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Research Article

Morphometrics and predation potential of green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Peterson) on cowpea aphid, *Aphis craccivora* Koch

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ABSTRACT: A research trial to exploit the importance of life cycle phases and predatory potential of *Chrysoperla zastrowi sillemi* (Esben-Peterson) on cowpea aphid, *Aphis craccivora* Koch was carried out under laboratory conditions during 2022-23. Predator grub emerged from the egg within 3.00±0.72 days with a hatching percentage of 89.54±2.58. The avg. duration of the first, second, third instar and total larval phase was 2.48±0.50, 3.44±0.50, 3.84±0.99 and 8.68±0.47 days, respectively. The avg. pre-pupal duration was 1.00±0.00 days and that of pupa was 8.26±01.32 days. The mean interval of oviposition was 24.7±5.15 days. Male and female adult longevity was 23.96±3.61 and 34.36±3.81days, respectively. The total life cycle was completed in 34.38±5.81 days. In the feeding potential study, the average daily consumption of aphids during the first, second and third larval instars were 9.28±0.45, 20.86±0.53 and 27.94±0.59 as well the average total number of aphids consumed was 31.20±4.04, 64.32±3.06 and 116.4±2.49, respectively. The total per day consumption of aphids and prey consumed in the entire larval duration was 58.08±0.89 and 211.6±6.4 number of aphids, respectively. According to the findings, the green lacewing, *C. zastrowi sillemi*, has a high chance of surviving on cowpea aphids at every stage and can be a great support to an organic pest management program, offering advantages all through the growing season.

KEYWORDS: *Aphis craccivora*, biology, *Chrysoperla zastrowi sillemi*, cowpea, feeding potential

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INTRODUCTION

Biological nitrogen fixation is one of the significant benefits of cowpea, *Vigna unguiculata* L. (Fabaceae) cultivation in diversified cropping systems, but it is infested by many insect pests and one of the reasons for low productivity. Aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae) is a major pest-sucking plant sap and is known as a vector to transmit a number of viruses and result in yield loss. In the last few years, there has been a trend of shifting from chemical pest control to integrated pest management in short-duration crops. In IPM, greater emphasis has been given to biological control for environmental safety and to avoid pesticide residues. Among the various predacious insect species, the common green lacewing, *Chrysoperla* spp. is awfully vital for managing sucking pests of various crops.

The common green lacewing, *Chrysoperla* spp. is a well-established and efficient predator in pest management packages. Its improved seeking ability and ravenous feeding habit allow it to capture a wide variety of hosts. There are many examples of *Chrysoperla* spp. available showing a broad range of prey acceptance and can be multiplied in large numbers under laboratory circumstances (Araujo & Bichao, 1990). *Chrysoperla* is the predominant genus in India with several species that are extensively used in augmentation (Gautam, 1994).

Despite all these benefits, *Chrysoperla* spp. in the field is rare due to the frequent use of non-selective agrochemicals (Nasreen *et al.,* 2005). Green lacewing, *C. zastrowi sillemi* is a wide-ranging predator of soft-bodied sucking insects *viz.*, aphids, whiteflies, thrips, mites along with immature mealybugs, scales and other pests (Saminathan *et al*. 1999). In India, green lacewing, *C. carnea* (Stephens) has been taxonomically modified to *C. zastrowi sillemi* (Venkatesan *et al.*, 2008; Henry *et al.*, 2010).

The suitability of prey for polyphagous predators can vary greatly according to habitat and the natural pressure of the ecosystem. Therefore to make use of predators in augmentation, the research trial based on the life cycle and

consumption perspective of *C. zastrowi sillemi* on cowpea aphid, *A. craccivora* was conducted under laboratory conditions.

MATERIALS AND METHODS

Culture of *Corcyra cephalonica*

To obtain eggs of *C. cephalonica* throughout the experimental period, the host culture was reared in large size under laboratory at the Bio-control Laboratory, Department of Entomology, NMCA, NAU, Navsari in order to have a continuous supply of food to *C. zastrowi sillemi*. The insect culture was maintained on a sorghum grain-based artificial diet at the Bio-control laboratory to rear the various parasitoids and predators regularly.

Culture of predator, *C. zastrowi sillemi*

The initial culture of a pupa of a predator, *C. zastrowi sillemi* was procured from ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, Karnataka. Pupae were moved to an oviposition chamber after being housed in a container for adult emergence. A diet consisting of equal parts proteinex, honey, and yeast with a small amount of water and a vitamin E capsule was given to the adults along with castor pollen and cotton swabs dipped in drinking water, 50% honey solution and proteinex mixture kept in plastic container lids. The black paper sheet that surrounded the oviposition cage was changed daily. The top was covered with a cloth. On the black paper sheet, an adult female begins to lay eggs, and these sheets are changed every day. After cutting the egg stalks from the black paper sheets with a sharpened knife, the eggs were placed into plastic vials. These just-deposited eggs were used for further study.

Culture of prey insect (Cowpea aphid)

The aphid culture was reared on the cowpea plant. Seeds of cowpea were sown in pots for growing of host crop of test insects at the Department of Entomology, NMCA, NAU, Navsari. Cowpea aphids were collected from infested fields and released on cowpea plants throughout the experiment phase to maintain culture. After one month, the culture was developed and further utilized as a prey host for further research.

Development period of a predator, *C. zastrowi sillemi*

Development period from the egg stage (incubation, hatching per cent), instar-wise larval, pre-pupal and pupal periods were determined daily. After the emergence of adults from the pupa, they were transferred into the mating chamber. The mating chamber was made of glass goggles (5 cm x 10 cm) covered by a nylon net from the upper side. The adults were provided with an appropriate diet. After the determination of the sex of the adult, they were paired and one pair was transferred into an individual oviposition chamber. The oviposition container was surrounded by a black paper sheet from the inside. Observation on male and female adult longevity, pre-oviposition and oviposition duration and sex ratio were noted daily. The developmental period of the test insect was studied on *A. craccivora* under 25±1°C temperature, 70±5% Relative Humidity (RH) and 12:12 h photoperiod.

Predatory potential of *C. zastrowi sillemi* on *A. craccivora*

The same culture used for the developmental period of cowpea aphids, *A. craccivora* and *C. zastrowi sillemi* were utilized for the feeding potential study. Fifty freshly hatched larvae of *C. zastrowi sillemi* were reared on cowpea aphid*, A. craccivora* and the predator grub was fed with a counted number of aphids until they were pupated. The cowpea aphids of the second or third instar were selected by vigilant judgment from cowpea leaves under the Stereo zoom binocular microscope. The superfluous stages of cowpea aphids were discarded with the help of a soft hairbrush. The bottom of the Petri plate was covered with wet blotting paper. Observations on the number of preys consumed at an interval of 24 h were noted along with the total quantity of preys consumed in every instar of grub and per day throughout the life period. Average consumption along with standard deviation was estimated by using MS Excel to conclude.

RESULTS AND DISCUSSION

Egg

The female adult of green lacewing laid single-stalked green eggs. The eggs turned brown just before hatching. The length of the *C. zastrowi sillemi* egg was noted between 0.73 to 0.88 mm with avg. 0.80±0.05 mm, whereas the breadth was 0.27 to 0.38 mm (Avg. 0.33±0.03) (Table 1). These results are very similar to the findings of Shinde *et al*. (2009).

The incubation period ranged between 2 to 4 days with an avg. of 3.0±0.72 days (Table 2). This result is analogous to the figures of Vivek *et al.* (2013) who noted avg. 3.0±0.15 days incubation period of *C. zastrowi sillemi* on *A. craccivora*, while Singh *et al.* (2020) recorded 3.0±0.10 days on *C. cephalonica* under laboratory conditions. While slightly greater incubation period (3.94 days) than the present finding was noted by Mhaske *et al.* (2017) on cotton aphids. Likewise, Shinde *et al*. (2009) noted an avg. 4.46±0.50 days in *C. carnea* reared on *A. craccivora*, Sheilaja (2016) found an avg. 3.4±0.24 days in *Chrysoperla* sp. reared on, *A. craccivora*, and Beerendra (2019) counted an avg. 3.4±0.24 days in *Chrysoperla* spp., which is a longer period than the current investigation. However, a slightly lower period of *C. zastrowi sillemi* (2.60±0.16 days) was noted by Kumari *et al.* (2020) on cotton aphids.

The results of the hatching percentage of eggs varies from 85 to 92% with an avg. of 89.54±2.58% under laboratory conditions (Table 2). Previously, Mhaske *et al.* (2017) found 89% hatching in *C. zastrowi sillemi* on cotton aphids, while Saminathan *et al.* (1999), Shinde *et al*. (2009), Sheilaja (2016) and Beerendra (2019) reported 83.72, 73.17 to 84.61, 76.0±2.45 76.27±1.42%, which is more or less nearer hatching percentage of *C. carnea* on *A. craccivora*. However, Imam (2020) recorded 95.87% hatching in *C. carnea* reared on *A. craccivora*, which is slightly higher than the present data.

First instar larva

The biometrical results can be seen in Table 1 showed that the length of the first instar larva varies from 1.92 to 2.71 mm (Avg. 2.29±0.26) and breadth from 0.41 to 0.71 mm (Avg. 0.56±0.10). The first instar was usually white or pale yellow. The larvae in their first instar have tiny bristles on their lateral sides and begin to lengthen in size before tapering progressively toward the head and body. Strong and well-developed, the mandibles have a sickle form. Larvae in their first instar lived for two to three days (Avg. 2.48±0.50) depicted in Table 2.

The present findings are similar to the observations of *C. carnea* recorded by Shinde *et al*. (2009), Sheilaja (2016) and Imam (2020) when reared on cowpea aphid, *A. craccivora*. While slightly higher first instar larval period of *C. zastrowi sillemi* was measured in reports of Vivek *et al*. (2013) and Kumari *et al.* (2020) with different aphid hosts. Also, the higher duration of *C. carnea* reared on different aphid species is found in few kinds of literature (Saminathan *et al*., 1999; Sattar *et al.,* 2011; Beerendra, 2019; Beerendra *et al*., 2022).

Table 1. Life cycle of *C. zastrowi sillemi* reared on cowpea aphid, *A. craccivora* under laboratory conditions

S. No.	Developmental stage	Total no. of insects observed	Duration (days)		
			Min.	Max.	Avg.±SD
1	Egg (incubation period)	50	2	4	3.00±0.72
	Hatching percentage	50	85	92	89.54±2.58
2	**Larval period**				
	First instar	50	2	3	2.48±0.50
	Second instar	50	3	4	3.44±0.50
	Third instar	50	3	5	3.84±0.99
	Total larval period (days)	50	8	9	8.68±0.47
3	Pre pupal days	50	1	1	1.00±0.00
4	Pupal days	50	7	10	8.26±1.32
5	Pre-Oviposition period	50	4	6	5.82±1.18
6	Oviposition period	50	19	30	24.7±5.15
7	Post oviposition period	50	6	8	7.14±0.85
8	**Adult longevity (days)**				
	Male	20	19	30	23.96±3.61
	Female	20	30	39	34.36±3.81
9	Total life cycle (days)	--	25	39	34.38±5.81
10	Sex ratio (Male: Female)	50	1:1.25	1:1.66	1.49±0.18

Table 2. Morphometrics of various stages of *C. zastrowi sillemi* reared on *A. craccivora* under laboratory condition

S. No.	Stages	Total no. of insects observed	Length(mm)			Breadth(mm)			Diameter (mm)		
			Min.	Max.	Avg±SD	Min.	Max.	Avg±SD	Min.	Max.	Avg±SD
1	**Egg**	10	0.73	0.88	0.80±0.05	0.27	0.38	0.33±0.03	-	-	-
2	**Larva**										
	First Instar	10	1.92	2.71	2.29±0.26	0.41	0.71	0.56±0.10	-	-	-
	Second Instar	10	3.56	5.65	4.74±0.80	0.81	2.41	1.35±0.57	-	-	-
	Third Instar	10	6.31	7.75	7.10±0.44	1.87	3.19	2.56±0.40	-	-	-
3	**Cocoon**	10	-	-	-	-	-	-	2.5	4.5	3.37±0.46

Second instar larva

With the exception of size and colour, it resembles the first instar. The second larvae had a deeper colour and were bigger. The larvae's head and thorax also clearly displayed prominent stripes of either brown or grey colour. The length of second instar larvae varies from 3.56 to 5.65 mm (Avg. of 4.74±0.80) and width from 0.81 to 2.41 mm (Avg. 1.35±0.57) (Table 1). The second instar grub phase was terminated between three to four days with an avg. of 3.44±0.50 days (Table 2).

These observations are found analogous to the figures of Vivek *et al*. (2013) and Kumari *et al*. (2020) noted on *C. zastrowi sillemi* against different aphids. Likewise, a similar instar phase of *C. carnea* reported by Shinde *et al*. (2009), Sheilaja (2016) and Beerendra *et al*. (2022) investigated various aphids. While slightly lesser than the present results found in the second instar larval duration of *Chrysoperla* spp. against different aphids in reports of Saminathan *et al*. (1999), Sattar *et al*. (2011), Beerendra (2019); Iman (2020).

Third instar larva

It was the last instar larva of *C. zastrowi sillemi* larger in size as well as dark in body colour (Table 1). The entire body region of the larvae also clearly displayed noticeable brown or gray stripes. The lateral side of the fully developed larval body is noticeably bristled. The powerful, sickle-shaped mandibles and developed proboscis of the mature larva are utilized to extract fluid from their prey. The length of this grub stage varies from 6.31 to 7.75 mm (Avg. 7.10±0.44) and breadth ranges from 1.87 to 3.19 mm (Avg. 2.56±0.40). Third instar larval period was ceased in three to five days (Avg. of 3.84±0.99) (Table 2).

These observations are similar to the results reported by Kumari *et al*. (2020) on *C. zastrowi sillemi* against *A. gossypii*. Same way, Saminathan *et al*. (1999), Shinde *et al.* (2009) and Sattar *et al*. (2011) recorded similar time frames in *C. carnea* on various aphid species. While, the higher duration than the present result was recorded by Beerendra *et al*. (2022) on *Chrysoperla* spp. on different hosts.While a slightly lesser period in the third instar larvae was reported by Vivek *et al.* (2013) on the same test and host insects. Likewise, Sheilaja (2016), Beerendra (2019) and Iman (2020) noted the lesser duration of *C. carnea* on various aphid hosts.

Total larval period

The result on the total larval duration between the first to third instar of *C. zastrowis illemi* ranged from eight to nine days (Avg. 8.68±0.47) on *A. craccivora* (Table 2). In few earlier literature, analogous observation was noted in predator, *C. carnea* reared on different aphis species (Saminathan *et al*., 1999; Shinde *et al.,* 2009; Sattar *et al.,* 2011; Sheilaja, 2016 and Iman, 2020). Whereas, Kumari *et al*. (2020) noted a higher duration of *C. zastrowi sillemi* on *A. gossypii* as well as Beerendra *et al*. (2022) reported it on *C. carnea* against various hosts. While the duration phase is somewhat lesser in *Chrysoperla* spp. when reared on *A. craccivora* (Beerendra, 2019).

Pre-Pupa

The colour was light yellowish to brown in the pre-pupal stage and the duration remained only for one day (Avg. 1.00±0.00) (Table 2). This numerical finding is analogous to the results of Shinde *et al*. (2009) studies of *C. carnea* on *A. craccivora* and Kumari *et al*. (2020) on *C. zastrowi sillemi* reared on cotton aphids.

Pupa

According to the current observations on *C. zastrowi sillemi*, the fully developed larvae spun a spherical cocoon that was coloured white, pupated inside, and wrapped in silken threads. A day before the adult emerges, the cocoon turns green. Table 2 depicts the pupal span and found between seven to ten days with an avg. of 8.26±01.32 days on *A. craccivora*. The biometric data on the diameter of *C. zastrowi sillemi* in the cocoon was measured between 2.5 to 4.5 mm (Avg. 3.37±0.46) (Table 1). The findings of Kumari *et al*. (2020) in *C. zastrowi sillemi* on *A. gossypii* were nearer to the present study as well as comparable with the literature of Saminathan *et al*. (1999), Vivek *et al*. (2013) evaluated the pupal duration of *C. carnea* on various pest hosts. While, a slightly higher pupal period is counted in reports of Sheilaja (2016) studied *C. carnea* on *A. craccivora*. However, a lesser period was noted on various insect hosts tested against *Chrysoperla* spp. in other investigation findings (Shinde *et al*., 2009; Sattar *et al*., 2011; Beerendra, 2019; Beerendra *et al*., 2022).

Adult

They had transparent wings, a light green body colour, and a delicate body. Both the male and female have a wingspan greater than their body length. Wings stretched to the end of the abdomen and supported the body like a roof. The female abdomen was two to three times broader than the male abdomen, which was slender and tapered in males. The colour of compound eyes was either copper or golden.

Pre-ovipositional period

It was measured between four to six days (Avg. 5.82±1.18) (Table 2). Earlier, Shinde *et al.* (2009) noted a total pre-oviposition period between 4 to 6 days with a mean of 4.92±0.75 days in *C. carnea* reared on *A. craccivora*, while Sheilaja (2016) reported the pre-oviposition period of 5.6±0.24 days in *C. carnea* reared on *A. craccivora*.

Ovipositional period

It was noted between 19 to 30 days (Avg. 24.7±5.15) (Table 2). The findings of Vivek *et al.* (2013) in *C. zastrowi sillemi* reared on *A. craccivora* are similar. As well, the oviposition period was more or less similar in *C. carnea* reared on *A. craccivora* in literature of Shinde (2009), Sheilaja (2016); Beerendra (2019).

Post-oviposition period

It ranged from six to eight days (Avg. 7.14±0.85) reared on *A. craccivora* (Table 2). The present results are similar to reports of Shinde *et al*. (2009) in *C. carnea* on *A. craccivora* as well as Kumari *et al*. (2020) measured in *C. zastrowi sillemi* on *A. gossypii*.

Adult longevity

The male longevity was noted between 19 to 30 days with an avg. of 23.96±3.61 days (Table 2). Earlier, a slightly closer result was found in *C. carnea* reared on various host insects (Shinde *et al*., 2009; Sattar *et al.,* 2011; Kumari *et al*., 2020; Beerendra *et al*., 2022).

The longevity of females ranged between 30 to 39 days (Avg. 34.36±3.81) on *A. craccivora* (Table 2). In general, females lived longer than males. However, a slightly close period found in another literature that investigated *C. carnea* on various host insects (Shinde *et al*., 2009; Sattar *et al.,* 2011; Vivek *et al*., 2013; Sheilaja, 2016; Kumari *et al*., 2020; Beerendra *et al*., 2022).

Total life cycle

The entire life span of *C. zastrowi sillemi* starting from egg stage to death of adult counted between 25 to 39 days (Avg. 34.38±5.81) on *A. craccivora* (Table 2, Figure 1). However, a slightly higher duration than the present data was reported by Shinde *et al*. (2009) in *C. carnea* on various host insects.

Sex ratio

It was counted from 1:1.25 to 1:1.66 with an avg. of 1.49±0.18 (Table 2). Similar results noted by Shinde *et al*. (2009) found sex ratio ranged from 1:1.40 to 1:1.85 (Avg. 1:1.62) in *C. carnea* when reared on cowpea aphids. In other reports, *C. carnea* when reared on *A. craccivora* reported a 0.75:1 ratio (Sheilaja, 2016). Beerendra *et al*. (2022) pointed out that a sex ratio of 0.75:1 in *Chrysoperla* sp. reared on *D. citri*. These above results on life cycle more or less match with present findings and may vary due to some difference in host, species composition and prevailing laboratory condition.

Predatory potential of *C. zastrowi sillemi* grub (aphids consumed per day)

The data on the predatory potential of first instar larvae consumed 9 to 10 cowpea aphids per day (Avg. 9.28±0.45) (Table 3). The second instar larvae consumed 20 to 22 aphids, *A. craccivora* per day (Avg. 20.86±0.53). The predatory potential of third-instar larvae was about 27 to 29 aphids with an avg. of 27.94±0.59. These instar-wise observations were similar to some extent to the findings of Mounika *et al.* (2021) assessed *C. zastrowi sillemi* feeding potential on cowpea aphids and found nearer to the results of Shinde *et al.* (2010) evaluated *C. carnea* on cowpea aphid. While the slightly instar-wise higher consumption rate was noted by Kumari *et al*. (2020) in *C. zastrowi sillemi* on cotton aphids and Sheilaja (2016) in *C. carnea* reared on aphids.

Total consumption

The total prey consumption from the first instar to the third instar ranged from 56 to 59 aphids per day (Avg. 58.08±0.83) (Table 3). Here, a higher feeding potential than

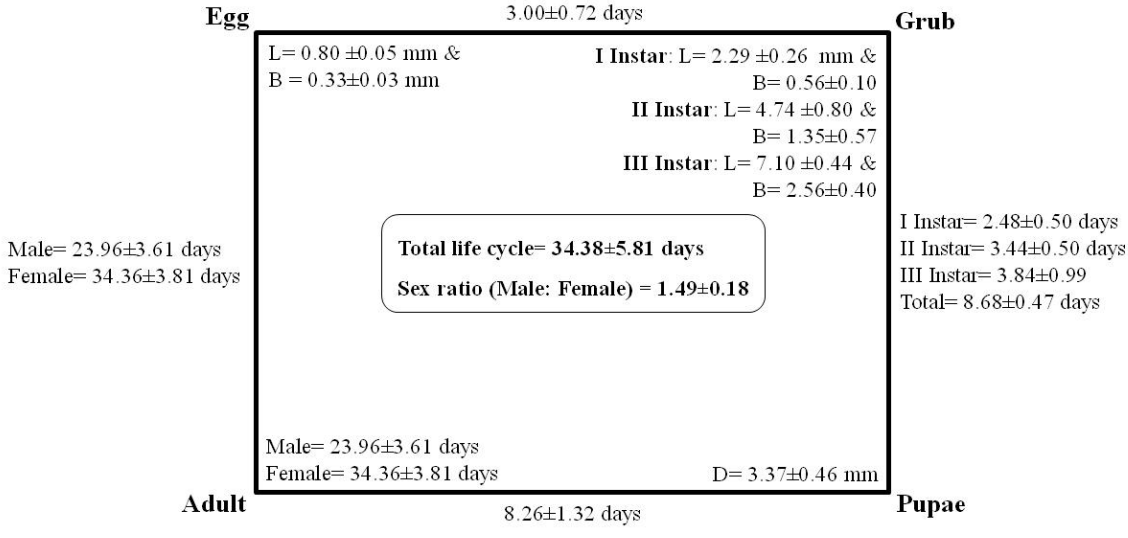


Figure 1. Life cycle and morphometrics of *C. zastrowi sillemi* on *A. craccivora* [L= Length, B= Breadth, D= Diameter].

the present investigation was noted by Shinde *et al.* (2010) in *C. carnea* on cowpea aphids; Satpathy *et al*. (2012) in *C. zastrowi sillemi* cowpea aphid and Breerendra (2019) in *Chrysoperla* spp. reared on cowpea aphids. However, the result with lesser consumption was investigated by Kumari *et al*. (2020) in *C. zastrowi sillemi* on cotton aphids. The variations in these observations might be due to the laboratory conditions and different insect species.

Predatory potential on total prey consumption

The predatory potential on total prey consumption by first instar larvae (Table 4) ranged from 27 to 37 aphids throughout the period on *A. craccivora* (Avg. 31.2±4.04). Afterwards, the total prey consumption by second instar larvae of *C. zastrowi sillemi* ranged from 60 to 68 aphids throughout the instar on *A. craccivora* (Avg. 64.32±3.06). The total prey consumption by third instar larvae was 116.4±2.49 in *C. zastrowi sillemi* when reared on *A. craccivora* (ranging from 114 to 120 aphids throughout the instar). The results of the analysis of variance showed that compared to the first and second instars, the third instar larvae ingested a noticeably larger amount of prey. Depending on the age of the larva, C. zastrowi sillemi larvae have different daily intake patterns for different prey. The predatory potential of total prey consumption from the first instar to the third instar ranged between 201 to 218 aphids throughout the entire larval duration (Avg. 211.6±6.03).

These instar-wise feeding potentials on total prey consumption (208.17 aphids) are analogous to the observations reported by Mounika *et al.* (2021) in *C. zastrowi sillemi* reared on cowpea aphid, *A. craccivora*. The slightly higher total consumption (304 to 484 aphids) than the present results are found in the findings of Shinde *et al.* (2010) and it was 445.2±6.21 aphids throughout the larval period in the study of Sheilaja (2016) noticed in C. *carnea* reared on cowpea aphid *A. craccivora*. However, Shah *et al*. (2013) noted higher prey total consumption (394.8±4.47 aphids) in *C. carnea* on *A. craccivora* as well as Bhojani *et al.* (2017) noted slightly more consumption in *C. zastrowi sillemi* (320.95±17.86 nymphs and 198.15±17.86 adult aphids) reared on cotton aphid, *A. gossypii*.

Table 3. Feeding potential of *C. zastrowi sillemi* on *A. craccivora* per day aphid consumption

Stages	Total no. of insects observed	Per day aphid consumption (No.)		
		Min.	Max.	Avg.±S.D.
Larva				
I instar	50	9	10	9.28±0.45
II instar	50	20	22	20.86±0.53
III instar	50	27	29	27.94±0.59
Total consumption	150	56	59	58.08±0.83

Table 4. Feeding potential of *C. zastrowi sillemi* on *A. craccivora*

Stages	Total no. of insects observed	Total consumption (No.)		
		Min.	Max.	Avg.±S.D.
Larva				
I instar	50	27	37	31.2±4.04
II instar	50	60	68	64.32±3.06
III instar	50	114	120	116.4±2.49
Total consumption	150	201	218	211.6±6.03

CONCLUSION

The results obtained on the biology of a predator, *C. zastrowi sillemi* reared on cowpea aphid, *A. craccivora* revealed that the total life span of *C. zastrowi sillemi* male and female adults was 23.96±3.61, 34.36±3.81 days, respectively. The feeding potential of *C. zastrowi sillemi* was measured as 58.08±0.83 aphids per day, with a total of 211.6±6.03 aphids consumed throughout the entire larval duration. It indicated that each stage of green lacewing, *C. zastrowi sillemi* along with longer larval duration has a great potential to survive on cowpea aphids and can be excellent biocontrol agent contributing to the organic pest management program, providing benefits throughout the growing season.

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