Research Article

Potential of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) Fed on Aphid, *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) under Controlled Conditions

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Abstract | Life table attributes of *Chrysoperla carnea* (Steph.) fed on *Myzus persicae* (Sulzer) were investigated under controlled conditions at 25 °C, a relative humidity of 60 %, with a light-to-dark time ratio of 16:8, in 2018.The results regarding biological parameters indicate that larvae duration was 10.34 days. The larvae consumption rates were 379.2 aphids during their life span. Functional response of larval instars indicates that with increasing prey densities, the number of aphids consumed linearly increase and then become static after attain the asymptote level at certain densities were 25, 35 and 70 aphids per first, second and third instar larvae. The life table's immature stage survival and female fecundity rate revealed that the stage of eggs had the greatest death rate, at 12%, followed by pre pupal stage. The lowest mortality was observed in 2nd instar stage. Sx was determined to be maximal during the second instar stage and minimal at the pre-pupal stage. The total mortality per generation (K-value) from all immature stages was 0.26. The total female fecundity was 379.0 eggs and the fertile eggs ratio were 144 and net reproductive rate (Ro) was 2.57 eggs per female/day. The intrinsic rate of natural growth (rm) was 0.34 female per female per day, with a mean generation time (T) of 3.06 days. 1.404948 females per female per day was the limited rate of growth (λ). The DT for the population was 2.06742 days. The approximate generation time (Tc)was 3.1 days and innate capacity for increase (rc) was 0.335371 days. The present finding indicates that *C. carnea* is a voracious predator which can very easily be utilized for the management of *M. persicae*.

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Introduction

The green peach aphid, *Myzus persicae* Sulzer, (Hemiptera: Aphididae) is economically the most important crop pest worldwide (Bass *et al*., 2014). A variety of characteristics contribute to this species reputation as a pest, including its ability to disseminate, host range, dispersal, harm methods, life cycle, and pesticide resistance. It causes harm by feeding directly on the host, resulting in the spread of essential plant viruses (Blackman and Eastop, 2007). Chemical pesticides have traditionally been used by growers to control *M. persicae*, but their widespread usage has resulted in the development of several types of resistance (Bartonm and Anthon, 2014). Biological control agents are getting a lot of attention in relation to the resistance issues with this pest species, particularly *C. carnea*, which is regarded as an important aphid predator in agricultural crops because of some of their unique attributes, including: a wide variety of prey, ravenous feeders, and show a rapid response (Dixon, 2000). The larvae of *C. carnea* fed on extensive kind of pests types whereas, the adults are able existing fed simply on sap, pollens and sweetie (Seirrafi *et al*., 2000). It acknowledged more attention from scientists as well as growers as possible biotic management agents (Al-Asady *et al*., 2010; Saljoqi *et al*., 2015). Attentiveness in using this valuable predator as the utmost vital components of IPM packages for field and nursery crops has newly better as farmers initiate substitutes to insecticides for controlling pest (Sattar *et al*., 2007). As according estimates, the introduction of *C. carnea* and the release of insect predators is responsible for up to one-third of successful biological control programs for insect pests (Sattar and Abro, 2011).

Life table studies of insect, existence and fecundity of a group of insect also delivers important data of inhabitant dynamic. A existence table is considered to estimate the suitability's of a inhabitants as caused by dissimilar existing and dead reasons (Gaabre *et al*., 2005). It is best key to identify features similar development, differences in phases, eggs laying and destructive prospective for effective mass rearing of hunters in biotic management program (Chai and Lieu, 1985). Time, phase real living and dead of mature female fertility rate (mx), survivorship (lx) from start to finish age are the parameters of the tables (x). When the previously charted lx and mx additional limitations with a population's mean age group time (T), repetition period (DT), net generative rate (R0) may be purposeful. As a result, the essential rate of normal rises (rc), which only best describes the expanding number of classes under mentioned circumstances (Mandouor, 2009).

Functional response of predator is the main factor in adaptable of the inhabitant's undercurrents of chaser victim structure (Sinclair and pech, 1996). Functional reaction of hunter is excessive position which assistance to regulate up to level and in what way types are dependent to his host. Functional response hunters to victim depend on the bodily heterogeneity of the territory (Price, 1984). There are three sorts of efficient response. Type 1 functional response of predator is a distinctive reaction of predator in which hunters consume definite sum of victim in each unit time. The type 2 functional response of an entity in which the hunter hold on its target (Thompson, 1975). In type 3 functional response predator-prey link is sigmoid. Target control period becomes primary section in the existing time (Morozov and Petrovskii, 2013).

The purpose and novelty of the study was to construct life table parameters of *C. carnea* and to find out functional response on *M. Persicae* aphid and evaluate its potential as a bio-control agent against *M. persicae.*

Materials and Methods

The present studies were investigated on biological characteristics and life table factors of *C. carnea* fed on *M. persicae* s under laboratory condition at 25 ±1°C temperature, 60±5 % relative humidity and 16:8 hours photoperiods. The experiment was conducted at Bio Control Labs. at IPMP, NARC Islamabad during, 2018.

Sowing of host plants

To maintain culture of *M. persicae*, cabbage and potato plants were sown in glass houses on beds measuring (8×4) sq. feet. Normal approaches were used to raise the plants of both cabbage and potato in separate glasshouses in Insectary at NARC, Islamabad (Figure 1A).

Culture maintenance of M. persicae

The culture of *M. persicae* was maintained on cabbage and potato plants in separate glasshouses on beds. Initially the aphids were collected from potato field at

National Agricultural Research Centre. The infected leave was only isolated from the planted plants and kept into the terminal portion of the new emergent host plants in glass houses. The colonies were maintained throughout the experimental duration (Figure 1A).

Figure 1: *(A) Rearing of M. Persicae on potato and Cabbage plants under glasshouse conditions. (B) Colony maintenance of M. Persicae on infested leaves of cabbage.*

Rearing of C. carnea

C. carnea adults were reared in a rectangular cage, made of 6cm thick, transparent plastic sheet. The cage was 35cm long, 35 cm high and 20cm wide. Two circular windows each of 13 cm diameters covered with lids of the same material situated diagonally near opposite corners of a front wall of the cage are made for handling adults, as well as for cleaning sanitation and provision of water in Petri dish etc. Artificial foods containing yeast + sugar + honey + water (2:1:1:6) (Ulhaq *et al.*, 2006) were provide in food strips of 0.5 centimeter width incised in upper side of 2 plastic rods of 4 mm thick and 22 cm length width wise at the opposite inside in the cage. A filter of round hole (2 mm in diameter) bored into the sidewalls to confirm appropriate aeration in the cage for well existence and fertility of adults a dark granulated sheet base the detachable upper of the firsthand cage as an oviposition substrate (Figure 2A).

Rearing of larvae

The newly hatched larvae of *C. carnea* were separated and kept in plastic containers. The newly emerged larvae were provided *M. persicae* inside the containers on infested leaves of potato and cabbage plants. The diet was replaced daily with fresh diet till the larvae convert in to pre-pupal and then pupal stage. The process was continuous till the larvae were convert in pupal stage. The pupae were collected and kept in another container for mature appearance. When adults appearance the adults were shifted in to adult rearing cages for further multiplication and maintenance of stock culture inside the laboratory throughout the experimental durations (Figure 2B).

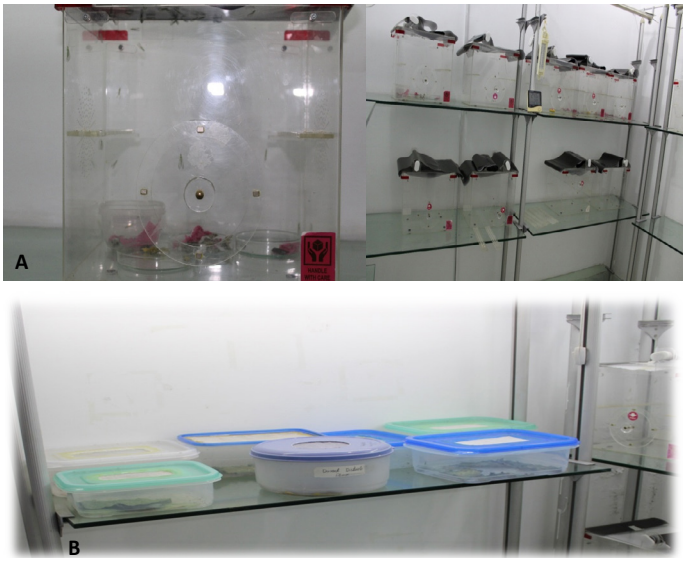

Figure 2: *(A) Culture maintenance of adult C. carnea in transparent cages under laboratory conditions. (B) Culture maintenance of C. carnea larvae in plastic containers under lab conditions.*

Developmental time and age and stage specific life table parameters of immature stages C. carnea fed on M. percicae

Two hours fresh eggs of *C. carnea* were collected from stock culture maintained on *M. persicae* under controlled conditions. A total of 100 eggs of the same age were collected and count under binocular microscope and kept in Petri dishes. Ten eggs were kept in each vials (6 x 3) cm with 10 replications. Percent hatching and incubation period of eggs were calculated. After hatching, first instar larvae were transferred in vials separately. Enough volume of aphids was provided on infected leaves of cabbage and potato plants in every vial. The vials were covered with muslin cloth at the top tight with rubber band separately. After 24 hours the old diets were changed with fresh diet each morning throughout the observation. The insect was observed for age and period specific life table parameters for each stage. The data were collected on molting, survival/ mortality during specific age and stage in different instars every day. The insect clearances through three larvae instars. The barn seen in each vial was evidence that the insects had progressed to the next instar. The

method was employed till pupation.

The following parameters were recorded for data collection.

- Eggs maturation duration in (days) and percent hatching of eggs
- Time of development of different larval instars duration of pre- and pupal stages developmental time from egg to adult
- Age and stage specific mortality/ survival rate from eggs to adults appearance
- Amount of male and female *C. carnea* appeared/ gender ratio

Statistical analysis

The data on developmental time and age and stage specific survival/mortality were subjected to analysis of variance with one way ANOVA using Statistix 8.1 package. Means were compared using LSD) test at 5% level of significance

Age and stage specific life table parameters

Age explicit life table parameters: The methodology used by (Ali and Rizvi, 2008) was followed with slighter modification. Active and late insects occurred from 100 eggs were calculated daily.

The given formulas were used for building of life tables parameters.

1	100 qx = Died in specific age interim x and calculated by formulation 100 q x = (d x/ l x)×100
2	x = age in (days) of the insect
3	lx = whereas insects lived at initial stage of his interval
4	dx = whereas insects deceased in each exact phase
5	ex = chance of existence or average life left over for individual of age x, and was calculated by ex = Tx / lx
6	Lx = Entitie active amongst life x and x +1, and was firm by Tx= lx + (lx+1) + (lx+2) upto +lw), where lw is the final life phase interval

Stage specific life table

To build specified period of life table the given method were used.

1	x = Show age of in insect.
2	lx= Complete number of entity lived at initial of the age time (x)
3	dx = Died during age time (x)

The data derived from overhead declarations were applied for manipulative the subsequent life table parameters.

Death rate/ Apparent mortality (102 qx) A.M = (dx/ lx) x 100

Existence Fraction (Sx): Sx of exact phase = lx of next step / lx of the certain phase.

Mortality Survivor Ratio (MSR)

The developments in inhabitants was firm by MSR = (Death in exact stage) / (lx of succeeding step)

Indispensable Mortality (IM)

IM = (No of adult developed) x (MSR of actual period)

K value

Killing power = killing power in Egg stage + k in Larvae1 + k in Larvae2 + k in Larvae3 + k in Pre-Pupal + k in Pupae, where k-values at egg, 1st to 3rd instar, pre-pupal, and pupal stage.

Biological attributes and life table parameters of adult female C. carnea

Upon adult emergence, a total of 31 female were paired with male *C. carnea* and kept in transparent small cages. The eggs laid by the female were kept for hatching and the larvae of each day were reared separately during the whole oviposition period. The procedure was continuous till the death of all pairs in rearing jars.

Figures were calculated on the next limitations:

- Pre oviposition period
- Oviposition period
- Post oviposition time
- No of eggs/ female
- No of eggs/Female/ day
- No of female progeny/female/ day

Life table parameters study

Life-tables parameters on adult female *C. carnea* were built through manipulative the figures of the section of early inhabitants for every pause quite active and total no of female offspring formed by females through every stage interval. In the table, the 1st pillar shows the sum age of group (x), the 2nd pillar list the existence portions (l_x) of the early inhabitants quiet active at the last of every period interval (x), and the 3rd pillar give the usual no (m_x) of female progeny formed every female/day quiet active at age x. Facts concerning female growing period, female portion in gender ratio and female fertility at specific life on regular base and existence for constructing life table were recorded.

The following population parameters were calculated

for construction life table parameters.
Gross reproductive rate (GRR= Σmx)
Net reproductive rate (R_o = Σ lxmx)
Approximate generation time (Tc) days Tc= Σx.lx. mx/ Σlx.mx
Innate capacity for increase rc (innate capacity for increase) =inr_{oo}/t R_m Euler's calculation, Σ $_e^-$r x l $_x$. m x =01
λ (Finite rate of increase) leads that the female progeny bentfemale^{-1}24 hrs^{-1}, formulated as λ=e r ^{c}
T(Generational time) =R^o / r cc

Doubling time (DT)
The (Doubling time) is the times need by inhabitants to twice in figures and considered by DT = ln2/r_c (Biirch, 1948).

Predatory potential of different larval instars of C. carnea fed on M. persicae
A total of 20 newly emerged first instar larvae were collected and shifted into transparent vials separately. The data were recorded on number of consumed, dead and unconsumed aphids in each vials daily under binocular microscope and the old diet was changed with fresh one each day during the time of observation. The process was continued till all larval instars convert in to pre pupal and pupal stage.

Functional response study of C. carnea larval instar against M. persicae
Experiments were conducted to analyze the efficient response of different larval instar of *C. carnea* fed on dissimilar prey densities of *M. persicae*. First and second nymphal instars of aphids of the similar physical ages were used for nourishing to 1st, 2nd and 3rd instar larvae of *C. cornea*. The target densities, for different larval instars were different. For first instar larvae, the target density were 10, 15, 20, 25 and 30 aphids per vials each with 10 replicates while for second instar larvae the prey density were 15, 25, 35, 45 and 55 aphids, respectively. While for third instar larvae the prey densities were 30, 50, 70, 90 and 110 aphids per larvae. Every target mass was duplicated 10 periods for every larvae instars. The larvae of *C. carnea* were kept in vials for 24 hours starvation without diet in plastic rearing vials. After starvation the larval instars were released in vials, consists different densities of prey insects. The vials was covered with muslin cloth and kept for 24 hours. After 24 hours the larvae were replaced from vials and the number of consumed, dead and unconsumed aphids were calculated.

The following observations were recorded with six-hour interval.
Number of consumed and unconsumed aphids per each larval instars fed on five constant prey densities.

Statistical analysis
The data on consumed and unconsumed aphids per every target density for each larvae instar were subjected to analysis of variance with one way ANOVA using Statistix 8.1 package. Means were compared using LSD) test at 5% level of significance.

Results and Discussion

Developmental time of immature stages of C. carnea
Developmental time of immature stages of *C. carnea* indicate that incubation period was recorded 4.51±0.07 days. Similarly, the duration of 1st, 2nd and 3rd instar of *C. carnea* were found 3.06±0.053, 2.89 ±0.017 and 4.38±0.10 days, respectively. Total larvae duration was noted 10.34±0.19 days. The recorded pre-pupal and pupal duration was 1.08 ± 0.05 and 5.43±0.10 days. The entire duration of egg to adult emergence was 21.36 ±0.18 days, respectively (Table 1).

Table 1: *Developmental time (days) ± SE of immature stages of Chrysoperla carnea (stephens) fed on Myzus persicae (Sulzer) (1st to 3rd) nymphal instars.*

Developmental stages	Developmental time ±SE	Min. and Max. duration in days
Incubation	4.51±0.069	4-5
1st instar	3.06±0.05a	2-3
2nd instar	2.89 ±0.08a	2-3
3rd instar	4.38±0.10b	4-5
Larvae	10.34±0.19	9-11
Pre pupae	1.08± 0.05	0.8-1
Pupae	5.43±0.10	4-6
Egg to adult emergence	21.36 ±0.18	20-23

Developmental time of adult male and female C. carnea
The result regarding adult biological parameters of *C. carnea* indicate that pre oviposition period was 5.0 ± 0.29 and oviposition period was 31.0±1.22 and post ovi- position period was 7.0±0.48 days (Table 2). The result shown that pre oviposition, oviposition and post ovi position period are significantly different from each other. The results regarding female and male

C. carnea total duration from the day of emergence to mortality were 43.0 ± 1.46 and 28.0 ± 1.67 days respectively (Table 2). The results regarding female of *C. carnea* different developmental stages indicate that the duration time were significantly different from each other except pre and post oviposition period (Table 2). Similarly, the duration of adult male and female *C. carnea* were significantly different from each other. The longevity of the female was longer higher than male *C. carnea* (Table 2).

Table 2: *Developmental time (days) ± SE of adult male and female Chrysoperla carnea (Stephens) under controlled conditions.*

Developmental Stage of *C. carnea* female	Duration in days + SE
Pre-Oviposition period	5.0 ± 0.29
Oviposition period	31. 0± 1.22
Post Oviposition period	7.0 ± 0.48
Female Longevity time	43.0 ± 1.4
Male Longevity time	28.0 ± 1.67
Mean No of eggs per female	379±3.46
Mean No of fertile eggs per female	144±2.16

Stage specific life table of C. carnea fed on M. persicae

The apparent (noticeable) mortality at egg, 1st, 2nd, and 3rd instars larvae were (12, 7.95, 4.93 and 10.38%, respectively (Table 3). The survival fraction (Sx) for eggs, 1st, 2nd, and 3rd instars larvae were (0.88, 0.92, 0.95 and 0.89, respectively. While the (Sx) of pre-pupa and pupal stage were 0.88 and 0.91 respectively. Maximum (Sx) were found in 2nd instar larvae while minimum was found in pre pupal stage (Table 3). MSR at egg, 1st, 2nd and 3rd instars larvae were 0.12, 0.07, 0.04 and 0.10 respectively, while (MSR) of pre pupal and pupal stage were 0.11 and 0.08, respectively (Table 3). IM for egg, 1st, 2nd and 3rd instars larvae were 6.72, 3.92, 2.24 and 5.6, respectively. The (IM) for pre pupa and pupae were 6.16 and 4.48, respectively (Table 3). The e^x for egg stage was greatest (4.54) and lowest for pupal stage (1.19), respectively. The life expectancy (ex) for 1st, 2nd and 3rd instars larvae were 4.09, 3.40 and 2.20, respectively (Table 3). The K - value k-value at egg phase was highest (0.06) and lowest (0.02). The k value for 1st, 2nd and 3rd instars larvae were (0.04, 0.02 and 0.05), respectively. The total K value for the whole generation was 0.26, respectively (Table 3).

Adult female fertility (mx) and survival (lx) of C. carnea female

The 1st exact fertility (mx) was observed at the time of day 6 and then gradually the number of mx per female were increased and maximum mx were observed at day 22 of female *C. carnea* (Figure 3). The maximum range was observed from day 19 to 25 days with maximum mx of 66 during this age. The first mortality was observed on day 7 and maximum mortality were 3 and 4 females died on day 16 and 29 age. The female laid their eggs up to the day of 36 and then further no eggs were observed in any pairs. The total duration was 43 days. The survivorship curve indicates that gradually decrease and after the age of 30 drastic mortality was observed in (Figure 3).

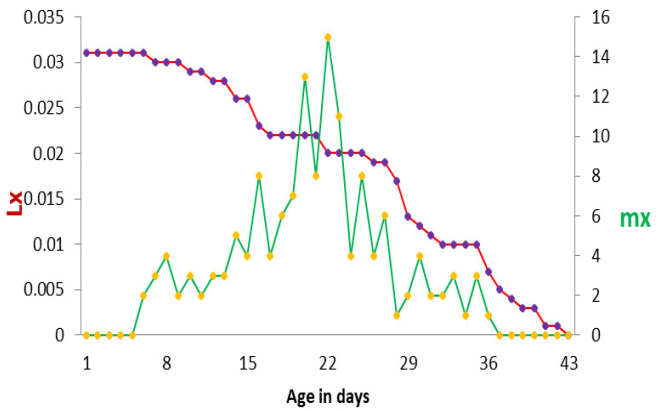

Figure 3: *Age specific survival (lx) and fertility (mx) of adult female C. carnea fed on M. persicae under controlled conditions.*

Table 3: *Stage specific life table parameters of C. carnea fed on M. persicae aphid.*

Stage X	Lx	Dx	Lx	100qx	Sx	Tx	MSR	IM	Log lx	Ex	k-values
Egg	100	12	94	12	0.88	454	0.12	6.72	2	4.54	0.06
1st instar	88	7	84.5	7.95	0.92	360	0.07	3.92	1.94	4.09	0.04
2nd instar	81	4	79	4.93	0.95	275.5	0.04	2.24	1.90	3.40	0.02
3rd instar	77	8	73	10.38	0.89	196.5	0.10	5.6	1.88	2.20	0.05
Pre-pupa	69	8	65	11.59	0.88	131.5	0.11	6.16	1.83	1.90	0.05
Pupa	61	5	58.5	8.19	0.91	73	0.08	4.48	1.78	1.19	0.04
Adult	56								1.74		K=0.26

Fertility life table parameters of adult female C. carnea

The results regarding female life table fecundity values of *C. carnea* are created in (Table 4). The results lead that Gross reproductive rate (∑mx) of adult female *C. carnea* was (144) and net reproductive rate was 2.83 when fed on *M. persicae* (Table 4). The results showed that R_o is greater > 1 and the population increase positively. The results regarding approximate generation time (Tc) was 3.1 and the innate capacity for increase (rc) was 0.335371. The intrinsic rate of natural increase was 0.34 and finite rate of population rise (λ) was 1.404948. The mean generation period was 3.06 days and the population doubling time was 2.07 days (Table 4).

Table 4: *Estimated life table parameters of C. carnea fed on M. persicae under controlled conditions.*

Life/ Fertility table statistics	Formulas	Value
Gross reproductive rate, GRR (Fertile eggs/ female)	∑(mx)	144
Net reproductive rate, R_o	∑ (lx.mx)	2.57
Approximate generation time, *Tc*	(mxlx)	3.1
Innate capacity for increase, *rc*	ln R_o/Tc	0.335371
Intrinsic rate of natural increase, *rm*	Σe^{-rx} lx.mx=1 (Euler equation)	0.34
Finite rate of increase, λ	e^{rm}	1.404948
Mean generation time, T	logR_o/rm	3.06
Doubling time, DT	ln(2)/rc	2.06742

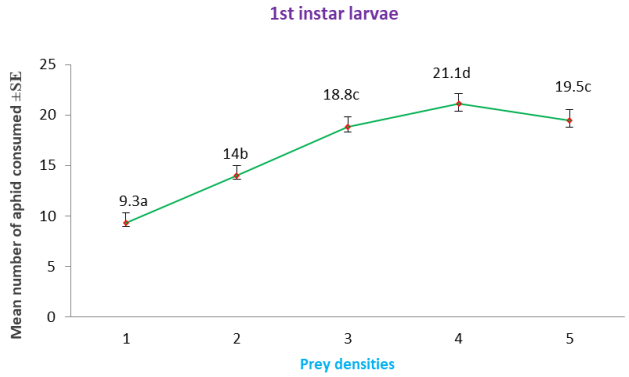

Figure 4: *Means followed by the same lower case letter are non-significantly different at ≤ 0.05 using LSD, test. Where 1= 10, 2=15, 3=20, 4=25 and 5=30 aphids per each density, respectively.*

Feeding efficiency of larval instars/ larvae of C. carnea fed on mix nymphal instars of M. persicae

The results regarding total feeding efficiency of different larval instars and larvae fed on *M. persicae* indicate that first, second and third instars consumed 46.8±1.04, 86.9±2.05 and 246.2±6.53, respectively and total larval feeding efficiency were 379.9±9.5894 aphids during their life span. The results indicate that feeding efficiency of all larval instars and larvae was significantly changed from each other. The data also revealed that third instar larvae ingested the most aphids when compared to the other two instars (Figure 4).

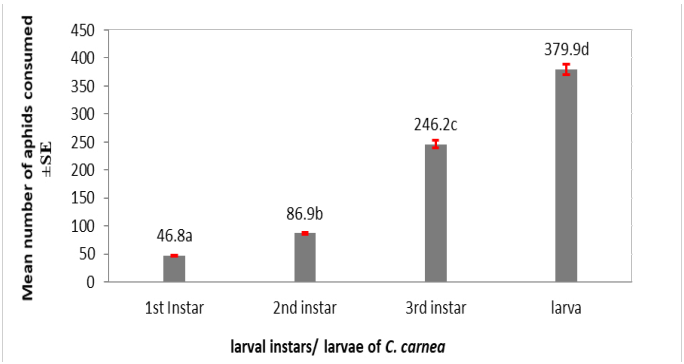

Figure 4: *Mean total feeding efficiency of larval instars/larvae of C. carnea fed on mix nymphal instars of M. persicae under controlled condition.*

Feeding efficiency of larval instars of C. carnea fed on constant prey density of M. persicae after 24 hours starvation

The findings regarding the impact of constant prey densities on the feeding effectiveness of first instar larvae show that the number of aphids consumed increases linearly with increasing prey densities before becoming static once it reaches the asymptote level at density, 25 Aphids vial^{-1} for 24 hours. The results indicate behind 25 aphid's density further increase in aphids have no significant increase while with further increase in prey density, significantly decreased the number of aphids consumed as compared to asymptote level. The graphical presentation revealed the first instar larvae exhibit type 2 functional response, which causes the rate of food consumption to first increase before becoming static at asymptote level (Figure 5). The results regarding consumption efficiency of second instar larvae of *C. carnea* on constant target density indicate with increasing prey density the number of aphids consumed increased. The second instar larvae attain the asymptote level at density 35 aphids per vials. The results further lead behind 35 aphids per vials extra surge in prey densities has no significant effect on food feeding rate. The second instar larvae also show type 2 functional response, in which the rate of food consumption surges initially before becoming static at encrypting level and that the subsequent surge in prey densities has no discernible impact on the rate of food consumption after a 24-hour fast (Figure 5). The results regarding

effect of constant prey density on 3rd instar larvae food consumption rate indicate the same results as it found in previous two instars. The findings show that the quantity of aphids taken improves linearly with the increase of prey density to become fixed when it reaches the securing level at 70 bugs/ vial. The findings also indicate that when the asymptote level is reached, additional increases in target densities have no appreciable influence on the rate at which food is ingested. The results indicate that maximum (66.1) aphids were consumed at density 90 but it was non significantly different from density 70 and 110 aphids per vials. The results also indicates that 3rd instar larvae of *C. carnea* also exhibit type 2 functional response as recorded for previous two larval instars, (Figure 5).

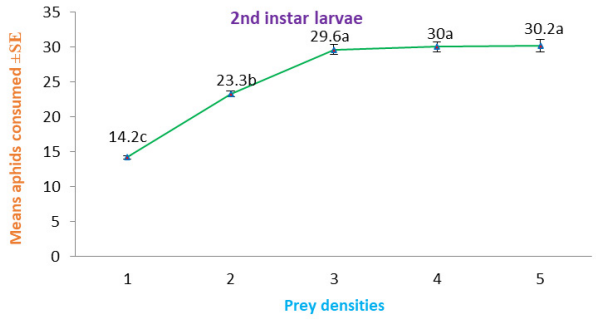

Figure 5: *Mean number of Myzus persicae consume by 2nd instar larvae of C. carnea fed on five constant prey densities after 24 hours starvation. Means followed by the same lower case letter are non-significantly different at ≤ 0.05 using LSD test. Where 1= 15, 2=25, 3=35, 4=45 and 5=55 aphids per each density, respectively.*

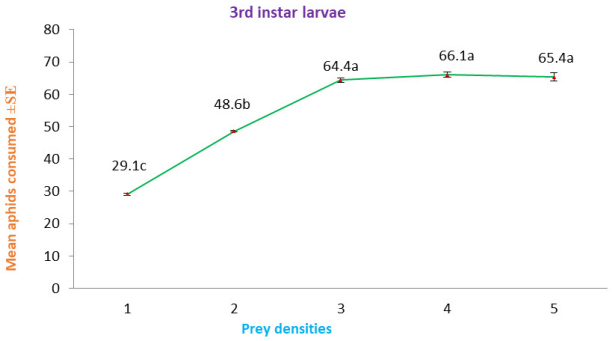

Figure 6: *Mean number of Myzus persicae consumed by 3rd instar larvae of C. carnea fed on five constant prey densities after 24 hours starvation. Means followed by the same lower case letter are non-significantly different at ≤ 0.05 using LSD test. Where 1= 30, 2=50, 3=70, 4=90 and 5=110 aphids per each density, respectively.*

The preceding sections have described the results regarding life table parameters and feeding efficiency of *C. carnea* fed on *M. persicae*. *C. carnea* also known as aphid lions are big hunters of extensive range of soft bodied arthropods including insects i.e., aphids, larvae, leafhopper, whiteflies, thrip and insect eggs (Carillo and Elanov, 2004). The current study was initiated investigate life table parameters of immature stages and feding efficiency of larval instars against *M. persicae* the aim of the study was to explore biological parameters and feeding efficiency of the predator. Previous authors indicate the developmental time of *C. carnea* on different hosts (Khan *et al.*, 2017), they reported the larval developmental duration was 12.0 ± 0.092 days with 85.05 survival rate. Similarly, Saljoqi *et al.* (2015) indicated that the larval developmental duration was 12.7±0.67, 11.7±0.69 and 10.6±0.66 days at 20, 24 and 28±1 °C, respectively when feeding on *Brevicoryne brassicae* aphids. Sattar *et al.* (2011) reported 8.50±0.32 days for larva when fed on *Aphis gossypi* aphids under controlled conditions. The slighter difference may be due to differences in their host insects as they used or may be due to different environmental conditions or strain of *C. carnea* they used in their experiments (Sayyed *et al.*, 2008).

The results of regarding the duration of the female are in line with previous workers data of Saljoqi *et al.* (2015) indicates that the duration of female *C. carnea* were 64.2±0.02, 50.1±0.02, 42.3±0.02 and 31.4±0.02 days at 20, 24, 28 and 32 ± 1 °C respectively. Similarly, Manan *et al.* (1997) investigated the biology of *C. carnea* on *A. gossypi* and *M. persicae*. The female survived extensive up to 35.70 and 38.80 days then male 32.20 and 35.80 days on 2 host insects respectively. The results of the present study are very close with Saljoqi *et al.* (2015) results only at 28 ± 1 °C and different from other tested temperatures. Similarly, the results are at little par with Manan *et al.* (1997) These differences likely may due to changed host insects they used and may be different ecological situations. The results of the present and that of the past workers who conducted experiments on biology of *C. carnea* indicate that developmental duration and survival rate are influenced by host insects, environmental condition such as temperature, relative humidity, photoperiod and food quantity Adane and Gautam (2002).

The life data parameters results of the present studies indicates that apparent mortality, Survival fraction, life expectancy and the total killing power per generation (k) values are similar to that Khan *et al.* (2017) on life table of *C. carnea* reare on *Corcyra cephalonica* eggs which indicated that life expectancy were maximum 5.24 and minimum 1.24 days during eggs and pupal stages. The results of gross

and net reproductive values were 144 and 2.57. The approximate generation time for multiplication and innate capacity for increase were 3.1 and 0.335371. The intrinsic rate for increase was 0.34 and finate rate of increase were 1.404. Elsiddig *et al*. (2006), who fed *Mallala boninensis* (Neuropetra: Chrysopidae) when fed on *C. cephalonica* eggs, the obtained values for life table were 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. Khan *et al*. (2017) indicates that when *C. carnea* was fed on *C. cephalonica* eggs the gross reproductive and net reproductive rate were 176.5 and 44.35. Sultan *et al*. (2017) indicated that when *C. carnea* were fed on Sugarcane whitefly that the gross reproductive and net reproductive rate were mx (138) and Ro were 65.89. The results of the present study showed variation with that of the previous workers. These differences may be due to different host insects and due to different environmental condition, they used in their experiments. The results regarding feeding efficiency of different larval instars indicate that 3rd instar larvae consumed maximum aphids. While some previous authors reported that *C. carnea* consumption rate was different when on different host insects. i e. Jagadish and Jayaramaiah (2004), mentioned that the 3rd instar larvae of *C. carnea* had consumed about 67.14 aphids. Michaud (2001), The maximum aphid consumption rate were 242.25 was obtained by feeding *Brevicoryne brassicae* and *Brevenia rehi* 230.25, *Aphis craccivora* 237.25. Rana and Sriivastav (1998) declared that the larvae of *C. carnea* can consume up to 349.80 aphids which showed relatively high rate of predates in comparison to present findings which may be near to Rana and Sriivastav (1998) prey density. The result of the present study shows variation with that of previous authors. These changes may due to changed ecological factors, different host insect they used in their experiments.

The results regarding functional response of *C. carnea* shown a great predation potential to the *M. Persicae*, but 3rd instar larvae of *C. carnea* was found extra effective on this prey. The potential concerning the consumption rate of the 3rd instar larvae of the *C. carnea* was found greater than of the 1st and 2nd. Batool *et al*. (2014) and Hany *et al*. (2010) stated greater predations on the 3rd instar of *C. carnea* stage as compared with the young one. The greater predations of the 3rd instar is reasonable reflections of its bigger size and ensuring better voracity. Before experiment starvation for fixed time interval may a significantly influenced the larval stages of the *C. carnea*.

Conclusions and Recommendations

It is concluded from the life table data and biological attributes that the population of *C. carnea* can successfully multiplied on *M. persicae*. The existence, reproduction and predacious potential of different stages were quite high. Present finding offers valued data for set up mass rearing techniques of *C. carnea*. In addition to aphids, *C. carnea* may be a useful bio-control predator, according to the results of the recent investigations. Additional research should also be done in the field to fully understand the biology, ecology, and role of this economically significant insect pest in the IPM program.

Novelty Statement

The novelty of the study is the use of *C. carnea* against *M. persicae*, which will help in minimize the use of toxic insecticides against *M. persicae.*

Author's Contribution

Ahmad-Ur-Rahman Saljoqi: Design the experiment.
Imtiaz Khan: Wrote the manuscript.
Javed Khan: Analyzed the data.
Shahid Sattar and Bashir Ahmad Khan: Review the manuscript.
Muhammad Salim and Ijaz Ahmad: Performed the experiment.

Conflict of interest
The authors have declared no conflict of interest.

References

Adane, T. and R.D. Gautam. 2002. Biology and feeding potential of green lacewing, *Chrysoperla carnea* on rice moth. Indian J. Entomol., 64(4): 457-464.

Alasady, M.A.A, O.B. Dzolkhifli and I.B. Yousaf. 2010. Life table of the green lacewing *Apertochrysa* sp. (Neuroptera: Chrysopidae) reared on rice moth *Corcyra cephalonica* (Lepidoptera: Pyralidae). Int. J. Agric. Biol., 12(2): 266-270.

Ali, A. and P.Q. Rizvi. 2008. Effect of varying temperature on the survival and fecundity

of *Coccinella septempunctata* (Coleoptera: Coccinellidae) fed on Lipaphis erysimi. J. Entomol., 5: 133–137.

Ashifaq, M., Nasreen and G.M. Cheema. 2002. A new technique for mass rearing of green lacewing *Chrysoperla carnea* on commercial scale. Pak. J. Appl. Sci., 2(9): 1-2. https://doi.org/10.3923/jas.2002.925.926

Asin, L., and X. Pons. 2001. Effect of high temperature on the growth and reproduction of corn aphids (Homoptera: Aphididae) and implications for their population dynamics on the Northeastern Iberian Península. Environ. Entomol., 30: 1127-1134. https://doi.org/10.1603/0046-225X-30.6.1127

Bartonm, B.T. and R.I. Anthony. 2014. Direct and indirect effects of warming on aphids, their predators, and ant mutualists. Ecology, 95(6): 1479-1484. https://doi.org/10.1890/13-1977.1

Bass, C., A.M. Puinean, C.T. Zimmer, I. Denholm, L.M. Field, S.P. Foster, O. Gutbrod, R. Nauen, R. Slater and M.S. Williamson. 2014. The evolution of insecticide resistance in the peach potato aphid, *Myzus persicae*. Insect Biochem. Mol. Biol., 51: 41-51. https://doi.org/10.1016/j.ibmb.2014.05.003

Batool, A., K. Abdullah, M.M. Rashid, M.K. Khattak and S.S. Abbas. 2014. Effect of prey density on biology and functional response of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Pak. J. Zool., 46(1): 129-137.

Birch, L.C., 1948. The intrinsic rate of natural increase of an insect population. J. Anim. Ecol., 17: 15-26. https://doi.org/10.2307/1605

Blackman, R. L. and V.F. Eastop. 2007. Book review aphids on the worlds herbaceous plants and shrubs. John Wiley and Sons, Chichester, England, pp. 1439.

Carrillo, M. and P. Elanov. 2004. The potential of *Chrysoperla carnea* as a biological control agent of *Myzus persicae* in glass houses. Annl. Appl. Biol., 32: 433-439.

Chi, H. and H. Liu. 1985. Two new methods for the study of insect population ecology. Bull. Inst. Zool. Acad. Sin., 24: 224–240.

Dixon, A.F.G., 2000. Insect predator prey dynamics: Ladybirds and Biological Control/ Cambridge University Press, pp. 146.

Elsiddig, S.I.Y., R.D. Gauta and S. Chander. 2006. Life table of predator, *Mallada boninensis* (Okamoto) (Chrysopidae: Neuroptera) on the eggs of *Corcyra cephalonica* Stainton and larvae of *Tribolium castaneum* Herb. J. Entomol. Res., 30: 301–307.

Gabre, R.M., F.K. Adham and H. Chi. 2005. Life table of *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae). Acta Oecol., 27: 179–183. https://doi.org/10.1016/j.actao.2004.12.002

Hany, A.S., A. El-Gawad, A.M.M. Sayed and S.A. Ahmed. 2010. Functional response of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) larvae to *Phthorimaea operculella* (Lepidoptera: Gelechiidae) Eggs. Aus. J. Basic Appl. Sci., 4(8): 2182-2187.

Hoddle, M.S., and L. Robinson. 2004. Evaluation of factors influencing augmentative releases of *Chrysoperla carnea* for control of *Scirtothrips perseae* in California avocado orchards. Biol. Contr., 31: 268-275. https://doi.org/10.1016/j.biocontrol.2004.06.007

Hodek, I. and A. Honek. 1996. Ecology of coccinellidae. Kluwer Academic Publishers, Dordrecht, pp. 480.

Jagadish, K.S. and M. Jayar https://doi.org/10.1007/978-94-017-1349-8 amaiah. 2004. Biology and predatory potentiality of *Chrysoperla carnea* on the tobacco *A. gossypii*, *Myzus nicotianae* (Homoptera). J. Ecobiol., 16(3): 161-167.

Khan, J., E. Haq, T. Mahmood, A. Rasool, N. Aslam, H. Shah, A. Blouch, M.M. Mahmood and I. Ahmad. 2017. Life table attributes of *Chrysoperla carnea* (Neuroptera: Chrysopidae) reared on *Corcyra cephalonica* (Lepidoptera: Pyrilidae) eggs under laboratory condition. Int. J. Biosci., 10(1): 52-59. https://doi.org/10.12692/ijb/10.1.52-59

Mandour, N.S., 2009. Influence of spinosad on immature and adult stages of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Bio Contr. 54: 93–102. https://doi.org/10.1007/s10526-008-9161-1

Mannan, V.D., G.C. Varma and K.S. Barar. 1997. Biology of *Chrysoperla carnea* (Stephens) on *Aphis gossypii* (Glover) and *Myzus persicae* (Sulzer). J. Insect Sci., 10: 143-145.

Michaud, S.P. 2001. Population dynamics of bean aphid (*Aphis craccivora* Koch) and its predatory Coccinellid complex in relation to crop type (Lantil, Lathyrus and Faba bean) and weather conditions. J. Entomol. Res., 18 (1): 25-36.

Morozov, A., and S. Petrovskii. 2013. Feeding on multiple sources: Towards a universal parameterization of the functional response of a generalist predator allowing for switching. PLoS One, 8(9): e74586. https://doi.org/10.1371/journal.pone.0074586

Morrison, R.K., 1985. *Chrysoperla carnea*, in handbook of insect rearing, 1 (eds. P. Singh and R.F. Moore), Elsevier Science Publisher, Amsterdam, pp. 419–426.

Price, P.W., 1984. Insect ecology, 2nd ed. John Wiley and Sons, New York. S.E. and J. M. Harp. 1987. Nutritional ecology of spiders, pp. 645-672.

Rana, B.S. and R.C. Srivastava. 1998. Feeding potential and growth rate index of aphid lion, **Chrysoperla carnea** on different species of aphids. Paper presented in Nation. Sem. Entomol. 21st Century, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, April 30 to May 2.

Saljoqi, A.U.R., N. Asad, E.U. Khan, S. Haq, Z. Rehman, H.G. Huma, M. Saeed, M. Nadeem, M.B. Salim, H. Ahmad and Zada. 2015. The impact of temperature on biological and life table parameters of *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) fed on cabbage aphid, *Brevicoryne brassicae* (Linneaus). J. Entomol. Zool. Stud., 3 (2): 238-242.

Sattar, M., and G.H. Abro. 2011. Mass rearing of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) adults for integrated pest management programmes. Pakistan Journal of Zoology. 43(3).

Sattar, M., B. Fatima, B. Ahmed. N, G.H. Abro. 2007. Development of larval artificial diet of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Pak. J. Zool., 39: 103-107.

Sayyed, A.H., A.K Pathan and U. Faheem, 2010. Cross resistance, genetics and stability of resistance to deltamethrin in a population of Chrysoperla carnea from Multan Pakistan. Pest. Biochem. Physiol., 98: 325-332.

Seirrafi, H.A.K., A.H.A. Salam and N.F.A. Baky. 2000. Effect of four aphid species on certain biological characteristics and life table parameters of *Chrysoperla carnea* (Stephen) and *Chrysopa septempunctata* (Wesmael) (Neuroptera: Chrysopidae) under laboratory condition. Pak. J. Biol. Sci., 3(2): 239-245. https://doi.org/10.3923/pjbs.2000.239.245

Sinclair, A.R.E. and R.P. Pech. 1996. Density dependence, stochasticity, compensation and predator regulation. Oikos, 75(2): 164-173. https://doi.org/10.2307/3546240

Sultan, A., M.F. Khan, S. Siddique, M.F. Akbar and A. Manzoor. 2017. Biology and life table parameters of the predator, *Chrysoperla carnea* (Stephens, 1836) (Neuroptera: Chrysopidae) on sugarcane whitefly, sugarcane stem borer and Angoumois grain moth. Egypt. J. Biol. Pest Contr., 27(1): 7-10.

Thompson, W.R., 1975. The specificity of host relation in predacious insects. Can. Entomol., 83: 262-269. https://doi.org/10.4039/Ent83262-10

Ulhaq, M.M., A. Sattar, Z. Salihah, A. Farid, A. Usman, and S.U.K. Khattak. 2006. Effect of different artificial diets on the biology of adult green lacewing (*Chrysoperla carnea* Stephens.) Songklanakarin J. Sci. Technol. 28(1): 1-8