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Investigation on the Biological Characteristics and Thermal Requirements of Egg Parasitoid *Trichogrammatoidea bactrae* on Eggs of Cotton Pink Bollworm

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SDM and PT designed the study, performed the statistical analysis, wrote the protocol, and first draft of the manuscript. Authors VKB, SHT, BBF, MTN, VS, RP and VCBN managed the analyses and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The biological traits and thermal needs of *Trichogrammatoidea bactrae* Nagaraja was assessed on the eggs of the Pink bollworm, *Pectinophora gossypiella* to predict the ideal temperature for the release of the parasitoid. A card with 300 *P. gossypiella* eggs was offered to *T. bactrae* adults in a 5:1 ratio at temperatures 18, 20, 22, 24, 26, 28, 30, 32, 34 and 36 ^{o}C. All developmental stages of *T. bactrae* were monitored at each temperature, however, no parasitism or development occurred at temperature 36°C. The highest parasitism rate was observed at 28°C (76.03%), and emergence rates exceeded 85.65% between 18 and 30°C. Temperature variations affected both the development duration and adult longevity, with higher temperatures leading to shorter development times and reduced lifespan. The highest proportion of female offspring was recorded at 20°C (73.67%). The total heat requirement for complete development was calculated to be 136.98 degree-days (K), with a lower threshold temperature identified at 11.75°C.

Keywords: Biological control; cotton; Trichogrammatoidea bactrae; thermal requirements; pink bollworm; Pectinophora gossypiella.

1. INTRODUCTION

Cotton is an important commercial crop in India, accounting for 40% of the global cotton cultivation area and 21% of global production [1]. Cotton plays an important role in India's economy, occupies largest acreage and highest production in the world. However, the crop is being attacked by more than 251 arthropod pests, among them 12 are major pests which cause significant economic damage to the cotton [2]. Among the major insect pests of cotton, Pink bollworm, *Pectinophora gossypiella* emerged as a major pest of cotton with the development of resistance against BG I and BG II affecting cotton yield and quality [3,2]. The overuse of insecticides and the development of resistance, make it essential to find alternative and environmentally friendly pest management methods [4]. Integrated pest management, including the use of biological methods such as the egg parasitoid *Trichogramma*, is considered a promising approach. *Trichogramma species* are widely used as biological agents due to their ease of mass rearing and specificity in targeting pests without harming beneficial insects or the environment [5]. The effectiveness of *Trichogramma* species depends on various factors, including species potential, host interaction, thermal requirement, and climatic conditions [6,7]. The study of thermal requirements facilitates the understanding of the relationship between temperature and biological control agents [8]. The laboratory studies of *Trichogramma spp.* can provide a basis to predict the optimum temperature required for maximum percent parasitisation, percent emergence, developmental duration, adult survival, and the percent female progeny at known temperatures. The study aims to evaluate the biological parameters and thermal requirements of *Trichogrammatoidea bactrae* on the host cotton pink bollworm at different temperatures.

2. MATERIALS AND METHODS

The experiment was conducted at the insect biocontrol laboratory, ICAR-Central Institute of Cotton Research (CICR) Nagpur, during 2023-24. The study involved the mass multiplication of egg parasitoid *T. bactrae*, a parasitoid wasp and the rearing of the host insect, *P. gossypiella*.

T. bactrae was reared on the eggs of the factitious host, the rice moth (*Corcyra cephalonica*). The eggs of *C. cephalonica* were collected from the mass rearing facility, and were cleaned and sterilized with UV light to prevent hatching. These sterilized eggs were then used to prepare Trichocards, which were attached to nucleus cards containing parasitized eggs and placed inside a polythene bag for parasitization. After 3 to 4 days, the parasitized eggs in the Trichocards turned black, indicating successful parasitization. The Trichocards were then labelled and stored in a refrigerator for further multiplication.

The *P. gossypiella* population was reared on an artificial diet as described by Naik et al. [9]. For all the experiment, one-day-old *P. gossypiella* eggs were used. Approximately 300 eggs were glued onto paper cards and presented to *T. bactrae* adults at a 5:1 ratio, with three replications conducted at temperatures of 18, 20, 22, 24, 26, 28, 30, 32, 34 and 36^{o}C. Biological parameters, including development period, parasitization rate, emergence rate, longevity, percentage of female progeny, as well as thermal requirements such as the lower thermal threshold and thermal constant, were evaluated for *T. bactrae* on cotton pink bollworm.

2.1 Statistical analysis

The experimental data were subjected to statistical analysis using a completely randomized design (CRD) with the help of R software [10]. Prior to the analysis, normality of the data was checked, and appropriately transformed using arcsine and square root transformations if required. The treatment means were separated using the Duncan's multiple range test (DMRT) (p=0.05).

The following formulas were used for the calculation of the various biological parameters.

Percent Parasitisation = (No.of PBW eggs changed to black colour / Total PBW eggs kept for parasitisation) X 100

Percent emergence = (No.of parasitised PBW eggs with emergence holes / Total No.of parasitised eggs) X 100

Percent female progeny = (number of females / number of females + number of males) X 100

The development period (Egg-adult) was calculated by counting the number of days the adult lived till the mortality from the day just after parasitisation. Adult longevity was determined by counting the number of days required by an adult to complete the life cycle from emergence to death of the adult at different constant temperatures in BOD.

In addition to this, the calculation of lower threshold temperature and thermal constant in degree days were then determined by regressing the development rate on temperature [11].

Thermal constant (K) = Development duration (Temperature - Development threshold)
$K = D (T – T_0)$

Where, T = temperature at which insect species is reared, K = reciprocal of the regression coefficient (b) computed between development rate and temperature

Obtaining the equation: $Y = a + bx$

By definition, the insect stops developing at the lower developmental threshold (Y = 0):

The K was estimated as the reciprocal of the regression coefficient (b) between development rate and temperature.

$$K = 1/b$$

T_0 was determined ratio regression intercept (a) and (b).

$$T_0 = - a/b$$

3. RESULTS AND DISCUSSION

At a temperature of 36°C *T. bactrae* were incapable of parasitising and development and, therefore not considered while computing the results.

3.1 Percent Parasitisation

The parasitisation potential of *T. bactrae* against the eggs of *P. gossypiella* at different temperatures revealed that maximum parasitisation at 28°C (76.03%), followed by 26°C (74.74%) with minimum parasitisation was recorded at extreme temperature ranges at 34°C (26.44%) and 18°C (33.54%) (Fig. 1). These findings align with those of Jidung et al. [12], who reported parasitism rates of 82.71% and 84.71% at 25°C when *Trichogramma chilonis* was reared on eggs of *Corcyra cephalonica* and *Plutella xylostella*, respectively. *The results obtained were similar to the findings of Malik [13] reported that maximum parasitisation of 95.81% was found at a temperature of 28°C when T. bactrae was reared on P. gossypiella eggs.*

3.2 Percent Adult Emergence

The data indicated that there is a significant difference in percent emergence of *T. bactrae* at different temperature treatments. However, exhibiting the highest percent emergence at 26°C (98.81%). The next most effective treatment occurred at 20°C (98.41%), while the lowest percent emergence was recorded at 34°C (75.56%) (Fig. 1). The highest percentage of adult emergence, consistent with Asha et al. [4], who found maximum adult emergence (95.82%) at 25°C, and 92.22% at 28°C when *T. bactrae* was reared on *P. gossypiella* eggs. The findings supported previous research by Coutinho et al. [14], which indicated that the highest rate of adult emergence was at 25°C (95.82%) in both the strains of *T. preteosum* reared on eggs of *Neoleucinodes elegantalis* at different temperatures.

3.3 Developmental Period (Egg to Adult) of *Trichogramma* Species on Eggs of *P. gossypiella*

The longest development period recorded was 23.33 days at a temperature of 18°C, followed by 19.33 days at 20°C and 13.67 days at 22°C. Conversely, the shortest development period was noted at 34°C (Fig. 1). It was observed that with the temperature increased, the development period decreased up to a threshold of 34°C, beyond which no development occurred at 36°C. These results are in agreement with Hutchison et al. (1990), who reported that the development period of *T. bactrae* decreased from 22.8 days at 15°C to 7.1 days at 32.5°C for males, and from 28.4 days at 15°C to 7.3 days at 32.5°C for females. The present findings are in line with Pino et al. [15], concluded that development time decreases with an increase in temperature from 15°C, 20°C, 25°C, and 30°C in parasitoid species of *Trichogramma achaeae* reared on the eggs of *Ephestia kuehniella*.

3.4 Adult longevity

The maximum recorded lifespan for adult *T. bactrae* is 9.33 days at a temperature of 18°C, which is also matched at 20°C. In contrast, the minimum lifespan observed is 2.33 days at 34°C. Therefore, as the temperature increases from 18°C to 34°C, the longevity of adults decreases from 9.33 days to 2.33 days, respectively (& Fig. 2). Similarly, Tabeboardbar et al. [16] observed that temperature significantly influenced the longevity of female progeny, showing an inverse relationship, with longevity decreasing from 12.74 days at 22.5°C to 5.74 days at 40°C when *T. euproctidis* was reared on *Ephestia kuehniella* eggs. Similar results were shown by Atashi et al. [17] when *T. euproctidis* females reared on the eggs of H. armigera at different constant temperatures with 11.60 days to 4.57 days at 21 °C to 33°c respectively for females and 9.30 days to 3.03 days at 21°C to 33°C for males respectively.

3.5 Percent Female Progeny

The maximum percent female progeny was observed at 20°C (73.67%), the next best treatment at 18°C (72.00%) and 24°C (68%) with a minimum percent female progeny at a temperature of 34°C (51.67%). The results also indicated that the percentage of female progeny varied with temperature. Similar observations were made by Hutchison et al. [18], who reported that the proportion of female progeny decreased from 77.5% at 15°C to 51.6% at 30°C. In contrast, Maceda et al. [19] noted that progeny sex ratios varied depending on the parasitoid species and temperature.

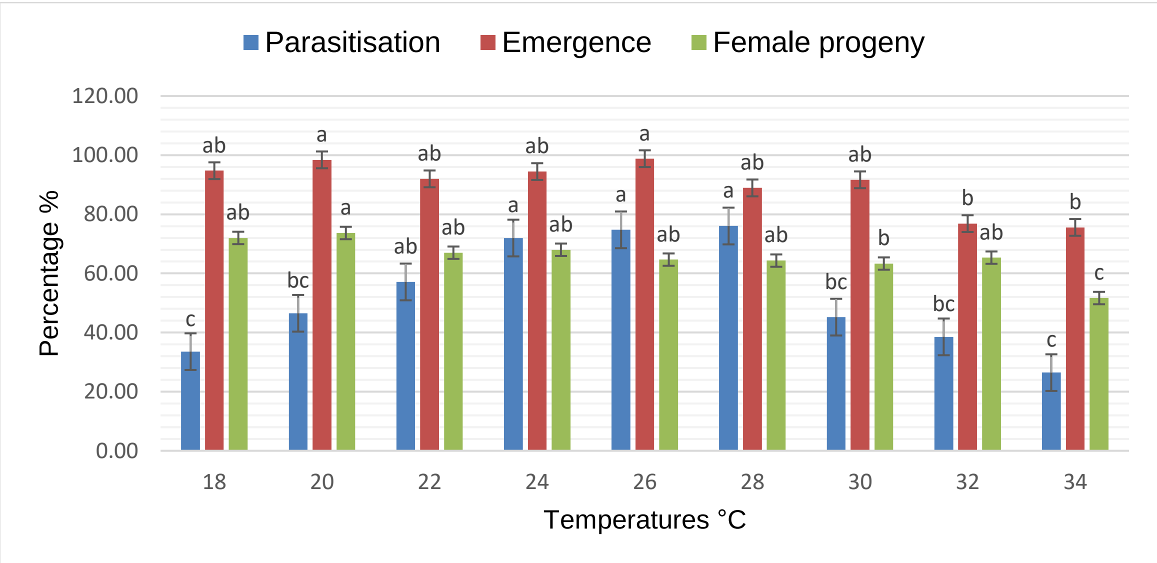

Fig. 1. Percent parasitization, percent emergence, percent female progeny of *T. bactrae* reared on eggs of *P. gossypiella* at different temperatures

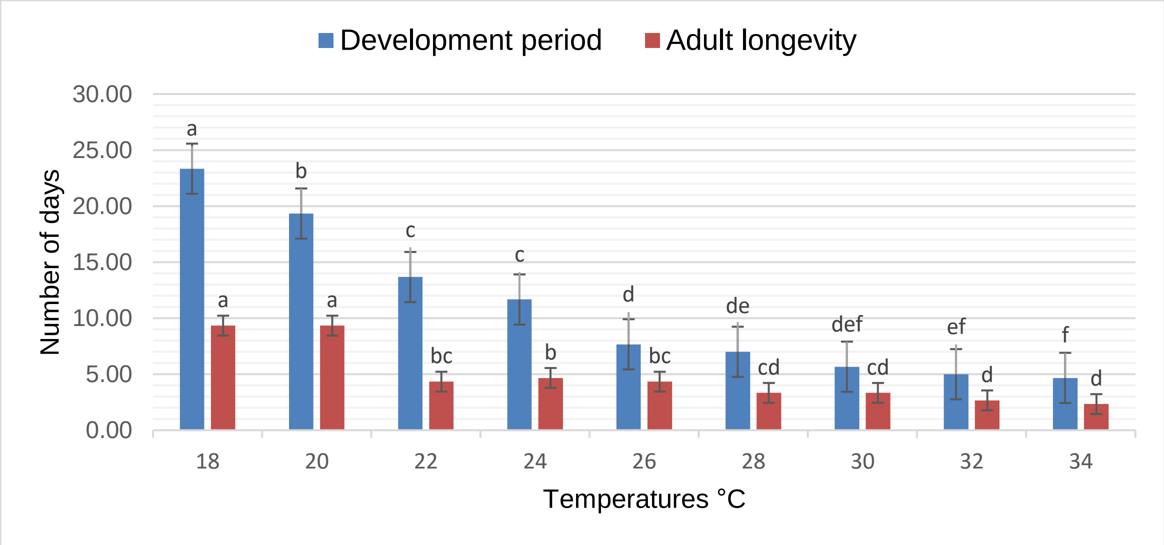

Fig. 2. Development period (Egg to adult), and adult longevity of *T. bactrae* reared on eggs of *P. gossypiella* at different temperatures

The developmental period of the egg parasitoid *T. bactrae,* measured in days from egg to adult, was utilized as a biological parameter to establish the threshold temperature (Tb) and the thermal constant in degree days (K) tested at a different constant temperature (18, 20, 22, 24, 26, 28, 30, 32, 34 and 36ºC) on the eggs of *P. gossypiella*. The development of the parasitoid *T. bactrae* began when the temperature remained above the lower threshold temperature of 11.75°C, and the accumulated heat necessary for complete development was 136.98 degree-days(K). The regression equation between temperature and development rate was found as, Y = 0.0073x - 0.0858 (R^2 = 0.88). The thermal requirements observed in this study were consistent with those reported by Hutchison et al. [18], who found that *T. bactrae* required a lower developmental threshold of 9.54°C and 143.16 degree-days for complete development. However, Carvalho et al. [20] reported that *Trichogramma pretiosum* TM exhibits a lower threshold temperature of 10.82°C and the cumulative heat required for complete development was 135.55 degree-days(K) when reared on the eggs of *H. armigera.*

4. CONCLUSION

The study revealed the optimal temperature range for both parasitism and adult emergence for *T. bactrae* was found to be between 24°C and 28°C. This temperature range would be the ideal for the release of the parasitoid to get the maximum parasitism benefit. The development period and adult longevity were longest at 18°C and shortest at 34°C. A temperature of 20°C yielded a higher percentage of female progeny, while 26°C resulted in the maximum number of progeny per host. The lower threshold temperature (T_0) and thermal constant (K) were determined to be 11.75°C and 136.98 degree-days, respectively. The analysis clearly showed that temperature has a significant influence on the life cycle of this egg parasitoid.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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