Original Research Article

Impact of thermal stress on biological parameters of *Chrysoperla zastrowi sillemi*(Esben Petersen)under laboratory conditions

.

ABSTRACT

Aphid lions (*Chrysoperla zastrowi sillemi,* Esben-Petersen) are important predators in integrated pest management for field crops and vegetables (Neuroptera: Chrysopidae). It is found in almost every environment on Earth, except temperate ones. One of the most significant environmental variables influencing an insect species' growth rate is temperature. Five consistent temperatures were observed: 20±1°C, 25±1°C, 30±1°C, 35±1°C, and 40±1°C. The impact of temperature on biological parameters and developmental phases of Aphid lions feeding on rice moth eggs was noted. The development time of *C. zastrowi sillemi* was found to be 47.26 days at 20°C and 22.18 days at 40°C. The lifespan of adult males and females was more than twice as long at the lower temperature range as it was at the higher one. The temperature of 25°C produced the greatest duration of oviposition (55.12 days), the highest percentage of pupils (91.43%) and adults' emergence (90.25%), the maximum fecundity (903.33 eggs/female), and the maximum degree of hatchability (90.84%) of eggs, suggesting that this temperature regime was more suited for the *C. zastrowi sillemi* that originated in Delhi. The results demonstrate significant variations in the developmental cycle of the immature stages at five distinct temperatures,with a negative relation between temperature increase and developmental duration.

Keywords: Green lacewing, biological parameters, Immature Stages, Temperature.

1. INTRODUCTION

Over the past few decades, a tremendous revolutionary change has occurred in agriculture. Farmers have started following organic agriculture since it is sustainable produces healthy food and retains a pollution-free environment [1]. In organic agriculture, controlling insect pests relies heavily on cultural, physical, mechanical, and biological means. The biocontrol strategy is particularly suitable as it aligns well with the natural interconnectedness within the agroecosystem, maintaining a balanced population of natural enemies [2]. Meanwhile, predators have been officially recognized as highly effective and efficient agents in biological control programs.

The aphid lion, *Chrysoperlazastrowi sillemi*(Esben Petersen) is predominately important and widely distributed globally [3]. Aphid lion has attracted substantial interest as a biological control agent due to its efficiency in treating numerous insect infestations. Its notable traits include strong searching capabilities and wide adaptability to different field conditions [4]. A significant general predator, *C. zastrowi sillemi* is known to ingest a vast spectrum of insect pests found in crops, fruit orchards, and vegetables. Its ravenous appetite for soft-bodied insect pests such as caterpillars, aphids, leafhoppers, psyllids, mealybugs, whiteflies, thrips, insect eggs, spiders, and mites establishes it as an essential part of IPM systems [5]. Green lacewing larvae are well-known for their excellent survival rate in agroecosystems, efficiency as predators, and capacity for food search [6].

Aphid lions can readily be mass-reared in the research laboratory and employed against insect pests in the crop field [7]. Because of its tolerance to a vast array of environmental circumstances, this is used as a vital biological control agent. Aphid lion has a high comparative frequency of occurrence in numerous agricultural contexts [8]. Berwaerts and Van Dyck, (2004) [9] observed that it has a wide prey range and good hunting ability, as well as a high tolerance to a variety of pesticides. The actions of insects are affected by changes in environmental conditions. The developmental time and survival rate of the Aphid lion are determined by parameters such as relative humidity, temperature, photoperiod, and the quantity and quality of food available [10].

The efficacy of natural enemies relies on environmental factors, mainly on temperature [11]. In the instance of lacewing species, it has been shown that elevated temperatures alter the pace of development in addition to the rate of survival and capacity for reproduction [12], [13], [14] and [15]. Temperature strongly affects the reproduction, survival, and population expansion of both natural enemies and pests [16]. Birch, (1948) [17] noted that temperature plays a vital impact in the eco-friendly traits, in which insect species evolve. As a result, any economic assessment of the link between temperature and development is vital. Therefore, it is very vital to research the association between temperature and development for any commercially important species.

The present effort is designed to provide some basic information on the impact of changing temperatures on the life phases of *C. zastrowi sillemi* under laboratory circumstances. This knowledge is vital for entomologists, ecologists, and notably for farmers and mass production laboratories to maximize the effective mass production of lacewings for pest management.

2. EXPERIMENTAL DETAILS

2.1. Rearing of *Corcyra cephalonica* (Stainton)

C. cephalonica eggs were used to raise the predator in large quantities. The larvae of *C. cephalonica* were cultivated in the laboratory using a predetermined protocol [18]. The Biological Control Laboratory, Division of Entomology, IARI, New Delhi, India, provided the *C. cephalonica* eggs.

2.2. Predator Cultivation in Large Scale *Chrysoperla zastrowi sillemi*

The Biological Control Laboratory, IARI, New Delhi provided the nucleus culture of *C. zastrowi sillemi,* which was thereafter maintained according to Gautam's [18] standard methodology.

2.3. Experimental procedure

It was established how various temperatures affected the biological characteristics and stage of development of *C. zastrowi sillemi*. The experiment was carried out at the Indian Agricultural Research Institute's (ICAR) Biological Control Laboratory in the Division of Entomology in New Delhi. Twenty *C. zastrowi sillemi* eggs were used in the experiment, and each egg was placed in a glass vial measuring 10 by 1 cm. After hatching, the neonates were given frozen *C. cephalonica* eggs. There was only one duplicate of this. Three replications were also taken into consideration. The temperature treatments that were tested were 20±1, 25±1, 30±1, 35±1, and 40±1 degrees Celsius.

The stages of development and growth parameters of *C. zastrowisillemi* were recorded. The length of the adult's life, the time it took the eggs to mature into their various instars, and the pupae were all observed. Every day, all larvae were examined, and the number of days that each developmental stage lasted until the adult emerged was noted. The percentages of pupation, adult emergence, fecundity, and hatching were recorded, together with the length of oviposition, pre-oviposition, and post-oviposition periods (in days) of *C. zastrowisillemi*. The exuviae inside the tubes made it simple to distinguish between the many instars. When the insect transforms into a pupa, a black disc inside the cocoon serves as a distinguishing feature between the pre-pupa and pupal stages [6].

Statistical Analysis: Twenty copies of each treatment were conducted. Under laboratory conditions, the experiment was carried out with a Complete Randomized Design (CRD) setup. One-way analysis of variance (ANOVA) and critical difference values were employed with OPSTAT software to identify significant ($P<0.05$) differences between treatments.

3. RESULTS AND DISCUSSION

As poikilothermic animals—that is, species whose body temperatures are impacted by the outside environment—insects are naturally unable to manage their body temperatures. The ideal temperature range for their physiological functions is known as the preferred temperature or temperature preferendum, which typically falls between 15-35°c. Deviations from this range, whether too low or too high, can lead to mortality or hindered growth and development. In our study, we observed that as temperature increased, the biological parameters and developmental stages of *C. zastrowi sillemi* decreased**.**

1. Impact of thermal stress on the biology of *Chrysoperla zastrowi sillemi* under laboratory conditions

The biological characteristics of *C. zastrowi sillemi* immature stages raised on *C. cephalonica* eggs at different temperatures were studied, and the results showed that temperature has a major impact on different developmental stages. The egg incubation duration (3.45 to 7.19 days), larval period (11.21 to 22.48 days), pupal period (8.13 to 20.22 days), male longevity (16.78 to 56.25 days), and female longevity (31.67 to 80.83 days) all showed significant differences over the temperature range examined (Table 1). Furthermore, the overall developmental duration showed significant fluctuations, spanning from 22.18 to 47.26 days, with a discernible reduction in developmental duration with rising temperatures. For example, at 20°C and 40°C, the longest and shortest larval and pupal times were measured, respectively. The developmental period was 47.26 days at 20°C and 22.18 days at 40°C. There is an inverse link between temperature and developmental time for *C. zastrowi sillemi*, as seen by a more than twofold increase in adult male and female longevity at lower temperatures compared to higher temperatures.

Our results agree with other research on similar lacewing species. According to Kuznetsova's [19]findings, *Chrysoperla carnea* preimaginal stages had higher mortality at 35°C, indicating that this temperature may restrict lacewing development. Similarly, Chiaki and Masashi [20] discovered that one generation of *C. carnea* had the shortest developmental period at 25°C, a temperature at which larval development was noticeably high. The ideal temperature ranges for raising *C. carnea* larvae have been offered by several authors: Milevoj [21] indicated temperatures between 23 and 27°C, Orešek [22] raised green lacewing larvae at an average of 28.6°C, and Duelli [23] suggested a range of 25±2°C. According to Khan et al [23] 28°C is the ideal temperature for *C. carnea* survival, with higher temperatures—especially at 34 and 37°C—resulting in higher mortality rates. Consistent with these results, we found that 20–25°C was the ideal temperature for green lacewing development, as shown by the larvae's high activity levels and peak cannibalism. Furthermore, Albuquerque et al. [24] found that raising lacewings at 40°C was extremely fatal to the adult predator *C. cornea's* developmental features, emphasizing the significance of temperature regulation in lacewing development.

Table-1. Impact of thermal stress on biological parameters of*C. zastrowi sillemi* under laboratory conditions.

Treatments V	Incubation Period (days) †	Larval Period†			Larval period (days) †	Pupal period (days) †	Developmental Period (days) †	Longevity (days) †	
		1st Instar	2nd Instar	3rd Instar				Male	Female
Temperatures (°C)									
20	7.19 (2.77)	7.67 (2.86)	7.35 (2.80)	8.63 (3.02)	22.48 (4.79)	20.22 (4.55)	47.26 (6.91)	56.25 (7.53)	80.83 (9.02)
25	5.95 (2.54)	6.97 (2.73)	6.66 (2.68)	7.23 (2.78)	19.63 (4.49)	15.36 (3.98)	39.05 (6.29)	45.32 (6.77)	70.92 (8.45)
30	4.67 (2.27)	5.61 (2.47)	4.24 (2.18)	5.68 (2.49)	13.54 (3.75)	11.26 (3.43)	28.48 (5.38)	30.14 (5.54)	55.63 (7.49)
35	4.08 (2.14)	4.54 (2.24)	4.04 (2.13)	4.86 (2.32)	12.11 (3.55)	9.41 (3.15)	24.64 (5.01)	20.34 (4.57)	41.45 (6.48)
40	3.45 (1.99)	3.94 (2.11)	3.68 (2.04)	4.59 (2.26)	11.21 (3.42)	8.13 (2.94)	22.18 (4.76)	16.78 (4.16)	31.67 (5.67)
C.D.	(0.496)	(0.398)	(0.495	(0.475)	(0.327)	(0.377)	(0.234)	(0.244)	(0.186)
SE(m)	(0.155)	(0.125)	(0.155	(0.149)	(0.102)	(0.118)	(0.073)	(0.077)	(0.058)
SE(d)	(0.220)	(0.176)	(0.219	(0.210)	(0.145)	(0.167)	(0.104)	(0.108)	(0.082)

Figures in parenthesis are the square root (n+0.5) transformed values, Critical Difference at 5% level.

2. Impact of thermal stress on developmental stages of *C. zastrowi sillemi* under laboratory conditions

Effects of heat stress on *C. zastrowi sillemi* developmental phases in a lab environment revealed significant variations across different temperature settings, as outlined in Table 2. As the temperature increased, there was a notable reduction in the duration of oviposition, pre-oviposition, and post-oviposition periods of Aphid lions.

Specifically, temperature exerted a significant result on the pre-oviposition period (ranging from 3.22 to 6.22 days), oviposition period (from 22.64 to 55.12 days), as well as the post-oviposition phase (5.81 to 25.62 days). Additionally, temperature variations resulted in statistically significant differences in developmental stages, including percent pupation (ranging from 48.33% to 91.43%), percent adult emergence (from 58.66% to 90.25%), fecundity (ranging from 294.33 to 903.33 eggs), and percent hatching (from 59.66% to 90.84%).

Notably, the temperature of 25°C was identified as the most suitable regime for *C. zastrowi sillemi*, evidenced by the longest oviposition period (55.12 days), highest pupal percentage (91.43%), adult emergence (90.25%), fecundity (903.33 eggs), and hatchability (90.84%) of eggs. Conversely, the rise in temperature from 20°C to 40°C likely had adverse effects on the reproductive systems of female insects.

Our findings recommend that the mass rearing of *C. zastrowi sillemi* can be effectively conducted within a temperature range of 20 to 40°C, with optimal reproductive parameters observed at 25°C. This is consistent with earlier studies findings. Nadeem et al.[25] demonstrated that rearing *C. carnea* at 28±1°C resulted in optimal reproductive parameters, while Albuquerque *et al.*[24] reported that rearing at 35°C proved lethal for the developmental parameters of *C. carnea*. These references provide additional support and context to our observations about the impact of temperature on the stages of development of *C. zastrowi sillemi*.

Table 2. Impact of thermal stress on the developmental stages of *C. zastrowi sillemi* under laboratory conditions

Treatments V	Pre-oviposition Period (days) †	Oviposition Period (days) †	Post-oviposition Period (days) †	Sex ratio (M/F)	Pupation (%)*	Emergence (%)*	Hatching (%)*	Fecundity†
Temperatures (±2°C)								
20	6.22 (2.59)	48.99 (7.03)	25.62 (5.11)	01:01.1	63.34 (52.74)	73.91 (59.28)	75.24 (60.16)	541 (23.27)
25	5.41 (2.43)	55.12 (7.46)	10.39 (3.30)	01:01.3	91.43 (72.98)	90.25 (71.81)	90.84 (72.38)	903.33 (30.06)
30	4.81 (2.30)	42.39 (6.55)	8.43 (2.99)	01:01.5	86.76 (68.66)	82.6 (65.35)	79.33 (62.96)	688.33 (26.25)
35	3.68 (2.04)	31.42 (5.65)	6.35 (2.62)	01:01.4	60.72 (51.19)	65.24 (53.87)	69.27 (56.33)	482.56 (21.98)
40	3.22 (1.93)	22.64 (4.81)	5.81 (2.51)	01:01.2	48.33 (44.04)	58.66 (49.99)	59.66 (50.57)	294.33 (17.17)
CD	(0.443)	(0.227)	(0.396)		(2.292)	(2.213)	(2.076)	(0.058)
SE(d)	(0.196)	(0.100)	(0.175)		(1.015)	(0.980)	(0.920)	(0.026)
SE(m)	(0.139)	(0.071)	(0.124)		(0.718)	(0.693)	(0.650)	(0.018)

*Figures in parenthesis are the angular transformed values, Critical Difference at 5% level

† Figures in parenthesis are the square root (n+0.5) transformed values, Critical Difference at 5% level.

4. CONCLUSION

The current investigation concludes that *C. zastrowisillemi* can be successfully mass-reared at different temperatures in a laboratory setting. It was employed to investigate the effects of heat stress on the life parameters and reproduction of green lacewings under controlled conditions. Our findings suggest that temperature variations can both positively and negatively affect the developmental stages and reproductive capabilities of green lacewings. Specifically, we discovered that rearing *C. zastrowi* sillemi within the temperature range of 20 to 40°C is feasible. However, the most effective rearing conditions for optimal developmental and reproductive characteristics were observed at temperatures between 20°C and 25°C, surpassing outcomes achieved at other temperature ranges.

REFERENCES

1. El-Shafie HAF. Insect pest management in organic farming system Multifunctionality and Impacts of Organic and Conventional Agriculture. 20191-20.

2. Dara SK. The new integrated pest management paradigm for the modern age. Journal of Integrated Pest Management. 201910(1), 12.

3. Geetha B, Swamiappan M. Improved adult rearing cages for the predator, *Chrysoperla carnea.* Madras Agricultural Journal. 1998; 85:333-334.

4. Morrison RK. Handbook of Insect Rearing, Elsevier, Amsterdam the Netherlands. 1985; 419-426.

5. Rashid MMU, Khattak MK, Abdullah K, Amir M, Tariq M, Nawaz S. Feeding potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* on cotton mealybug, *Phenacoccus solenopsis.* The Journal of Animal and Plant Sciences. 2012; 22(3), 639-64.

6. Canard M, Principi MM. Life histories and behavior. In: Canard, M, Séméria Y, New TR. (Eds.), Biology of *Chrysopidae*. Dr. W. Junk Publishers, The Hague, 1984; pp. 57–149.

7. Syed AN, Muhammad A,Sohail A. Comparative effect of various diets on the development of *Chrysoperla carnea* (Neuroptera: Chrysopidae). International Journal of Agriculture and Biology. 2008 ;10(6), 728-730.

8. Bayoumy MH. Foraging behavior of the coccinellid *Nephus includes* (Coleoptera: Coccinellidae) in response to *Aphis gossypii* (Hemiptera: Aphididae) with particular emphasis on larval parasitism. Environmental Entomology. 2011; 40(4), 835-843.

9. Berwaerts K, Van Dyck H. Take-off performance under optimal and suboptimal thermal conditions in the butterfly *Pararge aegeria*. Oecologia. 2004;141, 536-545.

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

11. Samson PR, Blood PRB. Biology and temperature relationships of *Chrysopa sp*., *Micromus tasmaniae* and *Nabis capsiformis*. Entomologia Experimentalis et Applicata. 1979; 25, 253–259.

12. Albuquerque GS, Tauber CA, Tauber MJ. *Chrysoperla externa* (Neuroptera: Chrysopidae): life history and potential for biological control in Central and South America. Biological Control. 1994:4(1), 8-13.

13. Figueira lk, lara fm, cruzi i. efeito de genótipos de sorgo sobre o predador *Chrysoperla externa* (hagen, 1861) (neuroptera: chrysopidae) alimentado com *Schizaphis graminum* (rondani, 1852) (hemiptera: aphididae). Neotrop. Entomol. 2002; 31: 133–139

14. Fonseca A, Carvalho CF, Souza B. *Capacidade predatória* e aspectos biológicos das fases imaturas de *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) alimentada com *Schizaphis graminum* (Rondani, 1852) (Hemiptera: Aphididae) em diferentes temperaturas. Ciência e Agrotecnologia. 2001; 25, 251–263.

15. Maia WJSS, Carvalho CF, Souza B. Exigências térmicas de *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) alimentada com *Schizaphis graminum* (Rondani, 1852) (Hemiptera: Aphididae) em condições de laboratório. Ciência e Agrotecnologi. 2000; 24, 81–86.

16. Roy M, Brodeur J, Cloutier C. Effect of temperature on intrinsic rates of natural increase (rm) of a coccinellid and its spider mite prey. Biocontrol. 2003 ;48, 57-72.

17. Birch L. The intrinsic rate of natural increase of an insect population. The Journal of Animal Ecology. 1948;15-26.

18. Gautam RD. Present status of rearing of Chrysopids in India. Bull Entomol Res. 1994; 35:31–39,

19. Kuznetsova YI, The effects of temperature and humidity of the air on *Chrysopa carnea Stephens* (Neuroptera: Chrysopidae). *Zoologicheskii Zhurnal* 1969; 49, 1349–1357.

20. Chiaki F, Masashi N. Effects of photoperiod and temperature on larval development of *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). Japanese Journal of Applied Entomology and Zoology. 1999; 43: 175-179.

21. Milevoj L. Rearing of common green lacewing, *Chrysoperla carnea* Stephens in the laboratory. Zbornik Biotechniske Fakultete Univerge Ljubljani Kmetijsto. 1999; 73, 65-70.

22. Orešek E, Milevoj L. *Razširjenost tenčičaric* (Chrysopidae) v *intenzivnem sadovnjaku* in prehranske zahteve vrste *Chrysoperla carnea* (Stephens (Neuroptera, Chrysopidae): magistrsko delo. E. Orešek. Oddel. Agron. 2003; 85 p

23. Duelli, P. (1981). Is larval cannibalism in lacewings adaptive? Research Population Ecology, 23, 193-209.

24. Albuquerque GS, Tauber CA, Tauber MJ. *Chrysoperla externa* (Neuroptera: Chrysopidae): life history and potential for biological control in Central and South America. Biological Control. 1994:4(1), 8-13.

25. Nadeem S, Hamed M, Nadeem MK, Hasnain M, Atta BM, Saeed NA, Ashfaq M. Comparative study of developmental and reproductive characteristics of *Chrysoperlacarnea* (Stephens) (Neuroptera: Chrysopidae) at different rearing temperatures. The Journal of Animal and Plant Sciences. 2012; 22(2), 399-402