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Rearing of *Chrysoperla carnea* (Stephens) against two laboratory hosts and one natural host

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Abstract
The present study was conducted at Department of Entomology, Sindh Agriculture University, Tandojam during 2017. The maximum pre oviposition period of 6.8±0.38 days and oviposition 30.0±0.33 was recorded when larvae of *C. carnea* was fed on eggs of *S. litura* and minimum 5.6±0.25; 23.6±1.04 days respectively were observed on *A. craccivora* nymphs which compared to eggs of *C. cephalonica* (6.2±0.37 and 27.4±0.51). Highest egg hatchability (88.0±2.0), adult emergence (76.0±4.00) was obtained when larvae were fed with *C. cephalonica* eggs whereas lowest on *S. litura* (70.0±3.16 and 62.0±2.0) respectively. In that order, the highest adult longevity of 41.6±0.52 (female) and 34.6±0.26 (male) was seen in *S. litura* while the shortest female longevity 39.6±0.51 male 29.0±0.45 days on *C. cephalonica*. Sex ratio was slightly female biased on all three hosts where females survived longer than males.

Keywords: *C. carnea*, longevity, hosts, oviposition, fecundity

1. Introduction
Green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) also known as golden eyes and aphid lions, which is a cosmopolitan polyphagous and efficient predator commonly found in a wide range of agricultural habitat [1]. It plays an important role in natural control of sucking pests and effectiveness of *C. carnea* as a biological control agent has been demonstrated in field crops, orchards and green houses [2]. The female lays several hundreds of small stalked eggs underneath the leaves or on shoots during hours of darkness, and the larvae hatch in 3 to 6 days which eat voraciously and moult three times. The larvae are predaceous, feeding on eggs and neonates lepidopterous larvae, nymphs and adults of whiteflies, aphids, thrips, scale insects, mealy bugs, mites, etc, when food is scarce, they exhibit cannibalism [3]. In a larval period of 2 to 3 weeks, mature larvae secrete silk and build round, parchment like cocoons and adults emerge after 10 to 14 days of pupation which possess green cylindrical body, transparent wings with light green veins, long fili-form antennae, golden eyes and stalked eggs laid by adults offer protection from predation [4]. The adults are generally free living and feed on honeydew and pollen grains, the adult longevity of female ranges from 7 to 24 days and for male it will be 6 to 18 days [5]. The natural enemies are living organisms that kill or weaken the pests and cause their premature death or reduce their reproductive potential. A natural enemy feeds on its prey or host and thus promotes its own population. The preservation and maintenance of the natural enemies in the agro-ecosystem are essential for the establishment of the biological equilibrium and reduction of the production costs as well as to avoid side effects of the chemicals to environmental conditions [6].
Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae) is a poly-phytophagous insect damaging several vegetables and field crops in many Asian countries including Pakistan [7]. *S. Litura* is also called as the tobacco cutworm, common cutworm, the cluster caterpillar or tobacco caterpillar [8]. Though it had been a random pest of tobacco for many years, it has been becoming progressively a very important insect pest in the current years [9]. *S. litura* is a member of economically important insect pests that infest more than 120 host crop plants and causes serious crop losses [10]. Due to the excessive use of pesticides, it acquired resistance to many commonly used pesticides, particularly carbamates and pyrethroids, resulting in the collapse of effective controls [11, 12]. *S. litura* is a leaf feeding insect, and host plant survey for

two years from 3 different locations at Pakistan, cotton belt exposed 27 plant species belonging to 25 genera of 14 families including vegetables, cultivated crops, weeds, fruits and ornamental plants as host plants for *S. litura* [13]. There were two main objectives discussed here to study the biology on floral feeds of castor and the feeding potential of *C. carnea* on different aphid species.

2. Materials and Methods

2.1 Study area: The experiment was conducted under laboratory conditions, during 2017-18, Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam. The stock culture of *C. carnea*, *C. cephalonica A. craccivora* and *S. litura* were obtained from N.I.A laboratory.

2.2 Experimental Design: The adult larvae were collected from different crops and reared on different hosts under laboratory for stock culture. Natural diets like *C. cephalonica*, *S. litura* and *A. craccivora* collected from respective host plants. These diets were provided to the *C. carnea*.
There were three treatments including $T_{1=}$ *C. cephalonica* $T_{2=}$ *S. litura* and $T_{3=}$ *A. craccivora* each treatment was replicated thrice times. The experimental design was Complete Randomized Design (CRD). The temperature was maintained between 26±2 °C.

2.3 Data collection: After hatching from eggs the grubs were shifted in to new petridishes for experiments. Each grubs were fed by the selective hosts as diets. The developmental period of each grub instars, pre oviposition pupal emergence and oviposition were recorded. The newly emerging the adults were fed by the same diets. The fecundity, incubation period, percent egg hatching, larval duration, percent larval pupation, pupal duration days and adult longevity similarly.

2.4 Statistical Analysis: The collected data were subjected to statistical analysis and statistical differences existed between data sets (P<0.05), Fisher's Least Significant Differences (LSD) was being used to separate the differing means.

3. Results and Discussion

3.1 Biology of *C. carnea* on laboratory host, *C. cephalonica*

The results summarized in the Table-1 showed that the pre-oviposition period lasted for 6.2±0.37 days and oviposition period was 27.4±0.51 days. These results did not agreement with [14] who have recorded the pre-oviposition and oviposition period 5.4 and 40.6 days respectively. The total number of eggs laid by a single female throughout its oviposition period was 569.4±8.88. But unfortunately present findings do not agree by [15] whom noted that the highest number of eggs (769.50) was observed from a single female. In that order, the present findings also evaluated that egg hatchability was noted as 88.0 percent with an incubation period of 3.2±0.2 days. Those results are generally confirmedly by [16] whom obtained 83.88 percent egg hatching when multiplied on *C. cephalonica* respectively. Among the treatments the total larval period of *C. carnea* was recorded as 7.2±0.2 days. However, it was examined that larval duration of *C. carnea* by various researchers as 8.30 days [17], 8.20 days [18], 8.04 days [19] and 7.76 days [20] on eggs of *C. cephalonica*.
It was observed from the present study that about 86.0±2.45 percent larvae have pupated. On an average, the pupal duration lasted for 8.2±0.12 days and an adult emergence of 76.0±4.00% was recorded when fed on *Corcyra* eggs. Moreover, accordingly [21] discovered 80.00% adult emergence which is also slightly more than the present study. The male-female sex ratio was slightly female biased with a sex ratio 1:1.5 (M: F) where females survived for longer time (39.6±0.51 days) than males (29.0±0.45 days). Present results longevity of males and females were similar with the findings of [22]. *C. cephalonica* being used as the most common factitious host in the laboratory because of its easy-ness in rearing and larvae remaining fresh for long time, it could be used for mass multiplication. On the other hand, present investigation shown that the eggs of *C. cephalonica* could provide good nutritional substance, which supported the proper growth and development of the predator. A similar finding of [23] discussed here about the longevity of male and female adults of *C. carnea* were 35.85 and 39.25 days due to the larval diet as eggs of *C. cephalonica*.

3.2 Biology of *C. carnea* on laboratory host, *S. litura*

Data pertaining in the Table-1 showed that pre-oviposition period lasted for 6.8±0.38 days and was shorter than oviposition period (30.0±0.33 days). The total number of eggs laid by a single female was 359.6±5.57 eggs. However, the egg hatchability % was 74.0±2.4 with an incubation period of 4.6±0.24 days. Similar results are found by [24] who has studied developmental period from egg to adult emergence total was 22.2 days, larval and pupal period were 10.3 and 8.4 days, respectively. Males survived for 26.5 days and females for 39.0 days. In a period of 24 hours, a single larva could feed an average of 30.3 eggs of *C. cephalonica*, 33.4 eggs of *Helicoverpa arnigera*, and 0.54 egg masses of *S. litura*. In the present findings, the larvae pupated was recorded as 70.0±3.16. On an average, the pupal period lasted for 8.8±0.12 days with an adult emergence of 62.0±2.0 percent. These results were corroborated with the results of [25] whom recording a total larval period of 9.66 days, pupal period of 7.00 days and adult period of 43.33 days when *C. carnea* larvae were fed on eggs of *S. litura*. They also reported that development of *C. carnea* larvae on eggs required less duration than neonates of different lepidopterans. However, the male-female (1:1.5) sex ratio was slightly female biased where female survived for longer period (41.6±0.51 days) than males (34.6±0.25 days).

3.3 Biology of *C. carnea* on natural host, cowpea aphid

A. craccivora results were presented in the Table-1 showed that pre-oviposition period lasted for 5.6±0.25 days and was shorter than oviposition period (23.6±1.04 days). The total number of eggs laid by a single female throughout its oviposition period was 299.0±5.50 eggs. The egg hatchability% was 76.0±2.45 with an incubation period of 3.4±0.24 days. The study results are totally disagreed with [26] whom investigated about the pre oviposition, oviposition and post oviposition period as 6.55, 21.10 and 7.95 days on *A. gossypii* and 9.25, 21.85 and 11.20 days on *M. persicae*, respectively. The present findings further reported that mean fecundity of *C. carnea* was about 84.70 and 103 eggs and the incubation period was 2.25 and 3.68 days on two aphid species respectively. However, there was the 74.0±2.45 percent larval pupation. On an average, the pupal duration lasted for 9.0±0.35 days with an adult emergence of 70.0±3.16 percent. The male-female (0.75:1) sex ratio was slightly female biased being female surviving for longer time (37.0±0.89 days) than males (31.0±0.71 days) which could be partially compared with results of [27] who has observed total larval period of 8.6 days with a pupal period of 8.00 days

when fed on *A. craccivora*. They observed a total fecundity of 315.20 eggs per female throughout its oviposition period. The egg hatchability was 80.88 per cent with an egg incubation period of (2.70 days). Slight variation might be due to host plant on which the aphids were reared i.e., *A. craccivora* reared on cowpea.

Table 1: Biological parameters of *Chrysoperla carnea* on three different hosts

Treatments	T[1] *Corcyra cephalonica*	T[2] *Spodoptera Litura*	T[3] *Aphis craccivora*
Pre oviposition period (days)	6.2 ± 0.37	6.8 ± 0.38	5.6 ± 0.25
Oviposition period (days)	27.4 ± 0.51	30.0 ± 0.33	23.6 ± 1.04
Fecundity/female Eggs	569.4±8.88	359.6±5.57	299.0±5.50
Egg incubation period (days)	3.2 ± 0.2	4.6 ± 0.24	3.4 ± 0.24
Egg hatchability (%)	88.0 ± 2.0	74.0 ± 2.45	76.0 ± 2.45
Larval period (days)	7.2 ± 0.2	9.8 ± 0.2	9.0 ± 0.0
Percent larvae pupated	86.0 ± 2.45	70.0 ± 3.16	74.0 ± 2.45
Pupal duration (days)	8.2 ± 0.12	8.8 ± 0.12	9.0 ± 0.35
Adult emergence (%)	76.0 ± 4.00	62.0 ± 2.0	70.0 ± 3.16
Sex ratio (M:F)	1:1.5	1:1.5	0.75:1
Male longevity (days)	29.0 ± 0.45	34.6 ± 0.26	31.0 ± 0.71
Female longevity (days)	39.6 ± 0.51	41.6 ± 0.52	37.0 ± 0.89

3.4 Comparison biology of *C. carnea* on different hosts

C. cephalonica, *S. litura* and *A. craccivora* were compared and results are shown in the Table-4. It was clear from the results that less developmental period 7.2 days was recorded when *C. carnea* larvae was reared on eggs of *C. cephalonica* followed by 9.0 days with *A. craccivora* nymphs. In that order, the total developmental period of *C. carnea* was more (9.8 days) when fed on *S. litura* eggs. Results pertaining to the comparative larval period of *C. carnea* on three hosts, *C. cephalonica, S. litura* and *A. craccivora* revealed that first instar of *C. carnea* took only minimum of 2.0 days when fed on eggs of *C. cephalonica* followed by 2.8 days with nymphs of *A. craccivora*. In that Order, it was 3.0 days when fed with eggs of *S. litura*. On the other hand, the second instar took 2.2 days when fed with eggs of *C. cephalonica* but same period of 3.0 days was required when eggs of *S. litura* and nymphs of *A. craccivora* were provided as food. The third instar took maximum of 3.8 days where larval duration was longer when fed with eggs of *S. litura* which was about 3.0 days and 3.2 days when fed with eggs of *C. cephalonica* and nymphs of *A. craccivora* respectively. But according to [28] who noted the prey influenced the total development period of all insects and difference was not significant in the first instar larvae. However, difference was obtained in second third instars larvae only. Another researcher [29] who has examined that larval food significantly affected the length of developmental time. It was also cleared that unsuitable food could extend the pre-imaginal development of chrysopids and decrease the survival, fecundity and longevity of the adults [30, 31, 32] It was further emphasized by [33] that the species of prey is of paramount importance as part of a balanced source of food that influence the developmental period of the predator.

Table 2: Comparison of biology of *Chrysoperla carnea* on different hosts

Host	Duration of larval instars (Days)			
	I instar	II instar	III instar	Total (Days)
Corcyra cephalonica	2a±0.0	2.2a±0.2	3a±0.0	7.2a±0.2
Spodoptera litura	3b±0.0	3b±0.0	3.8c±0.2	9.8c±0.2
Aphis craccivora	2.8b±0.2	3b±0.0	3.2ab±0.2	9.0b±0.0
CD (0.05)	0.36**	0.36**	0.51**	0.51**

**: Significant

Means followed by same alphabet do not differ significantly by DMRT (P = 0.05%)

4. Conclusion

From this study, it was concluded that the total developmental period of *C. carnea* was suitable recorded on the natural prey *A. craccivora* nymphs, and utilizing *C. cephalonica* as laboratory host for mass multiplication of predator *C. carnea*. However, Abundance, colonization and commercialization of *C. carnea* under field conditions have to be studied.

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