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Developing a simulation model to study the effect of climatic change on the natural enemies: Green lacewing, *Chrysoperla carnea* (Stephens)

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Abstract
Climate change became the most significant global change that has worldwide attracted the scientific community's attention. We aimed to remodel a simulation model to study the potential effect of rising temperatures because of the climatic change on the generation's number of green lacewing, *Chrysoperla carnea*. Firstly, generations number among three periods including reference period (2021), current temperature effect, nearby future (2021–2040), and a far-future (2041–2100), were studied using the future climatic data obtained based on GHG-emissions scenarios (SSP-4.5). Our result highlights that there is a statistically significant difference in the mean quantities among the various levels of climate and generation in the Behera and Asyut governorates, respectively. Moreover, there is significant differentiation in the data distribution among DDUs-values in the future than those during the current climatic state compared to 2021-2040, 2041-2060, and 2081-2100 in both locations. But insignificant differences ($P>0.05$) between current climate DDUs for *C.carnea* consecutive generation and 2021-2040 or 2041-2060 in the Asyut governorate was found. These results show great differentiation of needed DDUs for each generation in 2021-2040, 2041-2060, and 2081-2100 compared with the current climatic state and among each other. This is mostly related to the expected temperature rise with mention to the significant differentiation from DDUs needed for the first generation compared to the consecutive following generation. Our results produce a new light on the days required for each generation to complete, which is differed no matter the predicted future decades was. This may be considered a promising aspect of other possible studies on the effect of climatic change on the natural enemies.

Keywords: climatic change; mitigation; biological control; global worming; natural enemies; mathematical model-predators

Introduction

The biological control of pests plays a key role in combined pest management programs in several agroecosystems. A valuation of the potential impacts of the climatic change on biological control is critical, but it is difficult because of the interspecific nature of these interactions (Skendžić *et al*., 2021) [20]. The climatic change exacerbates numerous current difficulties relating to environmental, social, and economic changes (Keenan, 2015) [12], as well as altering insect-invasive plant interactions (Nayak *et al*., 2021) [15]. The climatic change drivers may have an impact on the biological control by directly influencing the physiology or behavior of biological control agents and/or pests, as well as altering the spatial and temporal overlap among species. It also alters the interactions among multiple species involved in the biological control within the agroecosystem (Björkman and Niemelä, 2015). For instance, the impact on the biological control may be negative or positive based on the number of temperature fluctuations.

the predator *C. carne* was one of six common predators found in faba bean and cowpea fields in Egypt as a biological control agent alternative (El K enawy *et al*.,2021) [2]. In an investigation on the cereal leaf beetle *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae) and its parasitoid *Tetrastichus julis* (Walker) (Hymenoptera: Eulophidae), Evans *et al*. (2013) displayed those warmer springs instigate asynchrony between parasitoid and pest since the insect larvae acquire quicker under warmer circumstances than the parasitoid ensuing in less hold grubs accessible for mature wasps to parasitize when they appear from vegetating. Polyphagous pillagers, *i.e.,* coccinellids, which have an acceptable dispersion capability, utilize numerous preys (Grez *et al*. 2017) [14], and present suppleness in other life-history characters. The main probable consequences of climatic changes will be a variety shift and/or extension. Nevertheless, for some coccinellids, the climatic alteration may have a negative effect, exclusively for those species that need plentiful prey or are outcompeted by new aggressive species (Honěk *et al*. 2017). For instance, Kawakami and Yamazaki (2017) [11] assessed long-term gathering notes of the lady beetle *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) in Japan, and he

found that a decrease in the plenty of this pillager was associated with hotter, summers, drier, and a decline in prey plenty. Climate models that are linked to the environmental needs of a specific pest species can be a useful tool for estimating the range of future global changes. Modeling pest risk may also improve forecasting of the result of an insect infestation in conjunction with plant host responses to climate change Raza *et al*., (2019) [17].
Our study aimed to acquire a simulation model to examine the potential impact of rising temperatures instigated by the climatic change on the generation's number of green lacewing, *C. carnea*. In the first step, the generations number among three time periods: a reference period (2021) current temperature effect, the nearby future (2021–2040), and the further future (2041–2100).

Material and methods

- **Determination of degree-days units (DDU)**

Daily maximum and minimum temperatures recorded and obtained from Center Laboratory for Agriculture Climate (CLAC) were transformed to heat units using the lower threshold temperature of aphids (where, t0 was 10.8 °C with 336.7 units for generation according to Bezerra *et al*., (2012) and the lower. Degree-days units (DDU) were calculated by applying the Richmond *et al*., (1983) formula as follows:
H =Σ H J (Where: H = number of degree-days units).
H J = {(max + min)/2} – C (If *max*. > C and *min*. > C).
H J = {(max. – C) 2 /2 (*max*.-*min*.)} (If *max*. > C and *min*. < C).
H J = 0 (If *max*. < C and *min*. < C).
C = t0

- **Influence of current climatic change on *C. carnea***

These experiments were performed on *C. carnea*, at Behera and Asyut governorates- Egypt, during January-December for successive seasons 2021. Average temperatures (daily maximum and minimum) were calculated according to the data recorded and obtained from CLAC, Egypt.

- **Effect of expected future climatic change on *C. carnea***

This study was performed to predicate the numbers and durations of generations and DDU (accumulated thermal heat units) in expected future climatic change 2040s and 2100s. The future climatic data have been obtained based on the GHG emissions scenarios (SSP-4.5), increase the temperature (1.5 °C) near term 2021-2040 (2.0 °C) med term 2041-2060 and (2.7 °C), and long term 2081-2100 (IPCC 2021).

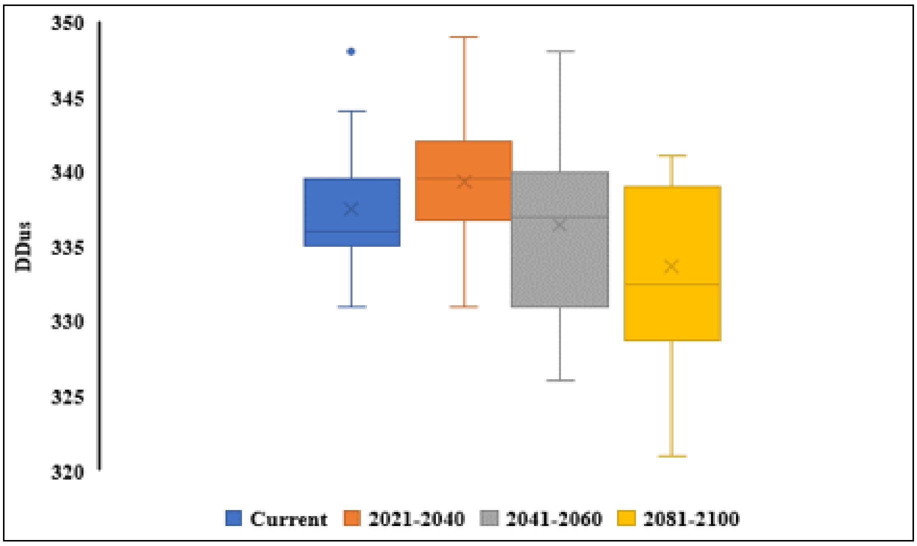
Data Analysis

Analysis of variance (ANOVA) *via* Fisher LSD assay to refuse the null hypnosis and verify the existence of significant variation among different data. The analysis becomes available using SigmaPlot V12.5 and MiniTab V18.1 software.

Results

Amplified temperatures will facilitate the expansion of natural enemies and conceivably result in more rounds of initiations per year (Abhishek Pareek *et al*., 2017) [1]. It has been projected that with a 2 °C temperature rise, insects might occurrence one to 5 extra life sequences per season (Yamamura and Kiritani, 1998) [21]. The expanded populace model ran efficaciously for both locations without combatting crashes.
For the two geographical regions Behera and Asyut, the estimated climatic changes by GHG emissions scenarios (SSP-4.5) for the nearby and far future caused in a rise of the yearly temperature mean between the reference period (2021) and the nearby (2021-2040) or afar future (2061–2100) of 1.0, 2.0, and 2.7 °C, separately. There is a statistically significant variation in the mean rates among the various levels of climate which is superior to what would be assumed by possibility after admitting for impact of differences in generation (f= 30.605, P <0.001), (f=35.138, P <0.001), and temperature (f= 5.592, P = 0.003), (f=4.502, P =0.008) in Behera and Asyut governorates, respectively (Fig. 1).
The expected temperature fluctuations manipulated the generation's number of *C. carnea* during the year. Related to the reference period, *C. carnea* consumed 337.5 DDU, 332.1 DDU to complete one generation under the current conditions on average of 26.0 and 22.5 d in Behera and Asyut governorates, respectively.
However, there is a statistically significant difference in the current, near, and remote future between climatic factors, the Generations number in the Behera governorate, and the near future 2021-2040 (Fig 2). *C. carnea* completed 14 generation/year with an average of 23.2 d/generation with 339.4 DDU (t=2.116, p=0.041). It also completed in 2041-2060 15 generation/year with an average of 22.3 day/generation with 336.4 DDU (t=3.111, p=0.007) and in 2081-2100 completed 16 generation/year with an average of 20.7 d/generation with 333.7 DDU (t=3.853, p=0.001). Alternatively in Asyut, there is a statistically significant variation only in the current vs. 2081-2100, where *C. carnea* completed 14 generation/year with an average of 22.5 d/generation with 332.1 DDU under the current condition and 17 generation/year with an average of 19.0 d/generation with 332.2 DDU in the far future (t=3.672, p=0.002). Moreover, no statistically significant difference between current vs. 2021-2040 and 2041-2060 (t=1.734, p=0.173), (t=1.728, p=0.092), respectively was found.
C. carnea generation shows the days expected for each generation to complete (Figs. 3 and 4). This reveals that the days required for each generation to complete is differed no matter the predicted future decades was. The first generation requires more time than following consecutive generations till generation 8 and 9 with the lowest require days to complete than a rise for required days for the following generation.

Behera



Asyut

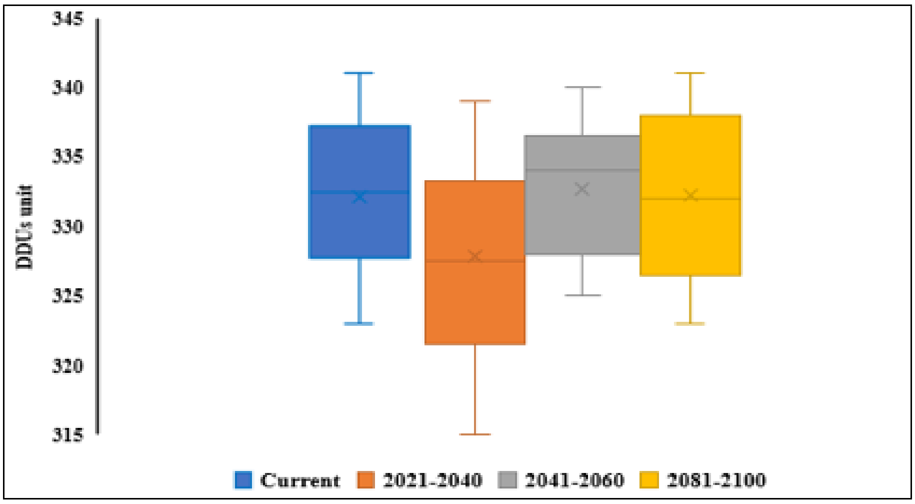
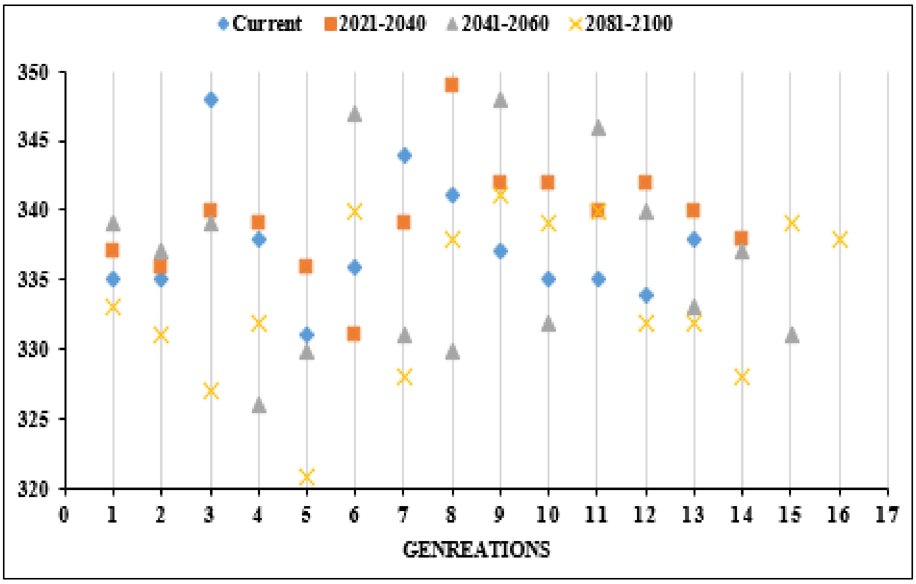


Fig 1: Box & Whisker chart shows the data distribution for DDUs for future expectation of *Chrysoperla carnea* during current climate state, in comparison to 2021-2040, 2041-2060 and 2081-2100 in Behera and Asyut governorate.

Behera



Asyut

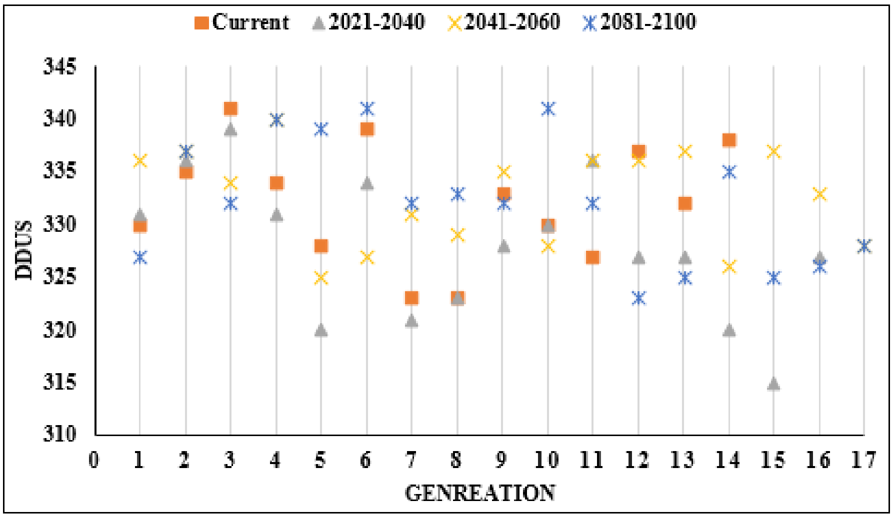
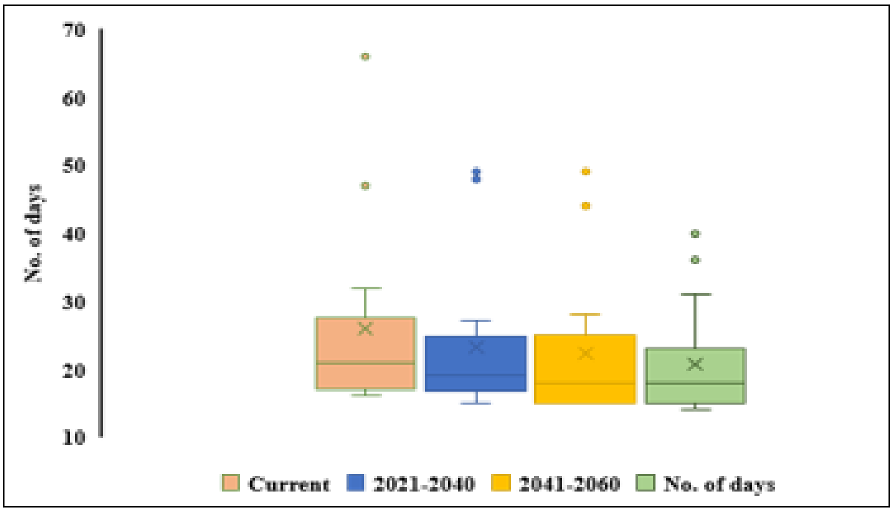


Fig 2: Scatter chart of *Chrysoperla carnea* generation shows the DDUs needed for each generation to complete. Which reveals that there is great differentiation of needed DDUs for each generation in 2021-2040, 2041-2060 and 2081-2100 in comparison to the current climate state and between each other

Behera



Asyut

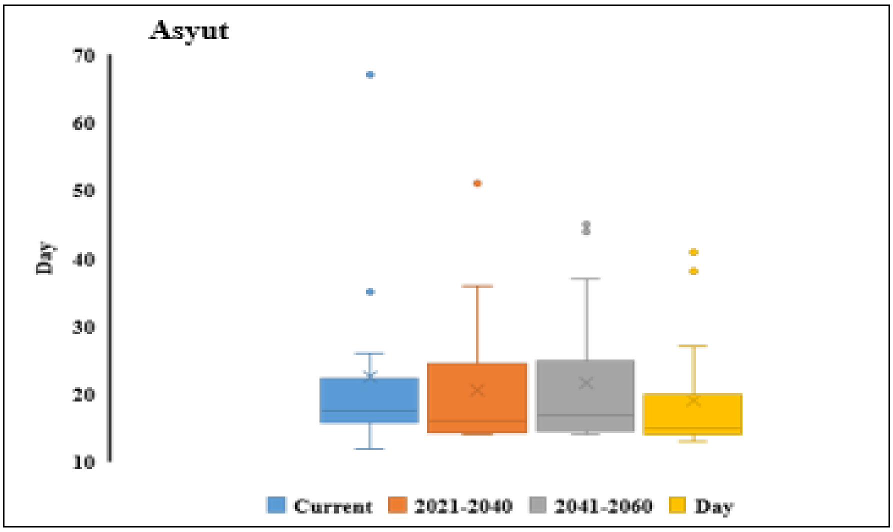
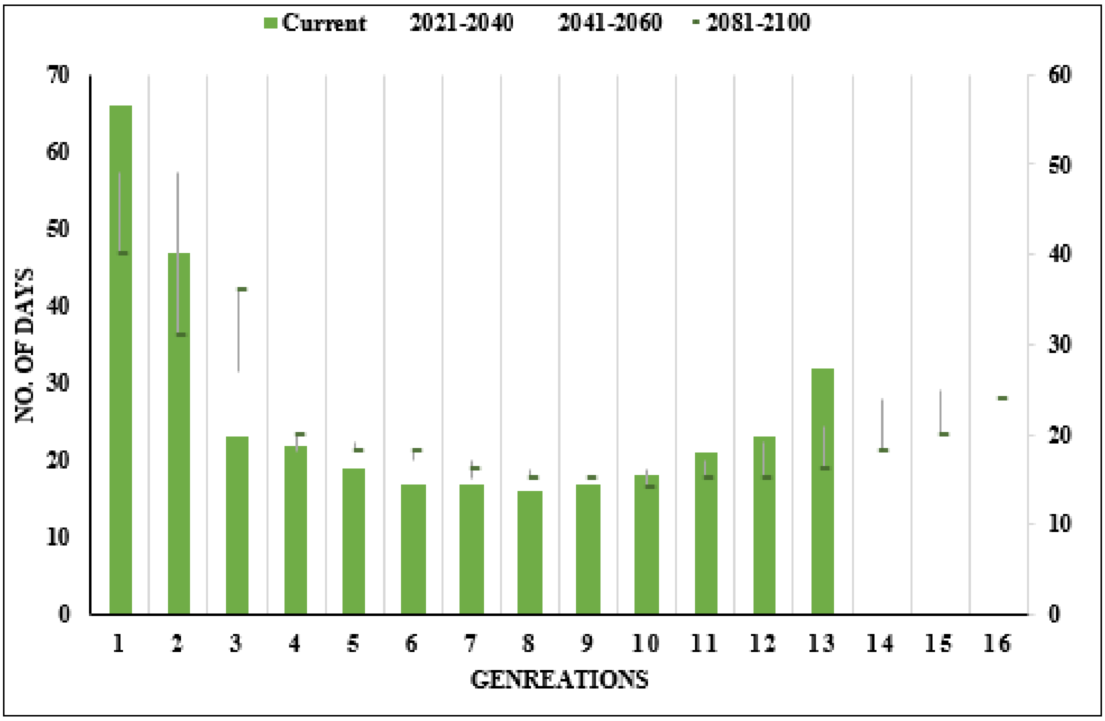


Fig 3: Box & Whisker chart shows the data distribution for days expected for generations of *Chrysoperla carnea* revealing the differentiation in data distribution in comparison to current climate state with recorded outer layer data for all predicted decades.

Behera



Asyut

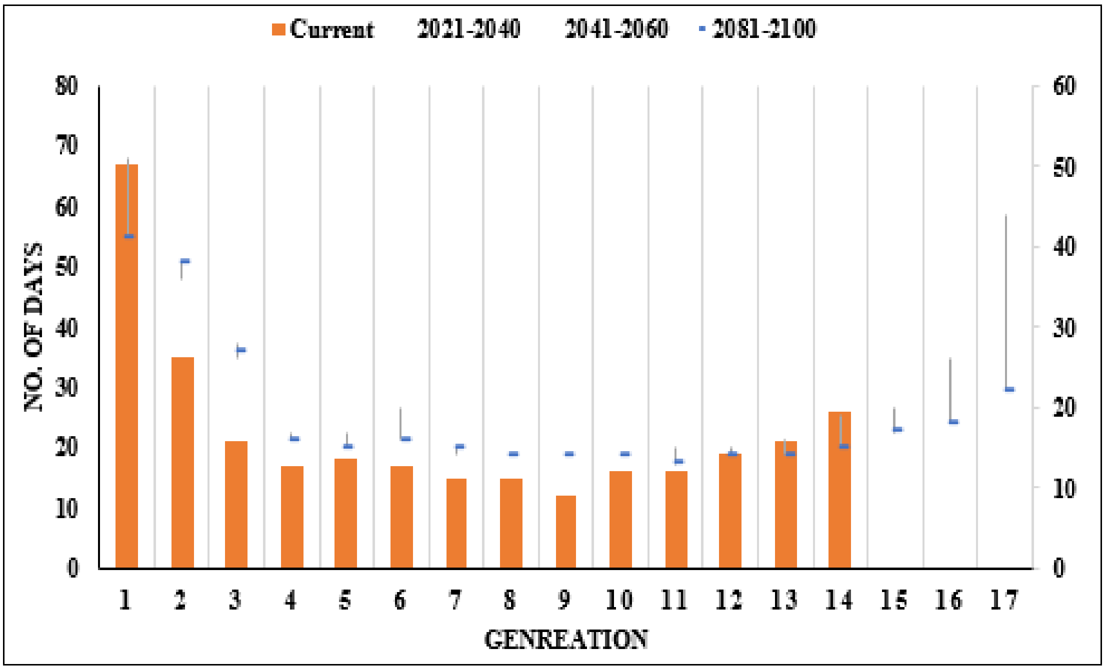


Fig 4: Scatter chart of *Chrysoperla carnea* generation shows the days expected for each generation to complete. Which reveals that days required for each generation to complete is differ no matter the predicted future decades was.

Discussion

The climate alterations could have dissimilar effects on the ordinary enemies of pest species. The climate change's rate and the number and/or significance of various climatic factors altering would influence the introduced predators and parasitoids, as well as aimed and non-aimed species, precisely by affecting expansion, existence, and generation, and secondarily through their influence on the landscapes, which impact the dispersion and colonization.

Our findings showed that the rise in temperature among the three-time periods protracted as predictable the activity season for the number of *C. carnea* generations significantly. These results go beyond previous reports, showing that the highest prey attack and intake rates were near 24 and 26 °C, respectively, suggesting sustained average temperatures above these values might begin to impair the biological control (Eigenbrode *et al.*, 2015)

[7]. These result ties well with previous studies wherein the ratios of the inferior temperature threshold using Latin-2 were 9.90, 10.90, 11.90, 11.40, 11.11, 11.61, and 11.30 °C for the cultivation period of 1st, 2nd, and 3rd larval instars, total larval period, and pupal and/or whole unripe phases, separately. The upper-temperature rates of threshold for the stated developing phases were 33.82, 37.66, 33.14, 34.04, 33.58, 32.14, and 32.18 °C, separately (Ranjbar, Nemati, 2020) [16].

Others have shown that Cannibalism enhanced with temperature increase, and it was the most concentrated at 25 °C. At this temperature, the larval transience was 22.0% after 2 d, while after 4 d it was attained 31.0 % (Rojht *et al*., 2009) [18]. However, agreeing with the findings of Canard 2005, it can be concluded that the chrysopids of temperate regions encounter seasonal alterations and must elopement the cyclic difficulty. One direction is *via* the brood's quantity per year. The greenest lacewings are elective multivoltine, with the sequence of creations most often controlled by photo amended diapause. The others are univoltine and some expand their life cycle to a couple of years in the dry or cold surroundings. Synchronization is a critical characteristic of seasonality, often beginning in spring. In univoltine species and occasionally, it is the finding of slight mechanisms, i.e., double inconsistent signs (quick advantage long day distances) for renaissance in spring, or a multi-accessibility of the preimaginal instars to photoperiod during a year, united with photo-regulated and coordinated egg placing in delayed summer. A similar pattern of results was obtained Nadeem *et al*., 2012 [13], tending at 31 and 35 ºC which had slight impact on both factors of the insect under this study. It was gathered from the current results that the speedy expansion of *C. carnea* was monitored at 31 ºC, which can provide functional tending when thr quick expansion is preferred in laboratories. At 25 ºC, the propagation proportion of an adult was the uppermost, as females incline to oviposit 10 d after appearance with 9 eggs per d and a full of 179.3 eggs per female. Meanwhile, general righter developing, and generative characters were noted at 28 ºC. Slow progress was noted at 20 ºC, while no progress was noted at an extreme temperature of 40 ºC.

Albuquerque *et al*., 1994 [3], who has stated that tending at 40 ºC was extremely lethal concerning the progress characters of the adult pillager, *C. carnea*. The progress characters of *C. carnea*, in our results, progressively declined with the rise in tending temperature and it helps the study narrated by Silva *et al*. (2007) [19] who have noted the developing time of *C. carnea* inclines to be quicker and at 25 ºC (31.1 d) and 30 ºC (26.5 d), but slow (46.2 d) at 21.5 ºC.

Short- and long-term shelf-life of diapausing *C. carnea* (Stephens) adults can be efficiently attained *via* the treatment of photoperiod, diet, and temperature. Short-term storing (up to 10 wk) was achieved under the short day quantities (10:14–8:16 [L: D] h) at a temperature up to 21 °C. Storing of 10–18 wk was achieved at a comparatively low storage temperature of 5-10 °C. Long-term storing (18-31 wk or longer) was the key effectual when pupae or young adults practiced a decline in day length and diapausing adults were kept under very short day length (8:16 [L:D] h) at 5 °C under these circumstances, multiplication by post storing adults equated that of un-stored adults. High existence and outstanding post storing generation happened when the animals obtained a high carbohydrate diet before storing, and a carbohydrate and protein diet throughout and after the storing (Yin-Fu Chang *et al*., 1995) [5]. This is agreed with what has been discovered by Katherine and Lighthart, 1989 [6], where the temperature stress impacted the *C. carnea* transience only when utilized in a mixture with nourishment and/or starvation.

Overall, these findings are in accordance with the findings reported by Khan *et al*., 2012 [10]. Developing periods of unripe phases of *C. carnea*, consuming on *C. cephalonica* eggs at 3 invariable temperatures of 24±1, 28±1, and 32±1 °C were considered. The findings signified that the cultivation period was 4.9±0.08, 3.8±0.08, and 3.0±0.06 d at 3 temperatures, separately. The developing period of the primary instar was 3.6±0.07, 3.0±0.11, 2.0±0.06 d, the second instar were 3.4±0.11, 3.0±0.07, 2.8±0.07, and the third instars were 4.9±0.10, 4.0±0.06, 3.4±0.13 d at 3 temperatures, separately. The larval developing duration was 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 d at 3 temperatures, separately. The biological series of unripen phases was 26.0±0.13, 21.8±0.08, and 18.0±0.56 d, separately with a total survival ratio from egg to adult appearance of 82, 68, and 42% at the individual temperatures

Conclusion

Natural enemies such as predators and parasitoids may suffer from climate change via extrinsic and intrinsic mechanisms. In our study a simulation model to study the potential effect of rising temperatures because of the climatic change on the generation's number of green lacewing, *Chrysoperla carnea* was developed. There is a statistically significant difference in the mean values among the different levels of Climate and the number of generations in both location. There is a differentiation in data distribution between in DDUs value in future than those during current climate state. These findings provide insights that will inform future effects of changes on natural enemies.

References

1. Abhishek Pareek Meena BM, Sitaram Sharma ML, Tetarwal RK, Kalyan BL, Meena. Impact of Climate Change on Insect Pests and Their Management Strategies. In: Prof Suresh Kumar, Manish Kanwat, P D Meena (eds) Climate Change and Sustainable Agriculture. New India Publishing Agency, India, 2017, 388.
2. Ahmed H El Kenawy, Mervat A El-Genaidy, Sayed S Eisa. Efficacy of a saponin extract derived from quinoa on Aphis craccivora (Hemiptera: Aphididae) and *Chrysoperla carnea* (Neuroptera: Chrysopidae) under laboratory conditions. International Journal of Entomology Research,2021:6(3)-54-60.

3. 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. https://doi.org/10.1006/bcon.1994.1002.
4. Canard M. Seasonal adaptations of green lacewings (Neuroptera: Chrysopidae). European Journal of Entomology,2005:102(3):317-324. https://doi.org/10.14411/eje.2005.049.
5. Chang Y-F, Tauber MJ, Tauber CA. Storage of the mass-produced Predator *Chrysoperla carnea* (Neuroptera: Chrysopidae): Influence of photoperiod, temperature, and Diet. Environmental Entomology,1995:24(5):1365-1374. https://doi.org/10.1093/ee/24.5.1365.
6. Donegan K, Lighthart B. Effect of several stress factors on the susceptibility of the predatory insect, *Chrysoperla carnea* (Neuroptera: Chrysopidae), to the fungal pathogen *Beauveria Bassiana*. Journal of Invertebrate Pathology,1989:54(1):79-84. https://doi.org/10.1016/0022-2011(89)90143-2.
7. Eigenbrode SD, Davis TS, Crowder DW. Climate change and biological control in agricultural systems: Principles and examples from North America. Climate Change and Insect Pests, 2015, 119-135. https://doi.org/10.1079/9781780643786.0119.
8. Evans EW, Anderson MR, Bowling PD. Targeted sugar provision promotes parasitism of the cereal leaf Beetle *Oulema melanopus*. Agricultural and Forest Entomology,2010:12(1):41-47. https://doi.org/10.1111/j.1461-9563.2009.00448.x.
9. Honěk A, Martinkova Z, Evans EW, Skuhrovec J. Estimating prey consumption in natural populations of *Harmonia axyridis* (Coleoptera: Coccinellidae) using production of feces. Journal of Economic Entomology,2017:110(6):2406-2412. https://doi.org/10.1093/jee/tox294.
10. Javed Khan, Ehsan-ul-Haq, Naheed Akhtar, Waseem Ahmad Gillani, Naila Assad, M Asif Masood *et al*. Effect of temperature on biological parameters of immature stages of *Chrysoperla carnea* (Neuroptera: Chrysopidae) feeding on rice meal moth, *Corcyra cephalonica* eggs Pakistan Journal of Agricultural Research,2012:25:224-227.
11. Kawakami Y, Yamazaki K. Disappearance of summer collection records for *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) during climate warming. Journal of Natural History,2017:51(17-18):1015-1020. https://doi.org/10.1080/00222933.2017.1324051.
12. Keenan RJ. Climate change impacts and adaptation in forest management: A Review. Annals of Forest Science,2015:72(2):145-167. https://doi.org/10.1007/s13595-014-0446-5.
13. Nadeem S, Hamed M, Nadeem MK, Hasnain M, Atta BM, Saeed NA, Ashfaq M. Comparative Study of Developmental And Reproductive characteristics of *Chrysoperla carnea* (Stephens) (Neuroptera:Chrysopidae) at Different rearing Temperatures. The Journal of Animal & Plant Sciences,2012:22:399-402.
14. Native coccinellids and biological control: A positive partnership that can be threatened by the Invasion of an alien species, Proceedings of the 5th International Symposium on Biological Control of Arthropods (eds. P.G. Mason, D.R. Gillespie and C. Vincent) | Conference paper, A.A. Grez1, T. Zaviezo2, C. González1, A. O. Soares3 and T. Poch, 2017.
15. Nayak SB, Elango K, Rao KS. Insect biodiversity and their conservation for sustainable ecosystem functioning. In: Biological Diversity: Current Status and Conservation Policies, Volume 1, Eds. Kumar., V., Kumar, S., Kamboj, N., Payum, T., Kumar, P. and Kumari, S, 2021, 304-314.https://doi.org/10.26832/aesa2021-bdcp-020.
16. Ranjbar Aghdam H, Nemati Z. Modeling of the effect of temperature on developmental rate of common green lacewing, Chrysoperla carnea (Steph.) (Neuroptera: Chrysopidae). Egyptian Journal of Biological Pest Control, 2020, 30(1). https://doi.org/10.1186/s41938-020-00341-x.
17. Raza A, Razzaq A, Mehmood S, Zou X, Zhang X, Lv Y *et al*. Impact of climate change on crops adaptation and strategies to tackle its outcome: A Review. Plants,2019:8(2):34. https://doi.org/10.3390/plants8020034.
18. Rojht H, Budija F, Trdan S. Effect of temperature on cannibalism rate between green lacewings larvae (Chrysoperla carnea [stephens], Neuroptera, Chrysopidae). Acta Agriculturae Slovenica,2009:93(1):https://doi.org/10.2478/v10014-009-0001-5.
19. Silva PS, Albuquerque GS, Tauber CA, Tauber MJ. Life history of a widespread Neotropical Predator, *chrysopodes* (Chrysopodes) *lineafrons* (Neuroptera: Chrysopidae). Biological Control,2007:41(1):33-41. https://doi.org/10.1016/j.biocontrol.2006.12.004.
20. Skendžić S, Zovko M, Živković IP, Lešić V, Lemić D. The impact of climate change on agricultural insect pests. Insects,2021:12(5):440. https://doi.org/10.3390/insects12050440.
21. Yamamura K, Kiritani K. A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Applied Entomology and Zoology,1998:33(2):289-298. https://doi.org/10.1303/aez.33.289