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Comparative study on biology of *Chrysoperla carnea* Stephen (Neuroptera: Chrysopidae) on two different hosts

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Abstract
The present investigation was conducted on biology and growth parameters of *Chrysoperla carnea* Stephen (Neuroptera: Chrysopidae) on two different hosts *viz.*, aphids and mealybugs during 2021-2022 at College of Horticulture, Anantharajupeta. The predator (*C. carnea*) was reared under laboratory conditions at temperature of 28±2 °C and 65-70% relative humidity. The biology of predator, *C. carnea* was studied on cowpea aphid, *Aphis craccivora* and guava mealybug, *Planococcus citri*. The incubation period of eggs on two different preys was similar but the total larval period slightly varied (10.31±0.68 days; 12.75±0.48 days) on aphids and mealybugs respectively. The pupal period was observed as 6.00±0.22 days when fed on aphids and 6.06±0.23 days on mealybug, not showing any significant difference. The total developmental period of *C. carnea* when fed on aphids (19.88±0.87 days) and mealybugs (22.38±0.63 days) showed a difference of two days. The pre-oviposition period, oviposition period and post oviposition periods of *C. carnea* when fed on aphids are 5.50±0.34, 23.50±1.38 and 12.83±1.08 days, respectively and with mealybug as hosts, they are 5.20±0.20, 21.00±2.93 and 14.20±0.97 days, respectively. The longevity of male and female adults were observed to be 28.73±0.68 and 41.83±1.30 days on aphids and 28.45±0.54 and 40.40±2.91 days reared on mealybugs. The total life cycle of *C. carnea* was completed within 50.81±1.66 days on aphids and 53.88±1.50 days on mealybugs.

Keywords: *Chrysoperla carnea*, aphids, mealybugs, biology

1. Introduction
Biological control is the natural control of crop pests which involves their natural enemies. Since the chemical control has become predominant in the present agricultural and horticultural ecosystems, the natural enemies affected from these chemicals should be protected and allowed to multiply. Indiscriminate pesticide application should be minimised and generalist predators like green lacewing, *Chrysoperla carnea* should be conserved in the crop ecosystems. Moreover, the natural enemies should be exploited commercially by rearing them and releasing into crop fields.

C. carnea has three larval instars and the entire larval stage is predacious in nature and adult is free living and feeds on honey and pollen obtained from flowers. *C. carnea* is a generalist predator and has wide adaptability to a broad range of environmental conditions as well as prey diversity (Chakraborty and Borat, 2010) [2]. It can survive by feeding on a wide range of insect pests, mainly soft bodied insects *viz*., aphids, mealybugs, whiteflies and some larvae like cotton bollworm larvae etc (Sultan and Khan, 2014) [7]. This predator has higher scope in the control of insect pests. *C. carnea* is known to be one of the best predators for controlling sucking pests in crop ecosystems and hence, is commercially exploited as an effective biological control agent both in India and abroad.

Biology of predators along with their growth parameters plays an important role in studying and assessing their predatory efficiency. This knowledge will be useful for the formulation of integrated pest management (IPM) practices for pest management. The success of any predator majorly depends on the nutritional quality of its prey on which it is predating. Hence, to know the effect of prey species on the biology of *C. carnea*, an experiment was designed and executed on two hosts *viz.*, aphids and mealybugs during 2021-22.

2. Materials and Methods
The present investigation was carried out during 2021-2022, at College of Horticulture, Anantharajupeta.

The predator (*C. carnea*) was reared under laboratory conditions at a temperature of 28±2 °C and 65-70% relative humidity.

2.1 Aphid culture maintenance

The present studies required regular supply of aphids, hence, the host plants which can harbour aphids in large scale (cowpea) were grown under field conditions. For this purpose, the seeds of cowpea were sown in a raised bed of 2 m x 2 m in the experimental fields of the college farm. Further, some plants are also maintained in the pots for continuous culture maintenance. All the recommended practices required for raising the crop were followed except insecticidal spray so as to ensure the natural infestation of aphids (*Aphis craccivora*).

2.2 Mealybug culture maintenance

The culture of the mealybugs (*Planococcus citri*) was maintained in the laboratory on ripe pumpkin fruit following the procedure given by Gunawardana and Hemachandra (2020) [9]. The pumpkin fruit was brought to the laboratory, washed with tap water to remove soil and dust particles attached to the surface and pat dried by using tissue papers. Later, surface sterilization of pumpkin was done by using 70% ethanol to remove all possible pathogens. Cleaned fruit was again kept for 48 hours in rearing cages for removal of adverse effect of ethanol on mealybugs. The mealybug culture collected from the guava fields, brought to the laboratory and released on the sterilised pumpkin fruit surface and observed daily. A gradual growth and multiplication of mealybug culture was noticed on pumpkin fruit. These mealybugs were used for further experimentation.

2.3 Maintenance of predator culture in the laboratory

The eggs of *C. carnea* were procured from the Biological Control Laboratory, Horticultural Research Station, Ambajipeta. The procured eggs were carefully transferred into petri dishes for hatching. After hatching the larvae were collected and reared individually in small bottles (3.5 cm x 3.5 cm) on the aphids and mealybugs separately until pupation. Then, the pupae thus formed were kept in the plastic boxes (3.5 cm x 3.5 cm) for adult emergence. The emerged adults were transferred to the oviposition boxes of 16.5 cm x 10 cm size. The male and female adults are differentiated based on the size of abdomen and two mating pairs were placed in each oviposition box by using camel hair brush. The abdomen of female adult is broader than that of male adult. These boxes were provided with a brown sheet at the top which can act as site for the oviposition. The freshly laid eggs were collected daily, kept individually in separate vials and were observed daily for hatching. On hatching, the larvae were reared on aphids and mealybugs until the emergence of adults. Once the larvae entered into pupation, they are separated and observed till adult emergence. The adults thus emerged were released into the oviposition cages. An artificial diet (with 50% honey solution, protinex mixture, pollen, yeast and vitamin-E capsule extract) provided to these adults. Cotton swabs dipped in artificial diet solution are provided at the neck portion of the oviposition box as food to the adults.

2.4 Preparation of artificial diet for adults

3 table spoons of honey was taken and mixed with 1 table spoon of glucose powder in a sterilized petri plate. Then, vitamin-E capsule was squeezed and added along with protinex powder (1 table spoon). A pinch of baker's yeast is taken and diluted with water. This yeast solution is added to the previously prepared honey solution. After thorough mixing of these ingredients, a pinch of dried pollen was added and mixed. The final solution obtained after mixing is taken and kept in refrigerator and used whenever needed.

The growth parameters like egg, larval, pupal and adult periods were recorded during the research. The dimensions (length and breadth) of the egg and larva, pupa were measured and recorded by taking the average dimension values of five randomly selected specimens. The measurements were also recorded for the adults separately for each sex.

3. Results and Discussion

The female adults of *C. carnea* reared on aphids laid stalked eggs singly which are light greenish in colour and turned into pale colour as they matured and changed to white colour just before hatching. The incubation period of *C. carnea* ranged from 3 to 5 days with an average of 4.2±0.10 days. Similar incubation period of 3-5 days was recorded when reared on mealybugs also. The average size of the egg was recorded to be 0.0045 mm long and 0.0022 mm wide. These observations are similar to the results of previous research workers, who reported that the incubation period of *C. carnea* as 4.82±0.24 days when fed on *Brevicoryne brassicae* (Chandana *et al*., 2020) [3]. The incubation period was reported as 3.75 days when fed on *Aphis craccivora* which is slightly lesser than the result obtained in present research (Babasaeb, 2010).

The larval stage of *C. carnea* passed through three instars and the different instars were identified based on the moulted skin. The first instar larva is light creamish to pale green in colour, while the second and third instars are cream coloured. The total larval period of *C. carnea* ranged from 9-15 days with mean of 10.31±0.68 days when fed on aphids. But when fed on mealybugs, there was a slight increase in larval duration (9-16 days) with a mean larval period of 12.75±0.48 days. The first, second and third larval instar durations ranged from 2-4, 3-5 and 4-7 days, respectively when fed on aphids but when fed on mealybugs the corresponding values were observed as 2-6, 3-6 and 4-8 days. These results are in conformity with the results of Saleh *et al*. (2017) [5] who reported that, the total larval period of *C. carnea* was 10.69±0.64 days when fed on *Aphis gossypii*. However, contrarily Saminathan *et al*. (1999) [6] reported larval period of *C. carnea* as 8.90 days, when fed on *Aphis gossypii* which was much shorter than the results obtained in the present research. This may be attributed to the variation in the nutritional status of the host insect. The average length and breadth of the first, second and third larval instars are 0.0094 mm x 0.0072 mm; 0.012 mm x 0.0091 mm; 0.019 mm x 0.011 mm, respectively.

The third instar larvae pupated by spinning a cocoon around them. The pupal case was round and creamish white in colour. The pupal duration ranged from 6 to 7 days with a mean period of 6.00±0.22 days when fed on aphids. The duration of pupa ranged from 5 to 8 days with a mean period of 6.06±0.23 days when fed on mealybugs, which was higher when compared to the aphids. Similar results were obtained by Sultan *et al.* (2021) [8] when fed on *Paracoccus marginatus* where the pupal period of *C. carnea* was reported as 6.75±2.14 days. The average diameter of the pupa was recorded to be 0.0096 mm.

The total developmental period of *C. carnea* on aphid from egg to emergence of adult ranged from 17- 26 days with an average of 19.88±0.87 days. This includes incubation period of 3-5 days with an average of 4.20±0.10 days, larval duration of 9-15 days with an average of 10.31±0.68 days. The larval period consists of 2-4 days of first instar, 3-5 days of second instar and 4-7 days of third instar duration and pupal period ranged from 6-7 days with an average of 19.88±0.87 days (Table-1).

When fed on mealybugs, the total development period of *C. carnea* ranged from 18-26 with an average of 22.38±0.63 days which was comprised of 3-5 days of incubation period with an average of 4.20±0.10 days, larval period of 9-16 days with an average of 12.75±0.48 days. Larval period consists of 2-6 days of first instar, 3-6 days of second instar and 4-8 days of third instar duration and pupal period ranged from 5-8 days with an average of 6.06±0.23 days (Table-2).

Within the developmental period, larval stage had occupied the maximum period followed by pupa and egg stages when fed with aphids and similar trend was noticed in when reared on mealybugs too. In a research done by Saminathan *et al.* (1999) [6] the total development period was reported as 19.75 days when fed on *Aphis craccivora* which is in conformity with the present results. The studies conducted by Sultan *et al.* (2021) [8] reported that the total development period of *C. carnea* when fed on *Paracoccus marginatus* was 17.89 days which is slightly less than the present results.

Oviposition period

The data from the table-3 revealed that, the pre-oviposition, oviposition and post oviposition periods of female adults of *C. carnea* which were reared on aphids ranged from 5-7, 10-27 and 9-16 days, respectively with the corresponding mean values of 5.50±0.34, 23.50±1.38 and 12.83±1.08 days, respectively. Similarly, when the larvae were fed on mealybugs, the pre-oviposition, oviposition and post oviposition periods of adult female were 5-6, 10-26 and 11-16 days, respectively with the corresponding mean values of 5.20±0.20, 21.00±2.93 and 14.20±0.97 days, respectively (Table 4). Similar results were given by Sree Chandana (2020) [3] who reported pre-oviposition (6.60 days), oviposition (25.40 days) and post oviposition (9.90 days) periods when fed on *Brevicoryne brassicae*.

Adult longevity

When fed on aphids, the male longevity was 28.73±0.68 days while the female longevity was 41.83±1.30 days. Similarly, when fed on mealybugs, the male and female longevities were recorded as 28.45±0.54 days and 40.40±2.91 days respectively. A similar trend was observed when *C. zastrowi* was fed on cabbage aphid, *B. brassicae* where male and female adult longevities were 29.40±1.86 days and 40.80±1.28 days respectively (Sree Chandana, 2020) [3].

In contrast, Sultan *et al.* (2021) [8] reported that the male longevity was 32.36±0.46 days which was higher than the present results and female longevity as 36.45±2.38 days which was lower than the observations made in present research. The deviations in the values of adult longevity might be due to the differences in the host species fed to the larvae and type of artificial diets provided to the adults.

Table 1: Duration of developmental stages of *C. carnea* reared on aphids

Sl. No.	Developmental stage		Duration (days)	
			Range	Mean±SE
1	Incubation period		3-5	4.20±0.10
2	Larval period	First instar	2-4	3.29±0.16
		Second instar	3-5	3.69±0.15
		Third instar	4-7	3.94±0.32
3	Total larval period		9-15	10.31±0.68
4	Pupal period		6-7	6.00±0.22
5	Total development period		17-26	19.88±0.87

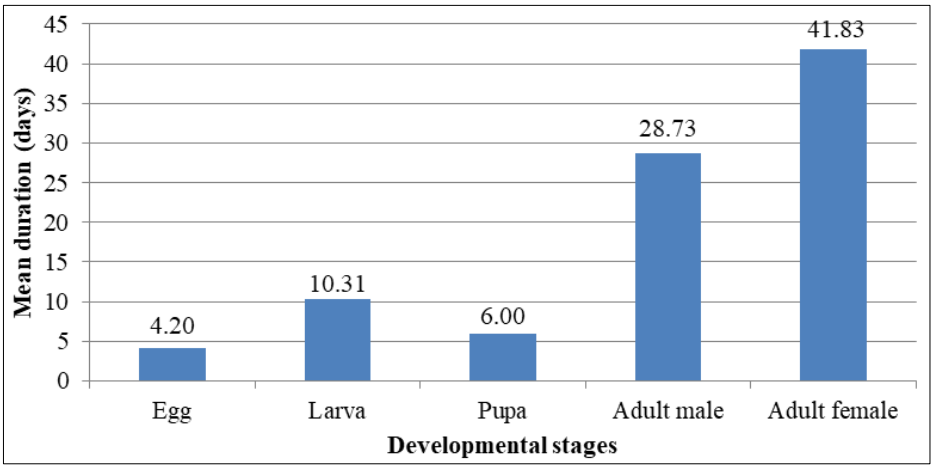

Fig 1: Mean duration (in days) of the different developmental stages of *C. carnea* on aphids

Table 2: Duration of developmental stages of *C. carnea* reared on mealybugs

Sl. No.	Developmental stage		Duration (days)	
			Range	Mean±SE
1	Incubation period		3-5	4.20±0.10
2	Larval period	First instar	2-6	3.87±0.17
		Second instar	3-6	4.64±0.14
		Third instar	4-8	5.13±0.30
3	Total larval period		9-16	12.75±0.48
4	Pupal period		5-8	6.06±0.23
5	Total development period		18-26	22.38±0.63

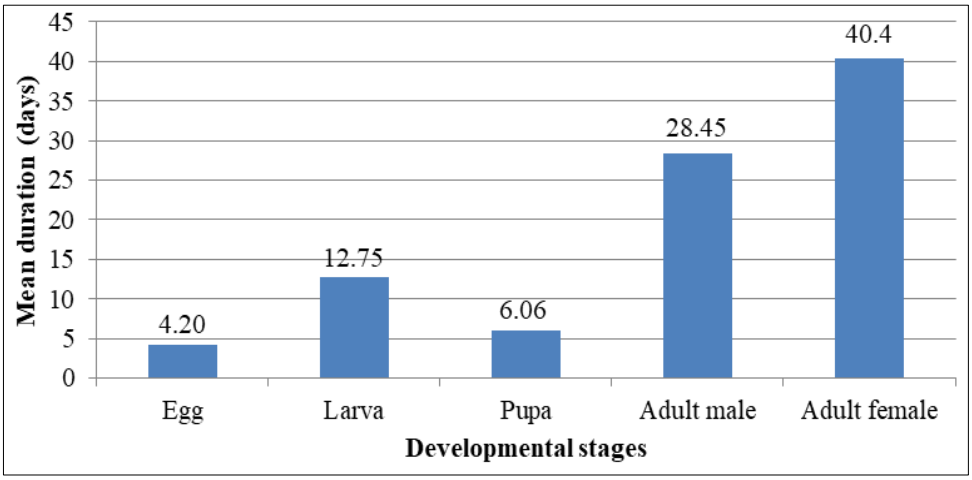

Fig 2: Mean duration (in days) of the different developmental stages of *C. carnea* on mealybugs.

Table 3: Duration of different reproductive stages of *C. carnea* reared on aphids

Sl. No.	Stage/Parameter		Duration (days)	
			Range	Mean±SE
1	Pre oviposition period		5-7	5.50±0.34
2	Oviposition period		10-27	23.50±1.38
3	Post oviposition period		9-16	12.83±1.08
4	Adult longevity	Male	24-34	28.73±0.68
		Female	31-48	41.83±1.30
5	Total life cycle		42-67	50.81±1.66

Table 4: Duration of different reproductive stages of *C. carnea* reared on mealybugs

Sl. No.	Stage/Parameter		Duration (days)	
			Range	Mean±SE
1	Pre oviposition period		5-6	5.20±0.20
2	Oviposition period		10-26	21.00±2.93
3	Post oviposition period		11-16	14.20±0.97
4	Adult longevity	Male	27-32	28.45±0.54
		Female	30-47	40.40±2.91
5	Total life cycle		49-62	53.88±1.50

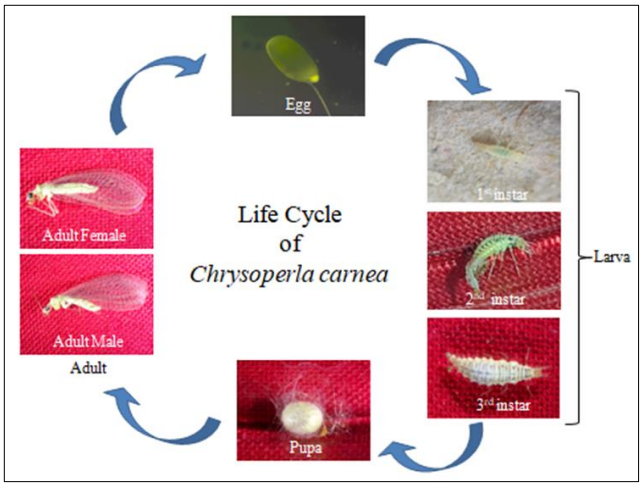

Fig 1: Lifecycle of *Chrysoperla carnea*

Conclusion

From the present research work it can be concluded that, the average incubation period of *C. carnea* eggs was 3-5 days when fed on either on aphids or mealybugs. The larval duration of first, second and third instars were ranged from 2-4, 3-5 and 4-7 days when fed on aphids and 2-6, 3-6 and 4-8 days when fed on mealybugs respectively. The pupal period was found to be in the range of 6-7 days and 5-8 days when fed on aphids and mealybugs respectively. The total developmental period was observed to be 17-26 and 18-26 days when reared on aphids and mealybugs respectively. Adult longevities of male and female adults were recorded as 24-34 and 31-48 days when fed on aphids and 27-32 and 30-47 days when fed on mealybugs. From the present investigation, though much variation was not observed on the larval duration when fed on either aphids or mealybugs, but adult longevity variations were noticed. Hence, it can be concluded that the biology of the predator can be affected by the species and nutritional status of prey insect on which it predates on during its life cycle.

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