Laboratory assessment of influence of alternating temperature on growth and development of Pectinophora gossypiella (Saunders) in Bt cotton

HARSHAVARDHAN P (harshapatin1@gmail.com)
Punjab Agricultural University

Amandeep Kaur
Punjab Agricultural University https://orcid.org/0000-0002-4383-932X

Vijay Kumar
Punjab Agricultural University

Research Article

Keywords: Pectinophora gossypiella, Alternate temperatures, total developmental period, fecundity, survival

Posted Date: October 30th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3406963/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Laboratory assessment of influence of alternating temperature on growth and development of *Pectinophora gossypiella* (Saunders) in Bt cotton

P. Harshavardhan\(^1\), Amandeep Kaur\(^{1,*}\) and Vijay Kumar\(^1\)

\(^1\)Department of Entomology, Punjab Agricultural University, Ludhiana-141004, Punjab, India.

*Corresponding author: amankaur17@pau.edu*
ABSTRACT

*Pectinophora gossypiella* is one of the most destructive pests of Bt cotton. *P. gossypiella* gradually became a serious threat after gaining resistance to Bt toxin owing to which resulted in huge economic losses to the cotton growers. Present investigation was carried in order to study the most favourable temperature of *P. gossypiella* for its growth and development under various altering temperature regimes (20:30°C, 24:30°C, 28:30°C, 20:35°C, 24:35°C, 28:35°C, 20:40°C, 24:40°C and 28:40°C) in Integrated Pest Management Laboratory, Department of Entomology, PAU, Ludhiana during *kharif* 2022-23. The results revealed that duration of all larval instars and total larval duration were significantly shorter at an alternating temperature of 28:40°C. The pupal duration, adult longevity and total developmental period of male and female were recorded significantly lower at an alternate temperature of 28:40°C. The fecundity and survivability (egg, larval and pupal) recorded maximum at 28:30°C, whereas the larval and pupal weights were recorded highest at an alternate temperature of 28:35°C. The correlation between developmental parameters and fecundity shown significant negative correlation, the survival of egg, larva and pupa show non-significant negative correlation, whereas the larval and pupal weights show non-significant positive correlation with alternate temperatures.

**Keywords:** *Pectinophora gossypiella*, Alternate temperatures, total developmental period, fecundity, survival.
INTRODUCTION

Cotton (*Gossypium* spp.) which is also called as ‘King of Fibres’ is one of the most valuable fibre crops in the world and it is grown in both tropical and warm temperate regions (Wendel and Cronn 2003). China holds the leading position in global cotton production, while India stands as the second-largest producer, having achieved an estimated production of 343.74 lakh bales in the year 2022-23. (Anonymous, 2023). Around the globe, India is the only country where all four cultivated species (namely *Gossypium arboreum, G. herbaceum, G. hirsutum* and *G. barbadense*) are commercially cultivated (Deshmukh et al 2016). In Punjab, cotton is the second most important *kharif* crop after rice and occupies around 3.25 lakh hectares in 2021-2022 which has increased around 75 thousand hectares from 2020-2021 cropping season and produced 21.86 lakh quintals of cotton in 2021-2022 (Anonymous 2022). Bt cotton has been genetically engineered cotton plant by inserting one or more genes from a common soil bacterium *Bacillus thuringiensis* and the insecticidal proteins are encoded by these genes and as a result, genetically modified plants create one or more toxins to prevent the insect damage (Malone et al 2008). In 2002, Bt cotton hybrid (Bollgard) introduced to India led to drastic reduction in the incidence of bollworms (Manjunath 2004). Nearly after a decade of introductions of Bt cotton, pink bollworm (PBW), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) has emerged as a prominent pest in cotton growing belts of Central and Southern India, with reports of the insect feeding and surviving on single gene Bt cotton (Bollgard I) in Gujarat and dual gene Bt cotton (Bollgard II) in Gujarat (Dhurua et al 2011). It has recently become a menace to cotton production in Southern and Central regions of India, where the pest has evolved resistance to Cry1Ac and Cry 2Ab expressing cotton, as well as showing insecticide resistance, and infesting late-season cotton (Naik et al 2018). Insect survival is significantly influenced by temperature and relative humidity under climatic conditions, so understanding how they respond to...
temperature and relative humidity variations is critical in order to modify pest management strategies as a result of climate change (Shrestha 2019). The status of the pest species can be affected by the changes in temperature and therefore it is very important to study the effect of the temperature on the development of the insects as it helps in estimating the seasonal and phenological development, pest population dynamics, risk analysis, pest forecasting and to develop the management strategies to minimize the pest population in the field level.

MATERIAL AND METHODS

Raising of test plant

The pure seed of RCH 773 BG-II cotton cultivar was procured from the local market. Two to three seeds of this cultivar were sown at 10 days interval in earthen pots filled with soil and farmyard manure to get a continuous supply of required stages of bolls for conduct of various experiments.

Initiation and maintenance of culture of P. gossypiella

The larvae of the pink bollworm were collected from infested cotton fields in the cotton belt (Bathinda, Mansa, Abohar and Mutksar districts) of Punjab. The larvae were fed on flower/cotton bolls of non Bt cotton cv. F 2228 in the laboratory at room temperature. To ensure their survival, food was provided on a daily basis. The pupal phase is defined as the time between pre-pupation and adult eclosion. They were sexed based on pupal characteristics, such as the size of the pupa (female pupa is bigger in size as compared to male pupa), the location of the genital and anal openings, which are located mid-ventrally on the 9th and 10th, 8th and 10th abdominal segments in males and females, respectively. The distance between the genital pore and the anal pore helps in differentiation of sex. When it comes to females, this distance is more than double than that of males (Sri et al 2020). Male and female pupae were kept in plastic jar with 10×15 cm diameter. Such sexed pupae were kept in emergence cages (14.5×20.5 cm) for adult eclosion. To facilitate feeding of adult
moths, diet was made using 2 g of methylparaben (MPB), 2 g of ascorbic acid, 50 g of sucrose, 50 ml of honey, 20 g of yeast and one tablet of vitamin E (Evion tablet) are mixed thoroughly in 1000 ml of water and a cotton swab dipped in the adult diet was hung in the oviposition cage by a thread as adult food. To facilitate the females to lay eggs in the oviposition cage, 10-15 days old boll was provided as substrate for the egg laying. The substrate was changed daily to get same age group of eggs. The cage was covered with black muslin cloth at the top and side. All eggs laid were collected until death of the adult female.

**Experimental procedure**

The experiments on effect of alternating temperatures (maximum and minimum) on development of *P. gossypiella* on Bt cotton was carried during 2022-23 crop seasons. The below mentioned set of minimum and maximum temperature treatments where T1- 20:30°C, T2- 24:30°C, T3- 28:30°C, T4- 20:35°C, T5- 24:35°C, T6- 28:35°C, T7- 20:40°C, T8- 24:40°C and T9- 28:40°C along with three replications each was maintained for 14:10 hr in an incubator. The relative humidity was maintained 65±5 per cent throughout the experiment. Twenty neonate larvae were used in each T and three such replications were maintained in different plastic jars (10 cm diameter and 18 cm height) by using camel hair brush and the larvae was fed on the locules of Bt cotton cultivar, RCH 773. The larval period is defined as the time from hatching to pre-pupation. The observations were recorded twice a day in the morning and evening sessions regularly. For recording the duration of each instar, cut the locules and examine it for casted skin. Pink bollworm pupae were kept in the emerging cage until they mature into adults.

To record the fecundity, detached cotton bolls of 10-15 days old was wrapped with moist cotton wick and placed in eppendorf tubes filled with 10 per cent sucrose solution to keep the cotton bolls fresh and this was placed in the oviposition cage of 14.5 x 20.5cm diameter (Fand *et al* 2019). To facilitate feeding of adult moths, diet was provided. For
mating purposes, five pairs of newly emerged adults were introduced into an oviposition cage (14.5x20.5 cm dia). The eggs which were laid by the adult female moth were collected separately. The cotton shoots were replaced after every two days. The number of eggs deposited on the old twig was counted. The incubation period was examined in the laboratory by keeping the cotton twig holding eggs at various alternate temperatures. The incubation period is the time between the deposition of egg and the emergence of first instar larva. After the death of males and females, the experiment was come to an end.

**OBSERVATIONS TO BE RECORDED**

The observations on various biological parameters including fecundity, incubation period, larval period (1\textsuperscript{st}, 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} instar), pupal period, larval weight, pupal weight, adult longevity, total developmental period, per cent survival of egg, larva and pupa.

The growth index was worked out as per the formula given below:

\[
\text{Growth index} = \frac{\text{Mean larval survival (\%)} \times \text{Mean larval period (days)}}{100}
\]

**RESULTS**

The study unveiled that the significant lowest incubation period was recorded in T9 (28:40°C) at 1.58±0.08 days and significant highest incubation period was observed in T1 (20:30°C) with a duration of 4.65±0.05 days (Table 1). The significantly lowest duration of first larval instar was recorded in T9 (28:40°C) as 1.56±0.03 days and highest duration was observed in T1 (20:30°C) with a duration of 4.06±0.08 days. The significant lowest and highest durations of second larval instar was recorded in T9 (28:40°C) and T1 (20:30°C) with 1.56±0.03 and 5.00±0.05 days, respectively. Third larval instar duration was lowest in T9 (28:40°C) with 3.36±0.03 days and highest in T1 (20:30°C) with 5.93±0.08 days. The fourth larval instar was lowest in T9 (28:40°C) with duration of 6.83±0.06, whereas the highest was recorded in T1 (20:30°C) with 10.46±0.03 days (Table 1). Similarly, the total larval duration
was significantly lowest in T9 (28:40°C), lasting for 14.30±0.05 days and highest was recorded in T1 (20:30°C) with a duration of 25.46±0.17 days (Table 1).

The male and female pupal duration was recorded lowest in T9 (28:40°C) with 4.71±0.06 and 5.82±0.09 days, respectively and highest in T1 (20:30°C) with 8.33±0.22 and 9.16±0.16 days respectively (Table 2).

The adult longevity of male and female was recorded minimum in T9 (28:40°C) with 4.91±0.08 and 6.36±0.08 days, respectively and maximum in T1 (20:30°C) with 10.08±0.16 and 11.38±0.05 days, respectively. The total developmental period of male and female follows the same trend where the lowest in T9 (28:40°C), lasting for 20.59±0.11 and 21.70±0.04 days, respectively and highest in T1 (20:30°C) with a duration of 38.45±0.21 and 39.22±0.11 days, respectively (Table 2).

Fecundity was significantly lowest in T9 (28:40°C) with 27.24±1.00 eggs per female and significantly higher in T3 (28:30°C) with 64.41±1.01 eggs per female (Fig. 1). Whereas, the sex ratio was recorded highest in T9 (28:40°C), with male: female sex ratio of 1:1.60 (Table 2).

The egg, larval and pupal survival was recorded highest in T3 (28:30°C) with 85.93±0.78, 90.04±0.79 and 93.33±1.01 per cent respectively. Whereas the lowest survival percentage was recorded in T9 (28:40°C) with 68.23±0.78, 71.72±1.91 and 76.26±1.26 per cent, respectively (Fig. 2).

The larval weights of first, second, third and fourth larval instars was recorded maximum in T6 (28:35°C) with 3.44±0.01, 10.27±0.17, 22.68±0.68 and 21.52±0.33 mg, respectively. Whereas, the minimum weight was recorded in T7 (20:40°C) with 2.80±0.02, 8.61±0.13, 19.81±0.41 and 18.96±0.23 mg, respectively (Table 3). The pre pupal weight is significantly higher in T6 (28:35°C) with 15.17±0.24 mg and lowest in T7 (20:40°C), weighing 13.22±0.27 mg. The male and female pupal weights were significantly higher in T6
Correlation between developmental parameters like incubation period, larval duration
of first, second, third, fourth instar’s, total larval duration, male and female pupal duration,
adult longevity and total developmental period showed highly significant negative correlation
with the alternate temperatures. Whereas, the fecundity shown significant negative
correlation with alternate temperatures. The first, second, third and fourth larval instars, male
and female pupal weights have shown non-significant positive correlation with the alternate
temperatures. The egg, larval and pupal survival has shown non-significant negative
correlation with alternate temperatures.

DISCUSSION

As insects are ectothermic, their growth, development, and reproduction are primarily
influenced by temperature as it plays crucial roles in their metabolism, metamorphosis,
mobility, host availability etc. Higher temperatures lead to accelerated metabolic activities in
insects, which, in turn, results in a shortened duration of their developmental stages (Shreshta
et al 2019). The findings on larval duration are consistent with the results of Likitha et al
(2022) and Shrinivas et al (2019), who observed a total larval period of 25.10±0.99 and
26.10±0.66 days, respectively when the pink bollworm was reared on artificial medium at a
temperature of 25±2°C. Additionally, Peddu et al (2019) found that the development of larva
increased from 20°C to 35°C and rapidly declined at the temperatures above 35°C. Our results
are also in agreement with the observations made by Syed and Rahman (1960), who noted a
total duration of immature stages to be 23.10 days at 25°C. However, the findings are in
contrast with earlier results of Rajput et al (2018), who reported a maximum fourth instar larval duration of 11.36±0.30 days at 27±2°C.

Results regarding the pupal period align with the observations made by Cacayorin et al (1992) who found that the average duration of pupal stage was 7.42 days. Similarly, Rajput et al (2018) found a pupal duration of 9.73 days at 27±2°C and 8.43 days at 25±2°C (Shrinivas et al 2019), both of which are consistent with our findings. Peddu et al (2019) found that the pupal period increased till 35°C and rapidly declined at the temperatures above 35°C.

Zinzuvadiya et al (2017) reported that the total developmental period of male was 31 to 46 (38.40±4.48) days at 28.34±3.15°C and 49.71±0.50 days at 21°C and 23.22±0.40 days longevity of male at 35°C by Hussain et al (2023). Sapna et al (2017) found that the complete life cycle of female from egg to adult emergence was 52.3±6.51 days at 25±1°C. Shrinivas et al (2019) from Raichur, Karnataka, reported that females survived longer than males. Hussain et al (2023) from Pakistan, reported that the longevity of male was 57.05±1.45 days at 21°C and 31.86±0.52 days at 35°C. An increase in body size and a decrease in development time with respect to increase in temperature are commonly observed outcomes of natural selection acting on individual organisms (Kingsolver et al 2004 and Harrison et al 2013).

Hussain et al (2023) reported the fecundity of 49.82±1.46 eggs/female at 35°C. Hentz et al (1998) found that fecundity was higher at 25°C and lower at 35°C. Additionally, Awaknawar (1976) reported a fecundity range of 9-34 eggs per female, with an average of 20.6 eggs per female. Philipp et al (2014) found that the higher the temperature, lower fecundity rates.

In the face of extreme heat, numerous insect species struggle to survive, primarily due to their lack of sufficient heat tolerance during gradual heat stress in their natural habitats.
(Bodlah et al 2023). The alternate temperatures led to elevated overall survival rates in *H. armigera* compared to the survival rates observed under corresponding constant temperatures, (Mironidis et al 2008). This outcome is possibly due to the fact that fluctuating temperatures offer intervals for recovery or enable adaptation to extreme hot or cold conditions (Vargas et al, 2000). Fand et al (2019) found that the survival percentage of egg and larva were 89.94±3.61 and 91.49±3.10 per cent, respectively at 27±1°C. Shrinivas et al (2019) found that the mean pupal survival was 88.32 per cent at 27±2°C and Murlimohan et al (2009) reported 91.66 per cent of adult emergence when reared on seeds of cotton at 28±1°C temperature.

An increase in body size with respect to increase in temperature are commonly observed outcomes of natural selection acting on individual organisms (Kingsolver et al 2004 and Harrison et al 2013). The recent observations regarding the larval weight of the pink bollworm align with previous research conducted by Dharajothi et al (2016) and found larval weight of 21.40±3.63 mg at 27±0.5°C. Similarly, Rajput et al (2018) reported the mean larval weight of 13.84±1.34 mg while feeding on Bt cotton 25±5°C. These results are consistent with the observations made by Fand et al (2019) who reported larval weight of 21.96 mg when fed on bolls of Bt cotton.

The correlation between alternate temperature and developmental stages shown negative correlation and our findings are in conformity with the earlier findings of Hussain et al (2023) who stated that the developmental stages of pink bollworm negative correlation with the temperature. Iqbal et al (2019) stated that temperature has negative significant relation with the developmental stages. Xia et al (2019) have similarly observed a strong positive correlation between growth rate and rearing temperature in the tropical population of *Ostrinia furnacalis* which significantly affect the growth pattern of *O. frunacalis* under controlled conditions.
CONCLUSION

It can be concluded that the shortest duration of *P. gossypiella* was recorded at alternate temperatures of 28:40°C and increased with decrease in temperature. The larval and pupal weight of *P. gossypiella* were highest at alternate temperatures of 28:35°C. An increase in body size and a decrease in development time with respect to increase in temperature are commonly observed outcomes of natural selection acting on individual organisms. The fecundity and per cent survival of *P. gossypiella* were highest at alternate temperatures of 28:30°C and decreased with both rise and fall of temperature. In the face of extreme heat, numerous insect species struggle to survive, primarily due to their lack of sufficient heat tolerance during gradual heat stress in their natural habitats. All the developmental parameters except fecundity showed highly significant negative correlation with alternate temperatures.

ACKNOWLEDGEMENTS

Authors are thankful to the Department of Entomology, Punjab Agricultural University, Ludhiana for providing necessary facilities for carrying out the study.

FUNDING

This research did not receive any specific grant from funding agencies in the public commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare that are relevant to the content of this article.
REFERENCES


https://doi.org/10.1007/s12600-019-00738-x


http://www.jstor.org/stable/24110575


http://dx.doi.org/10.23910/1.2022.3124


Naik VC, Kumbhare S, Kranthi S, Satija U, Kranthi KR (2018) Field evolved resistance of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), to transgenic *Bacillus thuringiensis* (Bt) cotton expressing crystal 1Ac (Cry1Ac) and Cry2Ab in India. Pest Manage Sci 74(11): 2544–54. https://doi.org/10.1002/ps.5038


Table 1. Effect of alternating temperatures on incubation period, duration of first, second, third, and fourth larval instars and total larval duration of *P. gossypiella* on Bt cotton during 2022

| Sr.No | Temp. (°C)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incubation period (days)</td>
</tr>
<tr>
<td>T1</td>
<td>20:30</td>
</tr>
<tr>
<td>T2</td>
<td>24:30</td>
</tr>
<tr>
<td>T3</td>
<td>28:30</td>
</tr>
<tr>
<td>T4</td>
<td>20:35</td>
</tr>
<tr>
<td>T5</td>
<td>24:35</td>
</tr>
<tr>
<td>T6</td>
<td>28:35</td>
</tr>
<tr>
<td>T7*</td>
<td>20:40</td>
</tr>
<tr>
<td>T8*</td>
<td>24:40</td>
</tr>
<tr>
<td>T9*</td>
<td>28:40</td>
</tr>
<tr>
<td>CD (p&lt;0.01)</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Note: *Minimum temperature:Maximum temperature; Mean±SE of three replications; *Maximum temperature for 10 hrs; Different alphabets in superscript indicate significant differences as per Tukey’s HSD test (p<0.01); Relative humidity: 65±5%
Table 2. Effect of alternating temperatures on pupal duration, adult longevity, total developmental period, fecundity and sex ratio of *P. gossypiella* in Bt cotton during 2022.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Temp.* °C</th>
<th>Pupa duration (days) (Mean±SE)</th>
<th>Adult longevity (days) (Mean±SE)</th>
<th>Total developmental period** (days) (Mean±SE)</th>
<th>Sex ratio (Male:Female)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>T1</td>
<td>20</td>
<td>30</td>
<td>8.33±0.22 a</td>
<td>9.16±0.16 a</td>
<td>10.08±0.16 a</td>
</tr>
<tr>
<td>T2</td>
<td>24</td>
<td>30</td>
<td>7.98±0.38 a</td>
<td>8.94±0.05 ab</td>
<td>8.91±0.14 b</td>
</tr>
<tr>
<td>T3</td>
<td>28</td>
<td>30</td>
<td>7.16±0.08 b</td>
<td>8.52±0.07 b</td>
<td>7.83±0.08 c</td>
</tr>
<tr>
<td>T4</td>
<td>20</td>
<td>35</td>
<td>7.77±0.22 a</td>
<td>8.89±0.05 ab</td>
<td>7.21±0.17 d</td>
</tr>
<tr>
<td>T5</td>
<td>24</td>
<td>35</td>
<td>6.66±0.06 b</td>
<td>7.93±0.06 c</td>
<td>7.06±0.06 d</td>
</tr>
<tr>
<td>T6</td>
<td>28</td>
<td>35</td>
<td>6.60±0.06 c</td>
<td>7.31±0.05 d</td>
<td>6.46±0.29 e</td>
</tr>
<tr>
<td>T7*</td>
<td>20</td>
<td>40</td>
<td>5.85±0.07 c</td>
<td>7.17±0.01 d</td>
<td>6.06±0.06 e</td>
</tr>
<tr>
<td>T8*</td>
<td>24</td>
<td>40</td>
<td>5.00±0.11 d</td>
<td>5.99±0.47 e</td>
<td>5.46±0.17 f</td>
</tr>
<tr>
<td>T9*</td>
<td>28</td>
<td>40</td>
<td>4.71±0.06 d</td>
<td>5.82±0.09 e</td>
<td>4.91±0.08 g</td>
</tr>
<tr>
<td>CD (p&lt;0.01)</td>
<td></td>
<td></td>
<td>0.53</td>
<td>0.53</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Note: *Minimum temperature:Maximum temperature; Mean±SE of three replications; *Maximum temperature for 10 hrs; Different alphabets in superscript indicate significant differences as per Tukey’s HSD test (p<0.01); Relative humidity: 65±5%
Table 3. Effect of alternating temperatures on larval and pupal weights of *P. gossypiella* on Bt cotton during 2022

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Temp.(^a) °C</th>
<th>Larval weight (mg) ((Mean±SE))</th>
<th>Pupal weight (mg) ((Mean±SE))</th>
<th>Growth index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1(^{st}) Instar</td>
<td>2(^{nd}) Instar</td>
<td>3(^{rd}) Instar</td>
</tr>
<tr>
<td>T1</td>
<td>20:30</td>
<td>2.91±0.03(^bc)</td>
<td>9.36±0.05(^d)</td>
<td>20.61±0.07(^bc)</td>
</tr>
<tr>
<td>T2</td>
<td>24:30</td>
<td>3.32±0.06(^ab)</td>
<td>9.54±0.07(^cd)</td>
<td>21.31±0.24(^abc)</td>
</tr>
<tr>
<td>T3</td>
<td>28:30</td>
<td>3.41±0.02(^a)</td>
<td>10.16±0.21(^ab)</td>
<td>22.17±0.67(^ab)</td>
</tr>
<tr>
<td>T4</td>
<td>20:35</td>
<td>3.18±0.05(^abc)</td>
<td>9.72±0.22(^bcd)</td>
<td>21.22±0.14(^abc)</td>
</tr>
<tr>
<td>T5</td>
<td>24:35</td>
<td>3.35±0.03(^a)</td>
<td>9.93±0.17(^abc)</td>
<td>21.44±0.48(^ab)</td>
</tr>
<tr>
<td>T6</td>
<td>28:35</td>
<td>3.44±0.01(^a)</td>
<td>10.27±0.17(^a)</td>
<td>22.68±0.68(^a)</td>
</tr>
<tr>
<td>T7*</td>
<td>20:40</td>
<td>2.80±0.02(^c)</td>
<td>8.61±0.13(^c)</td>
<td>19.81±0.41(^c)</td>
</tr>
<tr>
<td>T8*</td>
<td>24:40</td>
<td>3.21±0.18(^abc)</td>
<td>8.78±0.12(^c)</td>
<td>20.63±0.21(^bc)</td>
</tr>
<tr>
<td>T9*</td>
<td>28:40</td>
<td>3.29±0.01(^ab)</td>
<td>9.65±0.12(^cd)</td>
<td>21.95±0.79(^ab)</td>
</tr>
<tr>
<td>CD (p&lt;0.01)</td>
<td>0.37</td>
<td>0.45</td>
<td>1.44</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Note: *Minimum temperature:Maximum temperature; Mean±SE of three replications; *Maximum temperature for 10 hrs; Different alphabets in superscript indicate significant differences as per Tukey’s HSD test (p<0.01); Relative humidity: 65±5%
Fig. 1. Effect of alternating temperatures in fecundity of *P. gossypiella* in Bt cotton during 2022

Fig. 2. Effect of alternating temperatures on egg, larval and pupal survival of *P. gossypiella* on Bt cotton during 2022