13 ± 0.58 a	333.6 ± 15.63 c
3rd instar of P. solenopsis	3.67 ± 0.46 abc	22.60 ± 3.02 abc	7.20 ± 0.43 a	361.8 ± 16.47 bc
Adult of *P. solenopsis*	NA	NA	NA	NA
Eggs of *C. cephalonica*	2.87 ± 0.24 a	29.20 ± 2.65 a	6.93 ± 0.46 a	447.33 ± 21.71 a

In each column, figures followed by the same letter are not significantly different from each other at 5% DMRT. *NA = Not Applicable. First-instar larvae of *Chrysoperla zastrowi sillemi* did not survive when fed adults of *P. solenopsis*; therefore, the subsequent developmental parameters could not be recorded.

Table 3. Predatory Potential of *C. zastrowi sillemi* against *A. gossypii* and *P. solenopsis* in Laboratory Conditions (Mean ± SE)

Treatment	First instar	Second instar	Third instar	Total
Nymphs of *A. gossypii*	47.67 ± 1.45 c	118.33 ± 7.26 c	329.33 ± 5.23 b	495.33 ± 5.81 c
Adults of *A. gossypii*	40.66 ± 1.33 cd	96.33 ± 3.28 d	265.00 ± 15.00 c	402.00 ± 18.03 d
1st instar of *P. solenopsis*	133.66 ± 9.77 a	303.33 ± 12.01 a	456.66 ± 12.01 a	893.66 ± 13.73 a
2nd instar of *P. solenopsis*	34.00 ± 3.21 d	75.66 ± 3.48 e	172.33 ± 6.69 d	282.00 ± 7.02 e
3rd instar of *P. solenopsis*	19.66 ± 1.20 e	39.66 ± 3.71 f	105.66 ± 4.70 e	165.00 ± 5.13 f
Adult of *P. solenopsis*	0.00 ± 0.00 f	27.00 ± 2.64 g	36.66 ± 8.51 f	63.66 ± 10.8g
Eggs of *C. cephalonica*	67.66 ± 5.36 b	213.33 ± 12.01 b	443.33 ± 12.01 a	724.33 ± 24.67 b

In each column, figures followed by the same letter are not significantly different from each other at 5% DMRT.

of prey (Omkar and Bind**,** 2004), or the combination of these factors. Figure 1 highlights the predation activity of *C. zastrowi sillemi* first instar on eggs of *C. cephalonica.*

The second instar had the highest predation of 303.33± 12.01 first instar mealybugs, followed by eggs of *C. cephalonica* (213.33 ± 12.01) and nymphs of *A. gossypii* (118.33 ± 7.26) and the lowest predation was recorded on adults of *P. solenopsis* (27.0 ± 2.64). The third instar larva had the maximum predation on the first instar of *P. solenopsis* (456.66 ± 12.01), followed by eggs of *C. cephalonica* (443.33 ± 12.01). The total number of prey insects consumed during the larval stage of *C. zastrowi sillemi* was maximum in the first instar of *P. solenopsis* (893.66 ± 13.73), followed by eggs of *C. cephalonica* (724.33 ± 24.67). Minimum predation activity was recorded in adults of *P. solenopsis* (63.66 ± 10.8) (Figure 2).

Similar findings by El-Zahi (2017) who reported that during the entire larval stage of *C. carnea,* the single larva consumed 990.8 ± 19.08, 3457.4 ± 28.31, and 521.1 ± 9.79, and 144.0 ± 15.12 insects of *A. gossypii*, 1st, 2nd and 3rd instar nymphs of *P. solenopsis*, respectively and Sattar *et al*., (2007), informed that *C. zastrowi sillemi* in its entire larval period consumed an average of 1064.0, 689.0 and 144.7 of first, second and third instar nymphs of *P. solenopsis*, respectively, in no-choice feeding.

The high feeding potential of *C. zastrowi sillemi* on the first instar of *P. solenopsis* may be due to the absence of a waxy coating on the prey, its small size and high mobility compared to the other larval diets, where *C. zastrowi sillemi* prefers to attack fast-moving prey rather than slow ones (Huang and Enkegaard, 2010).

CONCLUSION

The present study explored the biology and predatory potential of *C. zastrowi sillemi* for managing *A. gossypii* and *P. solenopsis*. The findings indicated that feeding on different hosts in the larval stage of *C. zastrowi sillemi* had a significant impact on the various biological parameters from the egg to the adult stage of the predator. Larvae of *C. zastrowi sillemi* prefer laboratory hosts over natural prey. Among the natural prey, nymphs and adults of *A. gossypii* had a positive effect on their development and reproductive parameters. Notably, in the mass multiplication

of *C. carnea, A. gossypii* can be utilised as larval prey to restore the fecundity of *C. zastrowi sillemi* that may decline after continuous rearing on eggs of *C. cephalonica.*

Contemporary research on predatory potential indicated that *C. zastrowi sillemi* larvae are highly voracious feeders on nymphs and adults of *A. gossypii* and different instar nymphs of *P. solenopsis*. The second and third larval instars of *C. zastrowi sillemi* exhibited higher predatory potential than the first larval instar. The findings highlight the potential of releasing second-instar grubs of *C. zastrowi sillemi* to effectively reduce the population of *A. gossypii* and *P. solenopsis*. Further evaluation is recommended to confirm their efficacy under semi-field and field conditions and optimise application strategies for integrated pest management programs.

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