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Life table attributes of *Chrysoperla carnea* (Neuroptera: Chrysopidae) reared on *Corcyra cephalonica* (Lepidoptera: Pyrilidae) eggs under laboratory condition

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Abstract

Study was conducted to investigate the survivorship of immature stages for constructing life table and female fecundity rate of *Chrysoperla carnea* fed on *Corcyra cephalonica* eggs under laboratory condition *of* 25±2 °C with 65±5% relative humidity. Results showed that the highest mortality was observed in pupal stage (8.22%) followed by 2nd instar (8.14%) and egg stage (8%). Survival fraction (Sx) was found to be maximum (0.97) at 3rd instar stage followed by pre-pupal stage (0.95). The k-value was found maximum (0.04) at egg stage and minimum (0.01) at 3rd instar stage. The K- value for the all stages was (0.17). The gross reproductive rate (GRR) was 176.5 and net reproductive rate (Ro) was (44.39) females per female per generation. Mean generation time (T) was 19.96 days, while the intrinsic rate of natural increase (rm) was (0.19) female per female per day. The finite rate of increase (λ) was (1.21) females per female per day. The population double time (DT) was (3.63) days.

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Introduction

Chrysopids, also known as green lacewings can feed on more than 80 insect species and 12 tetranychid, mite species (Zia *et al*., 2008). The genus *Chrysoperla* contains some very important predators, which can be applied in augmentation programmes (Venkatsan *et al.,* 2008). Its adults live freely and use pollen and honeydew as feed. The larval stage is the main predatory stage that feds on the insect's eggs and also attacks different soft bodied insects such as aphids, thrips, cicadellids, coccids, psyllids (Ridgway and Murphy, 1984).

C. carnea is the most intensively studied species of Chrysopids because of its wide geo-graphical distribution, broad habitats with high relative frequency of occurrence, good searching ability (Morrison, 1985). *C. carnea* can adopt to a wide range of ecological factors and can be easily mass reared and applied in the field for controlling different kinds of insect pests (Hoddle and Robinson, 2004).

The larvae of *C. carnea* feed on a wide range of pest species while adults are free living and feed only on nectar, pollen and honey dew (El-Serafi *et al*., 2000). Green lacewing larvae are effective for inundative biological control of several pests of greenhouse and field crops (Sattar *et al*., 2007). They have short life cycle and a vast diversity of host; and can easily be mass reared. According to an estimate up to one third of the successful biological control programs for insect pests are due to the introduction of *C. carnea* and the release of insect predators (Williamson and Smith, 1994).

Life table is the most important diagnostic means for comprehensive information of population growth which provides a broad explanation of the life and anticipation of life. Systematic studies of life, reproductive tables, and stable population characteristics have their importance in IPM and mass raring program of natural enemies. It is important to know characteristics like growth, variations in stages, egg laying pattern for successful mass rearing of predators in biological control program (Gabre *et al.,* 2005).

Mass rearing of predators or any biological control agent is a pre-requisite for any successful biological control program, but it is impossible without using a standard host. Economic mass rearing of bio control agent is the first step in biological control program. The demand for biological pest management program increasing day by day. Augmentation of insect bio control agents is highly important for the management of insect pests.

Keeping in view the importance of *C. carnea* as bio control agent the present study was conducted on life table attributes reared on *C. cephalonica* eggs that will be helpful to provide the necessary data for its mass production under controlled condition and for further utilization and propagation in a pest management program.

Materials and methods

The stock culture of predator *C. carnea* and their host insect, *C. cephalonica* was maintained in Insectary at Department of Plant and Environmental Protection, National Agricultural Research Centre Islamabad Pakistan.

Culture maintenance of C. cephalonica

The stock culture of *C. cephalonica* was maintained on rice grains in rearing jars. The grain was infested once with sufficient eggs of *C. cephalonica* and kept in transparent rearing jars (12 × 6) cm, covered with muslin cloth at the top. Upon adult emergence from the grains inside the jars. The female moth lay their eggs from inside the jars through their ovipositor to the outside of muslin cloth at the top. The eggs were collected from the top of the jars daily and used for continuous stock culture maintenance. The eggs were also used for feeding to *C. carnea* larvae.

Rearing of C. carnea

Adults of *C. carnea* were reared in a mass rearing cages. The cage has two round windows (13cm diameter) covered with lids, occurred diagonally near corners of a front wall of the cage made up for the handling of adults. Artificial foods contained yeast, sugar, honey and water in ratio of (2 : 1 : 1: 4) tea spoon were

provided in food bowls of small size, 0.5cm diameter attached in the upper side of the two plastic rods, both of 4mm thick and 22cm long. Black granulated paper was placed on the underside of the removable top of the cage as oviposition substrate. The eggs were collected and kept for hatching and the stock culture was maintained.

Experiments

To study the life table parameters a total of 100 eggs of *C. carnea* of the same age were collected from stock culture and kept for hatching under controlled condition of 25 ±2 ºC and 65 ±5 % relative humidity. Alive and dead insects at each particular stage were documented daily. Data on stage specific survival and mortality was collected. Life-tables for adult female were constructed by determining for each age interval the fraction of the initial population of individuals still alive and the mean number of female progeny produced by these adult females at each age interval and followed the procedure adapted by (Birch, 1948). In such a table, the first column gives the mean age of the cohort (x), the second column lists the fractions (l_x) of the initial population still alive at the end of each age interval (x), and the third column gives the average number (m_x) of female offspring produced per female per day still alive at age x

Stage Specific Life-Table

Data on Stage specific life table was computed following the procedure adapted by (Ali and Rizvi, 2008). To construct stage specific life table the following standard heads were used.

x = Age (days) of the insect.

lx= No. of insects survived at start of the age interval (x).

dx = Mortality during age interval (x)

The information came from above statements were applied for calculating the following life table parameters.

ex = Probability of life or average life left over for individual of age x, and was computed by $e_x = Tx / lx$ wher, Lx and Tx were computed as below:

Lx = Individuals active between age x and x +1, and was determined by Tx= lx + (lx+1) + (lx+2).....+lw), where lw is the last age interval

Apparent Mortality (100 qx)

It provided the record (%) insect died and was determined by the formula.

Apparent Mortality = (dx / lx) X 100

Survival Fraction (Sx)

Data attained in apparent mortality was applied for the estimation of the stage specific survival fraction (Sx) of each stage with the equation:

Sx of particular stage = lx of succeeding stage / lx of that particular stage.

Mortality Survivor Ratio (MSR)

It is the enhancement in population and was determined by

MSR = (Mortality in particular stage) / (lx of subsequent stage)

Indispensable Mortality (IM)

IM = (Number of adults emerged) x (MSR of particular stage).

K-values

It is an important factor accountable for multiplication or reduction in number from one generation to another and was estimated as the variation in consecutive values for "log lx". The total generation mortality was determined by adding up the k values of various growth stages of an insect, which is designated as "K".

Female fecundity study

Life-tables for adult female *C. carnea* were constructed by calculating the numbers of the fraction of the initial population for each interval still alive and the mean number of female progeny produced by adult females during each age interval. In such a table, the first column gives the mean age of the cohort (x), the second column lists the survival fractions (l_x) of the initial population still alive at the end of each age interval (x), and the third column gives the average number (m_x) of female offspring produced per female per day still alive at age x.

The information regarding female growth time, female fraction in sex ratio, fecundity at particular age on daily basis and survival for construction life table was calculated. When the values for (l_x) and (m_x), once tabulated, then the following population parameters were calculated.

Gross reproductive rate (GRR= Σmx)

Gross reproductive rate is the total life time multiplication when no death occurred. It gives the average lifetime increase of the individuals that live to senescence. It is helpful in view of potential population growth by keeping the removal of all ecological limitations (predation, competitors, disease, and starvation).

Net reproductive rate ($R_o = \Sigma$ lxmx)

Mean No. of offspring's produced by an insect in its lifetime, keeping in view the usual mortality, lx is the chances of existence to age x, mx is the mean offspring's produced at that age, so (lx.mx) is the average number of offspring's produced by individuals of age x.

Approximate generation time (Tc) days

Approximate generation time is calculated by equation

Tc = Σx.lx.mx/Σlx.mx, where lxmx is the mean number of progeny born to female during age x.

Innate capacity for increase (rc)

Computed as $r_c = \ln R_o/Tc$

Intrinsic rate of natural increase (rm)

Determined by iteration of Euler's equation, Σe^{-rx} lx.mx=1

(i) Build an e^{-rx} column.

(ii) Build an e^{-rx}.lxm.x column and sum it. The summing terms rose to a negative exponent of r, so rise in r will decline the sum. Amend approximation of r and attempt again.

Finite rate of increase (λ)

The finite rate of increase indicate the female offspring produced per female/day, determined by,

$\lambda = e^{rm}$.

Corrected generation time (T)

Calculated by (T) = R_o/rm

Doubling time (DT)

The (DT) is the days required by a population to double in numbers and calculated by DT = $\ln 2/r_c$ (Birch, 1948).

Results and discussion

Stage specific life-table

Apparent mortality

The intrinsic rate of increase is basic parameter for predicting the potential of population growth (Robert and Miller, 2000). It is the rate of increase per head under specified physical conditions (Birch, 1948).

Table 1. Life table attributes of *C. carnea* reared on *Corcyra cephalonica* eggs.

Stage X	lx	dx	Lx	100 qx	Sx	Tx	MSR	IM	Log lx	ex	k-values
Egg	100	8	96	8	0.92	524	0.09	6.03	2	5.24	0.04
1st instar	92	6	89	6.52	0.93	428	0.07	4.69	1.96	4.65	0.03
2nd instar	86	7	82.5	8.14	0.92	339	0.09	6.03	1.93	3.94	0.03
3rd instar	79	2	78	2.53	0.97	256.5	0.03	2.01	1.90	3.24	0.01
Pre-pupa	77	4	75	5.19	0.95	178.5	0.05	3.35	1.89	2.32	0.03
Pupa	73	6	70	8.22	0.92	103.5	0.09	6.03	1.86	1.42	0.03
Adult	67		33.5		0	33.5			1.83		
Male/female	28/39										0.17

The (rm) values are positive at all tested temperatures which indicate the population growth. The present results are in conformity with results of Yu *et al.* (2013), who reported that intrinsic rate of increase (rm) and finite rate of increase (λ) was maximum at 25 °C and minimum at low temperature 15 °C.

The highest mortality was observed in pupal stage (8.22%) followed by 2nd instar (8.14%) and egg stage (8%). When the mortality of all the larval instars was compared, the highest mortality (8.14 %) was observed in second instar followed by first instar (6.52%), whereas, the minimum mortality was observed for 3rd instar (2.53%). Similarly, the apparent mortality for pupal stage was (8.22%) followed by pre-pupal stage (5.19%). These observations revealed that pupal stage was the most vulnerable stage in the life cycle while among the larval instars 2nd larval instar was much delicate than the other instars and hence, showed higher mortality at this stage. Similarly after pupal and 2nd instar stage, egg stage was also found to be sensitive stage (Table 1). These results are in contradiction from Alasady *et al.*, (2010) who observed highest mortality at egg stage (44.3%) followed by 2nd instar larva (15.4%) and pupal stage (11.4%).

Table 2. Female fecundity schedule of *C. carnea*.

Age (x_o)	Pivotal age ($X_)$	Probability (Lx)	Mx	Lx.Mx	X.Lx.Mx	rm= $\sum e^{-rx}$. Lx.mx=1
0-5	2.5	0.39	0	0	0	0
5-10	7.5	0.38	9.4	3.57	26.79	0.859
10-15	12.5	0.35	21.5	7.53	94.06	0.7
15-20	17.5	0.31	35.8	11.1	194.21	0.399
20-25	22.5	0.28	43.6	12.21	274.68	0.17
25-30	27.5	0.21	33.1	6.95	191.15	0.037
30-35	32.5	0.11	21.8	2.4	77.94	0.005
35-40	37.5	0.06	9.2	0.55	20.7	0
40-45	42.5	0.02	2.1	0.04	1.79	0
45-47	46	0.01	0	0	0	0
			∑=176.5	∑=44.35	∑=881.32	2.17

Survival fraction

Survival fraction (Sx) was found to be maximum (0.97) at 3rd instar stage followed by pre-pupal stage (0.95), while minimum Sx (0.92) was observed for pupal stage. Among the larval instars, maximum Sx was observed for 3rd instar (0.97) followed by 1st instar (0.93) (Table 1).

Mortality survivor ratio

Mortality survival ratio (MSR) was found maximum (0.09) at egg stage and minimum (0.03) at 3rd instar stage. Among the larval instars, the maximum MSR (0.09) was observed for 2nd instar followed by 1st instar (0.07) and 3rd instar (0.03). Similarly, the MSR values were observed as 0.05 and 0.09 for pre-pupal and pupal stages respectively (Table 1).

Indispensable mortality

Indispensable mortality (IM) was recorded maximum (6.03) at pupal and minimum (2.01) at 3rd instar stage. While comparing the IM values of larval instars, 2nd instar showed maximum IM (6.03) followed by 1st instar (4.69) and 3rd instar (2.01). Likewise, IM values for pre-pupal and pupal stages were observed as (3.35 and 6.03), respectively (Table 1).

Life expectancy (ex)

Life expectancy (ex) values were found to be maximum at egg stage (5.24) and minimum was obtained for pre-pupal stage (2.32). The ex values for 1st, 2nd and 3rd instar larvae were (4.65, 3.94) and (3.24) respectively. Similarly, ex values for pre-pupal and pupal stages were recorded as (2.32) and (1.42) respectively (Table 1).

K-values

The k-value was found maximum (0.04) at egg stage and minimum (0.01) at 3rd instar stage. While comparing the larval instars, highest 'k' value (0.03) was obtained for 1st and 2nd instar and minimum 'k' value (0.01) was obtained for 3rd instar. K-value for pre-pupal and pupal stages was evaluated as 0.03 for both the stages (Table 1).

*Age specific life-table*Age-specific survivorship and fecundity female *C. carnea* is presented in Table 2 and 3.

The data on population and reproductive parameters revealed that Gross reproductive rate (GRR) was (176.5) and net reproductive rate was (44.39). Mean length of approximate generation time (Tc) was calculated as (19.87) days. Estimated value of innate capacity for increase was 0.19. The doubling time DT was (3.63) days. The Tc, rc and DT are useful parameters for measuring the population growth under a given set of conditions (Siswanto *et al.*, 2008).

Table 3. Population and reproductive of *C. carnea* feed on eggs of *C. cephalonica*.

Parameters	Formula	Values
GRR=	$\sum$ (mx)	176.5
R_o=	R_o ($\sum$ (mx.lx)	44.35
Tc=	T: $\sum$ (lx.mx.x/$\sum$ (mxlx)	19.87
rc=	ln R_o/Tc	0.190806
rm=	$\sum e^{-rx}$ lxmx=1	0.19
λ =	e^{rm}	1.20925
DT=	ln (2)/rc	3.63273
T=	lnR_o/rm	19.96

The Intrinsic rate of natural increase (rm) of the predator was (0.19) per female/day with a mean generation time of (T) (19.96) days and daily finite rate of increase (λ) was (1.21). According to these statistics, the populations of *Chrysoperla* sp. (*carnea*-group) multiplied (44.39) times in a generation time of 19.96 days on *C. cephalonica* eggs, the rate of multiplication per day was 0.19 females/female. Jervis *et al.*, (2005) found out that prey species can influence the intrinsic rate of natural increase of predators.

The results of the present study indicate the value obtained for different parameters were found to be lower than the parameters studied by Bakthavatsalam *et al.*, (1994) (Ro = 63.90, λ = 1.558) and were also lower than that of by Elsiddig *et al.* (2006), who fed *M. boninensis* on *C. cephalonica* eggs and determined values as (Ro = 139.117, GRR = 225.42), but higher than the Alasady *et al.*, (2010) who determined (Ro = 2.28, GRR = 19.48, λ=1.02). Bansod and Sarode (2000) conducted the life table studies of *C. carnea* on different preys and concluded that highest fecundity was obtained on sterilized eggs of *C. cephalonica* and also concluded that the eggs of *C. cephalonica* are ideal food under laboratory condition. Takalloozadeh, (2015) studied that the pre-imaginal stage development and total development time in *C. carnea* were significantly affected by species of prey tested. There was also significant difference due to feeding on different preys in adult longevity.

The present study established the life table parameters of *C. carnea* suggesting its use in biological control programmes, due to its greater egg output, faster development, higher net reproductive rate, high finite rate of natural increase and innate capacity for increase. The significantly higher population parameters, along with shorter doubling times shows that its population can grow quickly and can be successfully used for the management of insect pests of economic importance and in short time an exert a controlling pressure on pest population.

Life table data helps in the evaluation of future progeny and in estimating the total number to be released in successful biological control programmes.

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