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Effects Of Different Thermal Stress On *Chrysoperla Carnea* (Neuroptera : Chrysopidae) Under Laboratory Condition

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Abstract *Chrysoperla carnea Stephens (Green lacewing) also known as Aphid lion belongs to family Chrysopidae, order Neuroptera. It is found in most of the environments throughout the world. Experiment was conducted to study the biological parameters of green lacewing Chrysoperla carnea to evaluate the optimum temperature regime under the laboratory conditions. The results showed that maximum mean hatching percentage of Chrysoperla carnea eggs (98.22±0.79) was noted under T6: 29^{0}C and minimum mean hatching percentage of Chrysoperla carnea eggs (84.89±0.97) was noted under T7: 31^{0}C. Maximum mean newly hatched larvae of Chrysoperla carnea (147.33±1.20) was noted under T6: 29^{0}C and minimum mean newly hatched larvae of Chrysoperla carnea (127.33±1.45) was noted under T7: 31^{0}C. Maximum mean larval period of Chrysoperla carnea (18.66±0.88 days) was noted under T1: 19^{0}C and minimum mean larval period of Chrysoperla carnea (10.00±1.15 days) was noted under T7: 31^{0}C. Maximum mean number of Chrysoperla carnea pupa (72.00±1.52) was noted under T6: 29^{0}C and minimum mean number of Chrysoperla carnea pupa (49.00±2.08) was noted under T7: 31^{0}C. Maximum mean pupation timing of Chrysoperla carnea (11.00±1.15 days) was noted under T1: 19^{0}C and minimum mean pupation timing of Chrysoperla carnea (4.66±0.88) was noted under T7: 31^{0}C. Maximum mean fecundity of Chrysoperla carnea (253.67±8.57 days) was noted under T6: 29^{0}C and minimum mean fecundity of Chrysoperla carnea (120.67±2.60 days) was noted under T1: 19^{0}C. Maximum mean oviposition rate of Chrysoperla carnea (54.33±1.76 days) was noted under T1: 19^{0}C and minimum mean oviposition rate of Chrysoperla carnea (24.33±2.02 days) was noted under T7: 31^{0}C. Maximum mean survival of Chrysoperla carnea male (24.00±1.15 days) was noted under T1: 19^{0}C and minimum mean survival of Chrysoperla carnea male (10.00±1.15 days) was noted under T7: 31^{0}C. Maximum mean survival of Chrysoperla carnea female (63.33±1.76 days) was noted under T1: 19^{0}C and minimum mean survival of Chrysoperla carnea female (38.33±3.75 days) was noted under T7: 31^{0}C.*

Keywords: Effects Of Different Thermal Stress On Chrysoperla Carnea (Neuroptera)

1. INTRODUCTION

Chrysoperla carnea Stephens (Green lacewing) also known as Aphid lion belongs to family Chrysopidae, order Neuroptera. It is found in most of the environments throughout the world. Larvae of *C. carnea* are a voracious predator of exposed eggs, small larvae of beetle and lepidopterous pests. It also feed on slow moving, soft-bodied arthropods such as aphids, jassids, thrips, whitefly, scales, mealy bugs and mites (Carrillo *et al*, 2004).It can be mass reared in the laboratory and used against vegetable pests. It is a very important biological control agent due to its tolerance to the wide ranges of ecological factors. *C. carnea* is found in different agricultural habitats (Zelany, 1984) in high relative frequency of occurrence. (New, 1984). It has broad prey range and effective searching abilities (Ridgway and Murphey, 1984) and high resistance to many widely used pesticides (Bigler, 1984). Rearing techniques which enable it to produce of large numbers of eggs and larvae needed for inundative release of *C. carnea* have been developed (Tulisalo, 1984). In order to start a biological programme using *Chryosperla carnea*; mass-rearing techniques which are economical as well as posses higher biological efficiency need to be worked out (Ulhaq, *et al*, 2006).

Their agricultural importance lies in their carnivorous habits. The larvae are all predators. Some are terrestrial, feeding on jassids, psyllids, aphids, coccids, mites etc., and others are aquatic. It is rare in the tropics to find a large colony of aphids without at least some neuropterous larvae feeding on them. One larva may devour as many as five hundred aphids in its life and there is no doubt that they play an important part in the natural control of many small homopterous pests (Michaud, 2001 and Legaspi and Nordlund, 1994). Among predators, lacewings are broad habitat species, about 1200 species have been known worldwide. Some of the known and common species are: Chrysoperla carnea (Stephens), C. rufilabris (Burmeister), C. plorabunda (Fitch), C. mediterranea (Hölzel), C. oculata (Say), C. adamsi (Henry, Wells and Pupedis), C. johnsoni (Henry , Wells and Pupedis), C. lucasina (Lacroix), C. nigricornis, C. downesi (Smith), C. mohave (Banks), C. comanche (Banks), C. formosa (Brauer), C. pallens (Rambur), C. lacciperda (Kimmins), C. scelestes (Banks). Chrysoperla spp., especially C. carnea and C. rufilabris, are sold commercially by numerous producers and suppliers (Hunter, 1994; Penny et al., 2000) to control insect pests.

Green lacewings, C. carnea, is an example of one of these species that is not predacious in the adult stage; larval stage is predatory stage while in some species adults are also predators (Michaud, 2001). These lacewings larvae are considered generalist predators; the larvae are sometimes called aphid lions and have been reported to eat between 100 to 600 aphids each (Tauber et al., 2000). Adults feed only on pollen, nectar and aphid honeydew. They are pale green, about 12-20 mm long with long antennae and bright, golden or copper-coloured eyes. They have large, transparent, pale green wings and a delicate body. These adults are active fliers, particularly during the evening and night and have a characteristic, fluttering flight (Mendel et al., 2003; Zhang et al., 2006). Adults have a strong flight urge, and may fly for 3 to 4 hours each of their first two nights and lay eggs on fifth day after adult emergence. Oval shaped eggs are protectively laid singly at the end/ tips of long silken stalks, resembling miniature cattails growing from the plant foliage, these are pale green, turning grey in 2-3 days. After 6-7 days eggs hatch out, the larvae which are very active, have three instars, and are grey or brownish, alligator-like with well-developed legs and large pincers with which they suck the body fluids of the prey. Larvae grow from <1 mm to 6-8 mm. Mature third instar larvae spin round, parchment like silken cocoons usually in hidden places in plants and pupate inside cocoons. Emergence of adults occurs in 8-10 days. There may be two to several generations per year (Tauber et al., 1997a, b; Zhu et al., 2005)

Developmental duration and survival rate of *C. carnea* are influenced by temperature, relative humidity, photoperiod, food quality and quantity (Adane and Gautam, 2002). Temperature is one of the most important environmental factors that influence the developmental rate of a particular insect species (Birch, 1948). Therefore, it is very important to study the relationship between temperature and development for any economically. *Chrysoperla carnea* is important predator, available commercially in many countries of the world for augmentative release in agro ecosystem for population management of many insect pests. Biology of *C. carnea* depends upon many factors biotic as well as a biotic. Biotic factors such as host species, its stage of development to be consumed as prey and the host plant on which *C. carnea* host is feeding. There is a huge amount of literature available on biology of *C. carnea*, here some of the selected references are reviewed on biology

REVIEW OF LITERATURE:

Rana *et al.* (2017) reported that green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) is the most effective polyphagous predator of different species of aphids and is commonly known as "aphid lion" . The experiment on feeding efficiency of green lacewing was studied in the laboratory of Entomology Division, NARC, Khumaltar, Lalitpur, Nepal from 21st, December 2015 to 26th, March 2016. The known number of predatory larva of green lacewings were fed with known number of seven different species of live aphid and frozen *Corcyra* eggs representing each treatment. The treatments were replicated four times. The predatory efficiency was calculated by counting the number of consumed host per day. The result revealed that the predatory efficiency of *C. carnea* larvae were increased from first to third instar and third instar were more voracious as compare to first two instars. It consumed significantly the highest rice moth, *Corcyra cephalonica* followed by *Aphis craccivora* and others aphid species, respectively. From this experiment, it is evident that the green lacewing is potent bio-agent against different aphid species and hence further research is required simultaneously in the farmer's field conditions.

Khan *et al.* (2015) investigated the control this menace, predatory potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* larvae under laboratory conditions (27 ± 5o C and 65 ± 5% RH). The experiments were conducted in no choice (only first, second, or third instar larvae of mealybug were offered at a time) and choice (first, second, and third instar larvae were offered simultaneously) feeding tests. Both predators had high consumption rates, with *C. montrouzeiri* being the most voracious feeder. In the no choice feeding tests, third instar larvae of *C. montrouzeiri* devoured the highest mean number of first instar *P. solenopsis* (439.38) In the choice feeding tests, a similar number of first instar nymphs (410) were consumed. In both feeding tests, *C. carnea* devoured relatively fewer numbers of *P. solenopsis* than *C. montrouzeiri*. Manly's preference index suggested that the both predators preferred first instar nymphs of *P. solenopsis* over second or third instar nymphs. Furthermore, studies on developmental rate and fecundity revealed that first instar nymphs of *P. solenopsis* significantly reduced development time but increased the fecundity of both predators.

Saljoqi *et al.* (2015) evaluated the impact of temperature on biological and life table parameters of Chrysoperla carnea (Stephens) fed on cabbage aphid, Brevicoryne brassicae (L.) at four different temperatures i.e. 20±1 °C, 24±1 °C, 28±1 °C and 32±1 °C with 65±5% RH and a photoperiod of 16:8 (L:D) hours in Insect Pest Management Program (IPMP), Institute of Plant and Environmental Protection (IPEP), National Agricultural Research Center (NARC), Islamabad during, 2012. Results showed that over all rearing at 28±1 °C the observed developmental, reproductive characteristics and life table parameters of C. carnea were found better, which proved to be the best among the other tested rearing temperatures. It was inferred from the present findings that rapid development of C. carnea was observed at 32±1 °C, which can be useful if quick development is desired in laboratories. At 28±1 °C, the recorded total female fecundity was highest, as females tend to oviposit a total of 323.9±0.2 eggs per female. Highest survival rate (96%) from egg to adult emergence was recorded at 28±1 °C as compared to all other temperatures. Highest survivorship rate (Lx) (0.896), maximum oviposition rate per female per day (Mx) (323.9) and highest values of R0 (264.95), rm (0.0655) were obtained by rearing of C. carnea at 28±1 °C. The longest mean generation time (T) (64.2), doubling time (DT) (9.678) and death rate (Dx) (24.48) of C. carnea was achieved by rearing at 20±1 °C.

Alexander *et al.* (2014) studied the effects of various temperatures on the development and survival of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) and *Chrysoperla externa* (Hagen) (Neuroptera: Chrysopidae) fed on *Rhopalosiphum padi*(Linnaeus) (Hemiptera: Aphididae), and some biological aspects among these predators were compared. On average, 70 nymphs of *R. padi* were added to each experimental unit with predator larvae and maintained at 12, 16, 20, 24, 28, or 32 °C. The duration (days) and survival (%) were measured for each immature stage of the two predator species. The developmental durations of all *H. axyridis* larval instars, the total larval stage, the pupal stage and total preimaginal stage were very long at 16 °C but shortest at 24 °C for the first, second and third larval instars and at 28 °C for the fourth larval instar, the total larval stage and the total pre-imaginal stage. Both at 24 °C and 28 °C, 92% of *H. axyridis*completed the larva to adult cycle, whereas survival was significantly reduced in the 16 to 20 °C range. At the highest temperature (32 °C), 70% of *H. axyridis* did not reach adulthood. In the case of *C. externa,* the durations of development of all larval instars and the total larval stage became progressively shorter as the temperature increased from 12 to 20 °C. At still higher temperatures the developmental duration this insect remained almost constant. The predator completed the larval stage at all temperatures from 12 to 32 °C. However, at 12 and 16 °C, mortality of the larvae was greater than 88%, and 100% of the pupae perished. Although the lower threshold temperatures estimated for both predator species were very similar, the development period from larva to adult of *H. axyridis* was only 59% as long as that of *C. externa.* By comparing certain biological parameters including durations of development and survival rates of the two predator species, it is suggested that *H. axyridis* has intrinsic advantages over *C. externa;* however, additional factors must be considered when choosing the species of predator for biological control of *R. padi* on grass pastures in Brazil.

Kayahan *et al.* (2014) investigated development periods and survivals of Chrysoperla carnea larvae fed on Aphis fabae and Aspidiotus nerii in climate cabinets with 26±0.0 °C temperature, 60±1 % humidity and 16: 8 hours light-dark period conditions. Results were statistically evaluated by SPSS 21.0, JMP 8.0 and Curve Expert Pro 1.6.8 package programs. As a result of the study, average periods of egg, 1st instar, 2nd instar, 3rd instar, pupa and total development of C. carnea fed on A. fabae and A. nerii were 3.00-3.00, 2.95-4.77, 2.80-3.77, 4.47-5.36, 6.53-7.10 and 19.62-23.40 days, respectively. Results of the statistical analysis showed that there were significant differences among all biological periods except egg period of C. carnea. Weibull distribution was fitted to survival rate of development periods of both C. carnea populations which was developed on two preys. Survival curves was fitted to Holling's type III life curves for both populations because of the high mortality at the development periods. Parameters of Weibull distribution equation were calculated as c = 0.55, 0.55; b = 64.18, 29.91 for both populations which were used as prey of A. fabae and A. nerii, respectively.

Nadeem *et al.* (2014) reported that c*hrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) known as common green lacewing, its adult feeds only on plant nectars and larva is the voracious feeder of aphids and hence used in biological control of insect pests. In present study, the effective storage temperatures at optimum durations for the developmental stages of *C. carnea* under laboratory conditions was carried out. The consequence of storage duration and low temperatures on the different developmental stages of *C. carnea* at egg, larval, pre-pupal and pupal stages revealed that the storage of eggs at temperatures of 6, 12, 14 and 16oC gave short term storage up to 15-20 days with minimum detrimental effects to the developing embryo. Whereas, 8 and 10oC conditions of storage suited for both short and long term storage for 40 days. It is inferred from the results that whenever, needed to conserve strains of *C. carnea* in laboratories for experimentation or field releases, the storage at low temperatures of 8oC proved effective for both short and long term durations.

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Khan *et al.* (2012) studied developmental durations of immature stages of *Chrysoperla carnea*, feeding on *Corcyra cephalonica* eggs at three constant temperatures 24 ±1 ºC, 28 ±1 ºC and 32 ±1 °C. The results indicated that incubation period was 4.9±0.08, 3.8±0.08 and 3.0±0.06 days at three temperatures, respectively. Developmental duration of first instar were 3.6±0.07, 3.0±0.11, 2.0±0.06 days, second instar were 3.4±0.11, 3.0±0.07, 2.8±0.07 and third instars were, 4.9±0.10, 4.0±0.06, 3.4±0.13 days at three temperatures, respectively. The larval developmental duration were 11.9±0.13, 9.7±0.31, 8.2±0.14 and pupal duration were 9.2±0.10, 8.3±0.10 and 6.8±0.07 days at three temperatures respectively. Biological cycle of immature stages were 26.0±0.13, 21.8 ±0.08 and 18.0±0.56 days, respectively with total survival rate from egg to adult emergence of 82%, 68% and 42% at the respective temperature. The results indicate that developmental cycle of immature stages were significantly different at three different temperatures and with increasing.

Nadeem *et al.* (2012) showed that rearing at the different tested temperatures 20, 25, 28, 31, 35 and 40oC, the developmental and reproductive characteristics of *C. carnea* observed quite suitable at 28oC which proved to be the best among the other tested rearing temperatures. Rearing at 31 and 35oC had little effect on both the parameters of insect under study. It was inferred from present findings that rapid development of *C. carnea* observed at 31oC, which can gave useful rearing when quick development desired in laboratories. At 25oC, the reproduction rate of adult was the highest, as females tends to oviposit 10 days after emergence with 9 eggs per day and a total of 179.3 eggs per female. While over all better developmental and reproductive traits were recorded at 28oC. Slow and prolonged development was observed at 20oC, while no development recorded at high temperature of 40oC. Hence, it is demonstrate from the present study that the developmental and reproductive traits of *C. carnea* are directly dependent upon prevailing temperature of the environment.

Qadeer *et al.* (2012) studied the effect of different photoperiod lengths on biological parameters of green lacewing, *Chrysoperla carnea*. Four different photoperiod regimes were selected with varying lengths of light/dark hours (8/16, 10/14, 24/0 and 0/24) at a constant 26±2°C temperature with 70 % RH (relative humidity) in the laboratory. Photoperiod regimes affected the development of *C. carnea* from egg to adult. In complete darkness (L: 0 D: 24), minimum egg laying, hatching, larval survival and adult emergence were recorded. Incubation period for eggs, larval period and pupal duration were also significantly longer in complete darkness as compared to other treatments 8L: 16D and 10L: 14D. Whereas, the treatment with complete light hours (L: 24, D: 0) resulted in maximum egg laying hatching, larval survival and adult emergence. The incubation period for eggs, larval and pupal duration significantly shortened as compared to other treatments. Sex ratios skewed towards female when full light hours were provided for development.

MATERIALS AND METHODS:

Experiment was conducted to study the biological parameters of Green lacewing *Chrysoperla carnea* to evaluate the optimum temperature regime under the laboratory conditions.

Rearing of host Angoumois grain moth, *Sitrotoga cerealella*

The Angoumois grain moth *Sitrotoga cerealella* was reared in glass jars (5 kg capacity) on rice grains under laboratory condition of 28±1°C with 65 ±5% relative humidity. The jars were covered with muslin cloth at the top. The eggs laid by the female moth outside the muslin cloth through their ovipositor at the top of glass jar were collected and provided as a fresh food for *C. carnea* larvae daily till pupation.

Rearing of predator, *Chrysoperla carnea*

Adult *C. carnea* was reared in transparent plastic cages. Upper top portion of the cage were lined with black sheet for oviposition. Adults of *C. carnea* were provided artificial diet adlibitum containing water: yeast: sugar: honey in ratio (6:2:2:1). This diet was sufficient for feeding to 50 adults for five days and the diet was replaced with new diet after each five days.

Procedure

One hundred fifty fresh eggs was randomly collected and exposed on different temperature into three replications (per treatment 450 eggs) in plastic petri dishes. To estimate the hatching percentage of eggs, the newly hatched larvae was noted on daily basis.A plastic container was used to rear 80 newly hatched larvae individually in three replications per treatment (total 240 larvae) to observe the larval period on different temperature. The number of pupa and the timing of pupation were recorded on different temperature, and 50 newly obtained pupae was transferred into new separate plastic containers with three replications per treatment (total 150 pupae). Male and female adults were exposed to different temperature i.e (19,21,23,25,27,29 and 31 oC) until the death of males and females. Ten female–male pairs were used in each treatment with three replications. Each female–male pair was reared in a single plastic jar. The fecundity, oviposition rate, and survival of male and female recorded on the daily basis. The experiment were terminated until the males and females died.

Experiment

With 7 Treatment (temperature regimes)
T1: 19°C
T2: 21°C
T3: 23°C
T4: 25°C used as controlled.
T5: 27°C
T6: 29°C
T7: 31°C

Statistical analysis

All the data was statistically analyzed by using SPSS program, where mean values were compared with the help of Duncan's Multiple Range Test (DMRT) at 0.05 probability level.

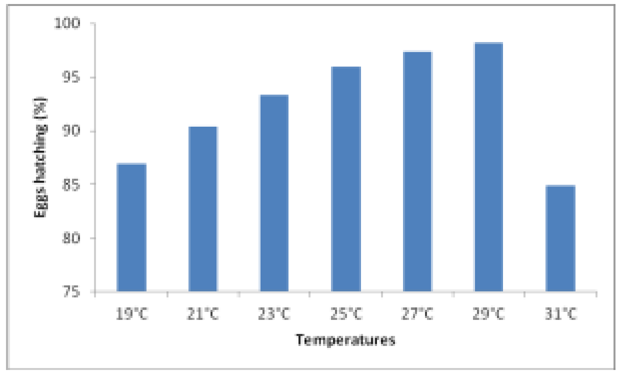
RESULTS:

Effect of temperatures on hatching percentage of *Chrysoperla carnea* eggs

Results in regards to effect of temperatures hatching percentage of *Chrysoperla carnea* eggs is presented in Table-1; Figure-1. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in hatching percentage of *Chrysoperla carnea* eggs among the different temperatures regimes. Maximum mean hatching percentage of *Chrysoperla carnea* eggs (98.22±0.79) was noted under T6: 29^{0}C followed by mean hatching percentage of *Chrysoperla carnea* eggs under T5: 27^{0}C (97.33±1.02), T4: 25^{0}C (96.00±0.76), T3: 23^{0}C (93.33±0.38), T2: 21^{0}C (90.44±0.44) and T1: 19^{0}C (86.89±0.58). Minimum mean hatching percentage of *Chrysoperla carnea* eggs (84.89±0.97) was noted under T7: 31^{0}C. The results indicates that optimum temperature for obtaining maximum hatching percentage of *Chrysoperla carnea* eggs was 29^{0}C and the temperature 31^{0}C considerably reduced the hatching percentage of *Chrysoperla carnea* eggs. Furthermore, hatching percentage of *Chrysoperla carnea* eggs linearly increases by the elevation of temperature from 19^{0}C to 29^{0}C. All pair-wise least significant difference test indicates significant difference in hatching percentage of *Chrysoperla carnea* eggs between T1, T2, T3, T4, T5 and T6, respectively.

Figure-1 Mean hatching percentage of *Chrysoperla carnea* eggs under different temperature regimes

SE± = 0.9011
LSD @ 0.05 = 1.9633
P-value = 0.0000



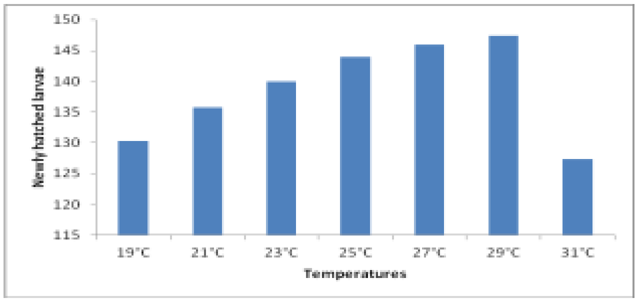
Mean (Value) same letter are significantly diffrenet

Effect of temperatures on newly hatched larvae of *Chrysoperla carnea*

The data with respect to effect of temperatures newly hatched larvae of *Chrysoperla carnea* is reported in Table-2; Figure-2. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in newly hatched larvae of *Chrysoperla carnea* among the different temperatures regimes. Maximum mean newly hatched larvae of *Chrysoperla carnea* (147.33±1.20) was noted under T6: 29^{0}C followed by mean newly hatched larvae of *Chrysoperla carnea* under T5: 27^{0}C (146.00±1.52), T4: 25^{0}C (144.00±1.15), T3: 23^{0}C (140.00±1.15), T2: 21^{0}C (135.67±0.66) and T1: 19^{0}C (130.33±0.88). Minimum mean newly hatched larvae of *Chrysoperla carnea* (127.33±1.45) was noted under T7: 31^{0}C. The results indicates that optimum temperature for obtaining maximum newly hatched larvae of *Chrysoperla carnea* was 29^{0}C and the temperature 31^{0}C considerably reduced the newly hatched larvae of *Chrysoperla carnea*. Furthermore, newly hatched larvae of *Chrysoperla carnea* linearly increases by the elevation of temperature from 19^{0}C to 29^{0}C. All pair-wise least significant difference test indicates significant difference in newly hatched larvae of *Chrysoperla carnea* between T1, T2, T3, T4, T5 and T6, respectively.

Figure-2 Mean newly hatched larvae of *Chrysoperla carnea* under different temperature regimes

SE± = 1.3511
LSD @ 0.05 = 2.9437
P-value = 0.0000

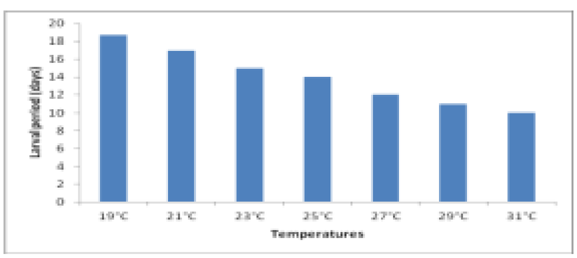


Effect of temperatures on larval period of *Chrysoperla carnea*

The effect of temperatures on larval period of *Chrysoperla carnea* is reported in Table-3; Figure-3. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in larval period of *Chrysoperla carnea* among the different temperatures regimes. Maximum mean larval period of *Chrysoperla carnea* (18.66±0.88 days) was noted under T1: 19^0C followed by mean larval period of *Chrysoperla carnea* under T2: 21^0C (17.00±1.15 days), T3: 23^0C (15.00±1.15 days), T4: 25^0C (14.00±1.15 days), T5: 27^0C (12.00±1.15 days) and T6: 29^0C (11.00±1.15 days). Minimum mean larval period of *Chrysoperla carnea* (10.00±1.15 days) was noted under T7: 31^0C. The results indicates that optimum temperature for obtaining maximum larval period of *Chrysoperla carnea* was 19^0C and the temperature 31^0C considerably reduced the larval period of *Chrysoperla carnea*. Furthermore, larval period of *Chrysoperla carnea* linearly decreased by the elevation of temperature from 21^0C to 31^0C. All pair-wise least significant difference test indicates significant difference in larval period of *Chrysoperla carnea* between T1, T2, T3, T4, T5 and T6, respectively.

Figure-3 Mean larval period of *Chrysoperla carnea* under different temperature regimes

SE± = 0.1782
LSD @ 0.05 = 0.3882
P-value = 0.0000

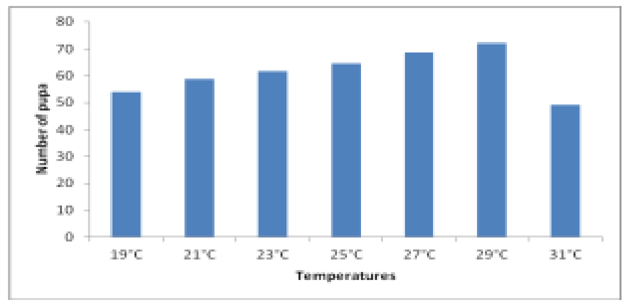


Effect of temperatures on number of *Chrysoperla carnea* pupa

Results regarding effect of temperatures on the number of *Chrysoperla carnea* pupa is reported in Table-4; Figure-4. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in number of *Chrysoperla carnea* pupa among the different temperatures regimes. Maximum mean number of *Chrysoperla carnea* pupa (72.00±1.52) was noted under T6: 29^0C followed by mean number of *Chrysoperla carnea* pupa under T5: 27^0C (68.66±2.60), T4: 25^0C (64.66±2.60), T3: 23^0C (61.66±1.76), T2: 21^0C (58.66±1.45) and T1: 19^0C (54.00±2.08). Minimum mean number of *Chrysoperla carnea* pupa (49.00±2.08) was noted under T7: 31^0C. The results indicates that optimum temperature for obtaining maximum number of *Chrysoperla carnea* pupa was 29^0C and the temperature 31^0C considerably reduced the number of *Chrysoperla carnea* pupa. Furthermore, number of *Chrysoperla carnea* pupa linearly increases by the elevation of temperature from 19^0C to 29^0C. All pair-wise least significant difference test indicates significant difference in number of *Chrysoperla carnea* pupa between T1, T2, T3, T4, T5 and T6, respectively.

Figure-4 Mean number of *Chrysoperla carnea* pupa under different temperature regimes

SE± = 0.8729
LSD @ 0.05 = 1.9018
P-value = 0.0000

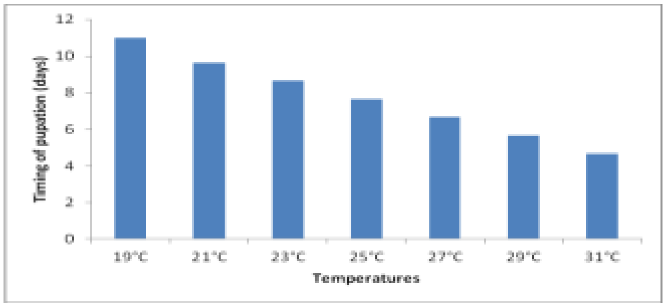


Effect of temperatures on pupation timing (days) of *Chrysoperla carnea*

The effect of temperatures on the pupation timing of *Chrysoperla carnea* is reported in Table-5; Figure-5. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in pupation timing of *Chrysoperla carnea* among the different temperatures regimes. Maximum mean pupation timing of *Chrysoperla carnea* (11.00±1.15 days) was noted under T1: 19^0C followed by mean pupation timing of *Chrysoperla carnea* under T2: 21^0C (8.66±0.88 days), T3: 23^0C (8.66±0.88 days), T4: 25^0C (7.66±0.88 days), T5: 27^0C (6.66±0.88 days) and T6: 29^0C (5.66±0.88 days). Minimum mean pupation timing of *Chrysoperla carnea* (4.66±0.88) was noted under T7: 31^0C. The results indicates that optimum temperature for obtaining maximum pupation timing of *Chrysoperla carnea* was 19^0C and the temperature 31^0C considerably reduced the pupation timing of *Chrysoperla carnea*. Furthermore, pupation timing of *Chrysoperla carnea* linearly decreased by the elevation of temperature from 21^0C to 31^0C. All pair-wise least significant difference test indicates significant difference in pupation timing of *Chrysoperla carnea* between T1, T2, T3, T4, T5 and T6, respectively.

Figure-5 Mean pupation timing of *Chrysoperla carnea* under different temperature regimes

SE± = 0.1782
LSD @ 0.05 = 0.3882
P-value = 0.0000

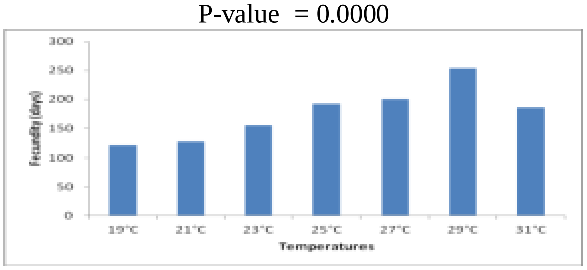


Effect of temperatures on fecundity of *Chrysoperla carnea* (days)

Results regarding the effect of temperatures on fecundity of *Chrysoperla carnea* is reported in Table-6; Figure-6. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in fecundity of *Chrysoperla carnea* among the different temperatures regimes. Maximum mean fecundity of *Chrysoperla carnea* (253.67±8.57 days) was noted under T6: 29^{0}C followed by mean fecundity of *Chrysoperla carnea* pupa under T5: 27^{0}C (200.67±5.20 days), T4: 25^{0}C (192.33±3.92 days), T7: 31^{0}C (185.33±2.90 days), T3: 23^{0}C (154.67±3.17 days) and T2: 21^{0}C (127.00±4.16 days). Minimum mean fecundity of *Chrysoperla carnea* (120.67±2.60 days) was noted under T1: 19^{0}C. The results indicate that optimum temperature for obtaining maximum fecundity of *Chrysoperla carnea* was 29^{0}C and the temperature 19^{0}C considerably reduced the fecundity of *Chrysoperla carnea*. Furthermore, fecundity of *Chrysoperla carnea* linearly increases by the elevation of temperature from 21^{0}C to 31^{0}C. All pair-wise least significant difference test indicates significant difference in fecundity of *Chrysoperla carnea* between T1, T2, T3, T4, T5 and T6, respectively.

Figure-6: Mean fecundity of *Chrysoperla carnea* under different temperature regimes

SE± = 3.1362
LSD @ 0.05 = 6.8333
P-value = 0.0000

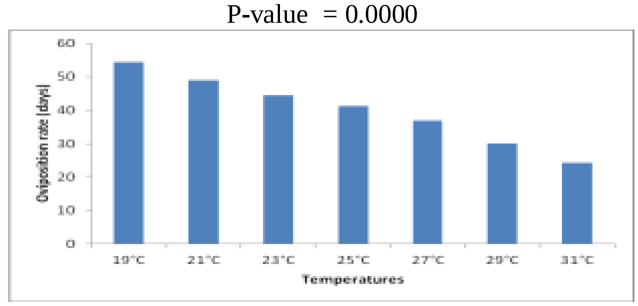


Effect of temperatures on oviposition rate (days) of *Chrysoperla carnea*

The effect of temperatures on oviposition rate of *Chrysoperla carnea* is reported in Table-7; Figure-7. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in oviposition rate of *Chrysoperla carnea* among the different temperatures regimes. Maximum mean oviposition rate of *Chrysoperla carnea* (54.33±1.76 days) was noted under T1: 19^{0}C followed by mean oviposition rate of *Chrysoperla carnea* under T2: 21^{0}C (49.00±1.15 days), T3: 23^{0}C (44.33±0.88 days), T4: 25^{0}C (41.33±0.88 days), T5: 27^{0}C (37.00±1.00 days) and T6: 29^{0}C (30.00±1.15 days). Minimum mean oviposition rate of *Chrysoperla carnea* (24.33±2.02 days) was noted under T7: 31^{0}C. The results indicates that optimum temperature for obtaining maximum oviposition rate of *Chrysoperla carnea* was 19^{0}C and the temperature 31^{0}C considerably reduced the oviposition rate of *Chrysoperla carnea*. Furthermore, oviposition rate of *Chrysoperla carnea* linearly decreased by the elevation of temperature from 21^{0}C to 31^{0}C. All pair-wise least significant difference test indicates significant difference in oviposition rate of *Chrysoperla carnea* between T1, T2, T3, T4, T5 and T6, respectively.

Figure-7 Mean oviposition rate of *Chrysoperla carnea* under different temperature regimes

SE± = 1.934
LSD @ 0.05 = 4.2081
P-value = 0.0000

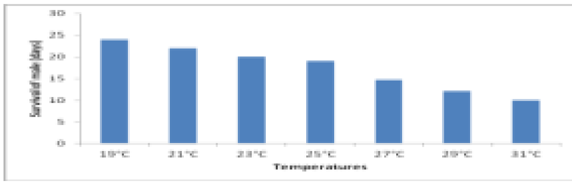


Effect of temperatures on survival of *Chrysoperla carnea* male (days)

The effect of temperatures on survival of *Chrysoperla carnea* male is reported in Table-8; Figure-8. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in survival of *Chrysoperla carnea* male among the different temperatures regimes. Maximum mean survival of *Chrysoperla carnea* male (24.00±1.15 days) was noted under T1: 19^{0}C followed by mean survival of *Chrysoperla carnea* male under T2: 21^{0}C (22.00±1.15 days), T3: 23^{0}C (20.00±1.15 days), T4: 25^{0}C (19.00±1.15 days), T5: 27^{0}C (14.66±1.45 days) and T6: 29^{0}C (12.00±1.15 days). Minimum mean survival of *Chrysoperla carnea* male (10.00±1.15 days) was noted under T7: 31^{0}C. The results indicates that optimum temperature for obtaining maximum survival of *Chrysoperla carnea* male was 19^{0}C and the temperature 31^{0}C considerably reduced the survival rate of *Chrysoperla carnea* male. Furthermore, survival rate of *Chrysoperla carnea* male linearly decreased by the elevation of temperature from 21^{0}C to 31^{0}C. All pair-wise least significant difference test indicates significant difference in survival rate of *Chrysoperla carnea* male between T1, T2, T3, T4, T5 and T6, respectively.

Figure-8 Mean survival of *Chrysoperla carnea* male under different temperature regimes

SE± = 0.1782
LSD @ 0.05 = 0.3882
P-value = 0.0000

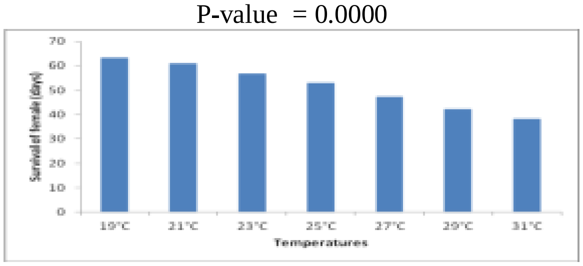


Effect of temperatures on survival of *Chrysoperla carnea* female (days)

The effect of temperatures on survival of *Chrysoperla carnea* female is reported in Table-9; Figure-9. The analysis of variance (ANOVA) represented highly significant ($p<0.05$) difference in survival of *Chrysoperla carnea* female among the different temperatures regimes. Maximum mean survival of *Chrysoperla carnea* female (63.33±1.76 days) was noted under T1: 19^0C followed by mean survival of *Chrysoperla carnea* female under T2: 21^0C (61.00±1.15 days), T3: 23^0C (57.00±1.52 days), T4: 25^0C (53.00±2.51 days), T5: 27^0C (47.33±1.76 days) and T6: 29^0C (42.33±2.60 days). Minimum mean survival of *Chrysoperla carnea* female (38.33±3.75 days) was noted under T7: 31^0C. The results indicates that optimum temperature for obtaining maximum survival of *Chrysoperla carnea* female was 19^0C and the temperature 31^0C considerably reduced the survival rate of *Chrysoperla carnea* female. Furthermore, survival rate of *Chrysoperla carnea* female linearly decreased by the elevation of temperature from 21^0C to 31^0C. All pair-wise least significant difference test indicates significant difference in survival rate of *Chrysoperla carnea* female between T1, T2, T3, T4, T5 and T6, respectively.

Figure-9 Mean survival of *Chrysoperla carnea* female under different temperature regimes

SE± = 1.5223
LSD @ 0.05 = 3.3169
P-value = 0.0000



Conclusions:

It was concluded that optimum temperature for obtaining maximum hatching percentage, newly hatched larvae of *Chrysoperla carnea,* maximum number of *Chrysoperla carnea* pupa and maximum fecundity of *Chrysoperla carnea* eggs was 29^0C and the temperature 31^0C considerably reduced biological parameters of *Chrysoperla carnea*. Maximum larval period, pupation timing, oviposition rate, survival of *Chrysoperla carnea* male and female was of *Chrysoperla carnea* was obtained at 19^0C and minimum values was recorded at 31^0C temperature.

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