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Effect of Different Hosts on Biology of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) in Laboratory Conditions

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Abstract.- Studies on effects of different hosts on biology of *Chrysoperla carnea* (Stephens) were carried out under laboratory conditions at 26±2°C and 65±5% R. H. indicated that the incubation period of eggs of *C. carnea* females feeding on different hosts as larvae was significantly ($P<0.001$) different from each other. The natural hosts were: cotton aphids, *Aphis gossypii* (Glov.) (nymphs/adults), American bollworm, *Helicoverpa armigera* (Hb.) (eggs), Pink bollworm, *Pectinophora gossypiella* (Saund.) (eggs), cotton mealy bug, *Phenacoccus solenopsis* (Tinsley) (Pseudococcidae: Homoptera) (nymphs) and Angoumois grain moth, *Sitotroga cerealella* (Oliver) (frozen eggs). The order of larval period on different prey species was *Sitotroga cerealella* > *Aphis gossypii* > *Phenacoccus solenopsis* > mixed host diet > *Pectinophora gossypiella* > *Helicoverpa armigera*. The maximum (100%) and minimum (50%) survival to adult stage was recorded on *S. cerealella* and *P. gossypiella* as hosts. The highest fecundity per female (503.3±9.17) and fertility (88.61±0.68%) of eggs were recorded for females reared on *S. cerealella* eggs as a larval diet. *C. carnea* larvae consumed maximum amount of food when feeding on *S. cerealella* eggs followed by *A. gossypii*.

Key words: *Chrysoperla carnea*, green lacewings.

INTRODUCTION

Biological control is the action of parasitoids, predators and pathogens in maintaining other organisms' density at a lower average level than would occur in their absence (DeBach, 1965). The advantages of biological control are numerous. The predators are scattered in about 167 families of 14 orders of class Insecta. Among the predacious insect orders, Coleoptera, Neuroptera, Hymenoptera, Diptera and Hemiptera contain exclusively (natural enemies) predators. It is estimated that possibly up to one third of the successful biological insect pest control programmes are attributable to the introduction and release of insect predators (Williamson and Smith, 1994). A natural enemy may be used in inoculative releases, as reported by Warner (2001). Production estimation and quality control procedures are a necessity. While the use of factitious hosts often makes mass rearing of certain natural enemies possible. The cost of developing and maintaining good quality natural enemies is a small price to pay for consistent and satisfactory performance in the field (Larock and Ellington, 1996). The procedures necessary will vary with the entomophagous species and the intended usage (Penny *et al.*, 2000; Florkin and Jeuniaux, 1974).

The green lacewings, *Chrysoperla carnea* (Stephens) is a cosmopolitan polyphagous predator, commonly found in agricultural systems. It has been recorded as an effective generalist predator of aphids, coccids, mites and mealy bugs etc. (Yuksel and Goemen, 1992; Singh and Manoj, 2000; Zaki and Gesraha, 2001). It has been widely used for aphid bio-control (Venkatesan *et al*., 2000, 2002) and other insect pests (Obrycki *et al*., 1989) because of its ubiquitos nature, polyphagous habits, and compatibility with selected chemical insecticides, microbial agents and amenability to mass rearing (Ridgway *et al*., 1970; Ridgway and Murphy, 1984; Obrycki *et al.,* 1989; Uddin *et al*., 2005). It has been mass-reared and marketed commercially in North America and Europe (Liu and Chen, 2001; Balasubramani and Swamiappan, 1994; Tauber *et al*., 2000) for population management of many insect pests (Ridgway *et al*., 1970; Sengonca *et al*., 1995; Daane *et al*., 1996; Legaspi *et al*., 1996;

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Atakan, 2000). In the present study we examined the influence of consumption of *P. solenopsis* nymphs, *A. gossipii* nymphs/adults, *H. armigera* and *P. gossypiella* eggs, mixed diet comprising all hosts in equal proportions, all major insect pests of cotton and compared with the factitious host (*S. cerealella* eggs) of *C. carnea*, one of the major species of predators in cotton crop ecosystem on development and survival of *C. carnea*.

MATERIALS AND METHODS

Biology of *Chrysoperla carnea* on five natural hosts was studied in Bio-control laboratory, Nuclear Institute of Agriculture Tando Jam. The natural hosts were cotton aphids, *Aphis gossypii* (Glov.) (nymphs/adults), American bollworm, *Helicoverpa armigera* (Hb.) (eggs), pink bollworm, *Pectinophora gossypiella* (Saund.) (eggs), cotton mealy bug, *Phenacoccus solenopsis* (Tinsley) (Pseudococcidae: Homoptera) (nymphs) and Angoumois grain moth, *Sitotroga cerealella* (Oliver) (frozen eggs). The eggs of first four hosts were collected from cotton field of Institute and reared in laboratory for experimental purpose on natural diet. Eggs of *S. cerealella* taken from laboratory culture, maintained for this purpose were provided to the larvae of *C. carnea* under control conditions (26±2°C; 65±5% R.H). This experiment had eight replications and each treatment consisted of 50 individuals.

All biological parameters including egg incubation, larval and pupal period (days), and total food consumption, pupal and adult survival, longevity of male and female (days), pre, post and oviposition (days) and fecundity per female with percent fertility were recorded daily. To avoid cannibalism, newly hatched (2 h old) larva was kept singly in glass vials (2.5 cm diameter and 8.5 cm length) covered with black muslin cloth, was offered weighed host till pupation; same procedure was used in mixed host diet.

The period of time from egg laying to hatching was considered incubation period; from hatching till spinning of cocoon was designated the larval period and from cocoon formation and coming out from pupal case as pupal period.

The time after emergence of adults and start of oviposition was considered as pre-ovipositional period, the period of egg-laying was considered oviposition and post-oviposition period of female was recorded as period between the days female ceased egg laying to the day of death. To study the percent hatchability, eggs were harvested with razor and separated along with black muslin cloth, counted and kept for hatching.

Two days old virgin adults were paired in the rearing glass chimney (4 x 7.5 cm), provided with standardized adults' diet on hard paper card and wet cotton was placed in glass vials in chimneys. The period of survival of each male and female was observed regularly in order to record longevity (days) and total number of eggs laid by each female during their oviposition period.

In mixed host diet all five hosts were given in equal proportions in glass vials (2.5cm diameter and 8.5 cm length) covered with black muslin cloth piece. The larvae were fed with eggs/ nymphs in these jars till pupation. The developmental period of the immature stages and all parameters were recorded daily. Data collected on fecundity, fertility, incubation, larval instars, pupal period and other various aspects of predator biology were subjected to analysis of variance and the treatment means were compared using Duncan's Multiple Range Test (Gomez and Gomez, 1984) with the help of MSTATC computer soft ware as analyzing tool.

RESULTS

Incubation period

The results in Table I showed that the incubation period of eggs of *C. carnea* feeding on different hosts was significantly different from each other ($F= 117.06$; $DF= 5, 42$; $P <0.001$). It was 2.25, 2.28, 2.36, 3.85, 2.25 and 2.80 days on *A. gossypii*, *P. solenopsis*, *S. cerealella*, *H. armigera*, *P. gossypiella* and mixed host diet, respectively. The minimum incubation period of 2.25 days was recorded for eggs laid by females fed on *A. gossypii* and *S. cerealella* as larvae.

Larval period

The results indicated that larval period of *C. carnea* feeding on different hosts was significantly different ($F= 34.34$; $DF= 5, 42$; $P <0.001$). Duration

Table I.- Effect of feeding of *C. carnea* on different hosts on different developmental parameters under laboratory conditions (Mean±S.E.).

Developmental parameters	*Aphis gossypii* (nymph/adults)	*Phenacoccus solenopsis* (nymphs)	*Helicoverpa armigera* (eggs)	*Pectinophora gossypiella* (eggs)	*Sitotroga cerealella* (eggs)	Mixed host diet
Incubation period (days)	2.25 c	2.28 c	2.36 c	3.85 a	2.25 c	2.80 b
Instars period 1st Instar (days)	2.62±0.18 b	2.87±0.12 b	4.00±0.00 a	3.00±0.00 b	2.50±0.18 b	2.87±0.29 b
2nd Instar (days)	2.75±0.16 c	3.00±0.00 c	4.12±0.12 a	4.12±0.12 a	2.75±0.16 c	3.50±0.18 b
3rd Instar (days)	3.12±0.12 c	3.62±0.26 b	4.25±0.16 a	4.25±0.16 a	3.00±0.00 c	4.62±0.18 a
Larval period (days)	8.50±0.32 d	9.50±0.32 c	12.37±0.18a	11.37±0.26 b	8.25±0.25 d	11.00±0.32 b
Pupal period (days)	7.75±0.16 bc	7.75±0.16 bc	8.37±0.18 a	8.50±0.18 a	7.37±0.18 c	8.25±0.25 ab
Larval survival (%)	87.50±12.50	62.50±18.30	75.00±46.29	50.00±18.90	100.00±0.00	75.00±16.40
Survival to adults stage (%)	87.50±35.35	62.50±51.75	75.00±46.29	50.00±53.45	100.00±0.00	62.50±51.75
Male longevity (days)	21.75±0.49 b	20.25±0.25 c	19.75±0.25 c	19.62±0.32 c	23.62±0.42 a	20.00±0.46 c
Female longevity (days)	38.00±0.65 a	32.25±0.72 b	30.87±0.39 b	30.87±0.35 b	38.62±0.62 a	31.25±0.99 b

Figures followed by same letter with in a row are not significantly different from each other at 5% DMRT.

of first larval instar was 2.62, 2.87, 4.00, 3.00, 2.50 and 2.87 days, while duration of second instar was recoded as 2.75, 3.00, 4.12, 4.12, 2.75 and 3.50 days and that of third instar was 3.12, 3.62, 4.25, 4.25, 3.00 and 4.62 days, respectively, on *A. gossypii*, *P. solenopsis*, *H. armigera*, *P. gossypiella*, *S. cerealella* and mixed host diet. The order of complete larval developmental period on different insect prey species was *S. cerealella* > *A. gossypii* > *P. solenopsis* > mixed host diet > *P. gossypiella* > *H. armigera*. The complete larval developmental period was 8.50, 9.50, 12.37, 11.37, 8.25 and 11.00 days on *A. gossypii*, *P. solenopsis*, *H. armigera*, *P. gossypiella*, *S. cerealella*, and mixed host diet, respectively. The shortest and the longest larval period of *C. carnea* were recorded as 8.25 and 12.37 days on *S. cereallela* and *H. armigera* eggs, respectively (Table I).

Pupal period

The pupal period of *C. carnea* (Table I) was significantly different on various hosts (F= 5.31; DF= 5, 42; P <0.001). The cocoon period of *C. carnea* was 7.75, 7.75, 8.37, 8.50, 7.37 and 8.25 days fed on *A. gossypii*, *P. solenopsis*, *H. armigera*, *P. gossypiella*, *S. cerealella*, and mixed host diet, respectively. The maximum to the minimum pupal period was in the order of *S. cerealella* > *A. gossypii* > mixed host diet, *H. armigera*, *P. solenopsis* > *P. gossypiella*.

Larval and pupal survival

Analysis of data (Table I) indicated a non-significant effect of hosts on the survival of *C. carnea* pupae (F= 1.35; DF= 5, 42; P >0.05) and adults (F= 1.40; DF= 5, 42; P >0.05). However, the maximum survival of pupae and adults was recorded when *C. carnea* was feeding on eggs of *S. cerealella* followed by nymphs and adults of *A. gossypii*. The minimum survival to pupal and adult stages was observed on eggs of *P. gossypiella*.

Reproductive attributes

Feeding of different hosts to larvae of *C. carnea* (Table II), significantly affected its fecundity (F= 87.17; DF= 5, 42; P <0.001). Similarly, significantly (F= 36.37; DF= 5, 42; P <0.001) higher fertility of eggs of *C. carnea* was recorded when fed on eggs of *S. cerealella* as larval host followed by *A. gossypii*. The maximum mean adult male and female longevity was recorded for *C. carnea* feeding on *S. cerealella* as a host followed by *A. gossypii*. There was significant (F= 17.13; DF= 5, 42; P <0.001) male and (F= 30.61; DF= 5, 42; P< 0.001) female variation in adult longevity due to feeding on different hosts. The maximum average

Table II.- Effect of feeding on different hosts on different reproductive attributes of *C. carnea* under laboratory conditions (Mean±SE).

Reproductive parameters	*Aphis gossypii* (nymph/adults)	*Phenacoccus solenopsis* (nymphs)	*Helicoverpa armigera* (eggs)	*Pectinophora gossypiella* (eggs)	*Sitotroga cerealella* (eggs)	Mixed host diet
Pre-oviposition period (days)	3.37±0.18 b	3.62±0.18 ab	4.12±0.12 a	3.87±0.22 ab	2.37±018 c	3.37±0.18 b
Oviposition (days)	27.62±0.42 b	21.62±0.49 c	19.12±0.61 d	19.25±0.36 d	29.50±0.82 a	20.12±0.74 cd
Oviposition/ day/ female (days)	15.21±0.27 c	17.82±0.44 b	17.74±0.23 b	17.58±0.30 b	17.13±0.47 b	20.15±0.83 a
Post-oviposition (days)	6.87±0.47	7.00±0.56	7.62±0.26	7.62±0.32	6.75±0.25	7.50±0.42
Fecundity/ female	419.80±6.35 b	384.00±3.15 c	338.90±9.19d	337.80±3.61 d	503.30±9.17a	401.63±5.30bc
Fertility (%)	87.88±0.74 a	85.09±0.70 b	82.75±0.52 b	75.10±1.11 c	88.61±0.68 a	82.92±0.95 b

Figures followed by same letter with in a row are not significantly different from each other at 5% DMRT.

pre-oviposition period of *C. carnea* after feeding on *H. armigera* was 4.12 days and the minimum 2.37 days after feeding on *S. cerealella*. The average longest oviposition period of *C. carnea* females was 29.50 days recorded on *S. cerealella* followed by 27.62 days on *A. gossypii*. The maximum mean post-oviposition period was 7.62 days recorded on *P. gossypiella* and *H. armigera*. The maximum mean fecundity per female of *C. carnea* was 503.30 eggs recorded when fed as larvae on *S. cerealella* followed by 419.80 eggs on *A. gossypii*, whereas, the minimum of 337.80 eggs was recoded when fed on *P. gossypiella* eggs.

DISCUSSION

Larval food significantly affected the length of larval period. The shortest larval period was recorded on *S. cerealella* eggs, while longest on *H. armigera* eggs. Balasubramani and Swamiappan (1994) studied development of *C. carnea* on different hosts in laboratory and found that larval development was rapid on eggs of *Corcyra cephalonica* (8.20 days) and longest on neonates of *H. armigera* (11.10 days). Mannan *et al*. (1997) studied biology of *C. carnea* on *A. gossypii* and *M. persicae* and observed that larval duration was long when fed on *M. persicae*. Saminathan *et al*. (1999) and Bansod and Sarode (2000) studied biology and feeding potential of *C. carnea* on different hosts and noted developmental period of *C. carnea* ranged from 18.6 days on *Aphis cracivora* to 22.7 days on *H. armigera* neonate larvae. Giles *et al*. (2000) studied nutritional interactions among alfalfa, *Medicago sativa* and faba bean, *Vicia faba*, as host plants, pea aphid, *Acyrthosipnon pisum* an herbivore and *C. carnea* a predator. *C. carnea* larvae developed faster on pea aphid reared on alfalfa than on pea aphid raised on faba bean. Chemical analysis showed that aphids reared on faba bean had 6.3 times more levels of myristic acid. The duration of development of *C. carnea* was significantly different on three aphid species. It was shortest when larvae were fed *A. gossypii* followed by *M. persicae* and *Lipaphis erysimi* (Liu and Chen, 2001). Ballal and Singh (1999) and Bartlett (1984) studied the host plant-mediated orientational and ovipositional behaviour of three species of chrysopids and found that *C. carnea* females had significantly higher preference for sunflower and cotton, while pigeonpea was less preferred. On cotton, *C. carnea* preferred to lay more eggs on underside of leaves than on buds. Flint *et al*. (1979) reported that damaged cotton plants release the terpenoid β caryophyllene which attracts *C. carnea*.

Survival to adult stage and fecundity of *C. carnea* was affected due to feeding on different hosts. The maximum survival to adult stage and fecundity were recorded when *C. carnea* were reared on *S. cerealella* eggs, while minimum survival to adult stage and fecundity were found for insects feeding on *P. gossypiella* eggs. Osman and Selman (1993) investigated the influence of different aphid species on larval development and

fecundity of *C. carnea*. *M. persicae* and *A. pisum* were suitable, while *A. fabae* was most unsuitable prey causing high juvenile mortality. *C. carnea* larvae fed on this aphid and *Macrosiphum albifrons* had reduced fecundity. The survival of larvae of *C. carnea* feeding on *A. cracivora*, *Drosophila melanogaster* and *C. cephalonica* were 51.8, 80.9 and 86.7%, respectively. While *C. carnea* laid 1079, 582 and 172.8 eggs/female when reared on *C. cephalonica*, *D. melanogaster* and *A. cracivora*, respectively (Tesfaye and Gautam, 2002). When Obrycki *et al*. (1989) fed *C. carnea* larvae on *Ostrinia nubilalis* and *Agrotis ipsilon* eggs, 26-40% larvae died and when reared on *A. ipsilon* neonates, 65%, while all larvae died when fed *O. nubilalis* neonates, which was due to entanglement in silk produced by these larvae.

Liu and Chen (2001) determined the development, survival and predation of *C. carnea* on three aphid species, *A. gossypii*, *M. persicae* and *L. erysimi*. Survival was significantly different on aphid species; when larvae were fed on *A. gossypii* and *M. persicae*, 94.4 and 87.6% individuals developed to adult stage, respectively; whereas, only 14.9% when fed *L. erysimi*. Duration of development was significantly short (19.8 d) when fed *A. gossypii* followed by *M. persicae* (22.8 d) and *L. erysimi* (25.5 d). Similarly, *C. carnea* consumed more *A. gossypii* (292.4) and *M. persicae* (272.6) than *L. erysimi* (166.4). Zheng *et al*. (1993) found a highly significant positive correlation between prey consumed during larval stage and adult body weight of *C. carnea*.

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