Determination of Thermal Constant and Development Threshold of Cotton mealybug, *Phenacoccus solenopsis* (Tinsley)

Uzma Manzoor¹*, Masarrat Haseeb¹ and Subhash Chander²

¹Department of Plant Protection, Aligarh Muslim University, Aligarh-202002, India
²Division of Entomology, Indian Agricultural Research Institute, Delhi-110012, India

**Abstract**
Effect of constant temperatures viz, 18±1, 21±1, 27±1, 30±1 and 33±1 °C on egg, nymphal and male pre-pupal and pupal stage development of *Phenacoccus solenopsis* revealed that the development rate of egg, nymphs and pupal stages gradually increased with increase in temperature, while total development period decreased. The development threshold was determined to be 12.7, 15.8, 9.05, 8.87 and 7.1 °C for egg, nymphs (I to III instar) and male pre-pupal and pupal stage, respectively with corresponding thermal constant being 24.4, 52.63, 58.82, 62.5 and 142.85 DD. Total thermal constant requirement to complete a generation was thus 341.2 DD.

**Keywords:** Degree day, *Phenacoccus solenopsis*, Thermal constant, Threshold of development

*Correspondence*  Author: Uzma Manzoor  
Email: uzmamanzoor52@gmail.com

**Introduction**

Okra (*Abelmoschus esculentus*) belongs to family Malvaceae and is an important vegetable crop grown throughout the year. Besides India, it is grown in many tropical and subtropical parts of the world. Due to their tender and supple nature and their cultivation under high moisture & input regimes, okra is more prone to insect pest attack. The crop is attacked by number of pests of which cotton mealybug causes serious substantial reduction in crop growth and yield. It has been described as a serious and invasive polyphagous pest with a vast host range. It causes significant economic damage on cotton, brinjal, okra, tomato, sesame, sunflower and China rose [1-3]. The sucking of sap by the pest results in the yellowing of leaves which lead to loss of plant vigour, foliage and fruit drop [4, 5].

Temperature is one of the major environmental factors influencing insects. Development, survival, adult longevity and fecundity data are vital for understanding the population dynamics of any insect species on a particular host [6]. Understanding phenology of an insect species at different temperatures is crucial for predicting its seasonal occurrence and planning for integrated management. Many mathematical models describe insect developmental rate as a function of temperature [7-10]. Linear model [11] is widely used to explain the straight line relationship between the developmental rate and temperature in the limited range and calculate lower developmental thresholds and thermal constants required to complete development of life stages. Keeping this in view, the present studies were undertaken.

**Experimental**

Nymphs and adults of the cotton mealybug were collected from the experimental field of Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh and were mass reared on okra cuttings (tender shoots and leaves) in laboratory at 27 ± 1 °C and 70-80% relative humidity. The cuttings were replaced every three days by new ones and the mealybug population was transferred to the new cuttings using a camel hair brush. From this stock culture, further experiment was conducted. 15 gravid females were collected from the laboratory culture and kept on okra shoots in petriplates provided with filter paper. Moist absorbent cotton was put under filter paper to maintain the humidity and fresh shoots of okra were provided as food daily and incubated until oviposition. Eggs laid on the same day were placed in small vials and put in incubators at 15 ± 1, 18 ± 1, 21 ± 1, 24 ± 1, 27 ± 1, 30 ± 1 and 33 ± 1 °C with 65-70% relative humidity. The mealybug cohorts were examined daily and development was recorded.

Development rate (R) for egg, nymphal stages and prepupal and pupal stages of male of cotton mealybug was computed as reciprocal of the mean number of days to complete development. Development threshold (To) and thermal constant (K) were then determined by regressing development rate on temperature [12] according to the rule of the constant sum of effective temperature as under:
Thermal constant = (Temperature – development threshold) X development duration

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

\[ K = \frac{1}{b} \]

To was determined by the ratio of regression intercept (a) and (b)

\[ To = -\frac{a}{b} \]

Result and Discussion

The present study revealed that the development duration of *P. solenopsis* decreased with increase in temperature from 15 ± 1 to 33 ± 1 °C (Table 1). The temperature increase from 15 ± 1 to 33 ± 1 °C reduced the incubation period from 5.15 to 1.15 days, 1\(^{st}\) instar nymphal period from 22.3 to 2.4 days, 2\(^{nd}\) instar nymphal period from 7.3 to 2.0, 3\(^{rd}\) instar female from 6.85 to 2.2, and male (pre-pupal and pupal) period from 13.45 to 4.25 days, respectively. The total life cycle duration of *P. solenopsis* was also observed at each temperature and it decreased from 48.2 to 9.8 days for males and 41.6 to 7.7 days for females with temperature increase. The total development period in male and female differed, and was noted to be dependent upon variations in temperature. Interestingly at lower temperatures (upto 21 °C) the duration was greater (6.6, 6.5, 5.0 days) than at higher temperature upto 33 °C where the difference was of only 2.1 days.

**Table 1** Determination of threshold temperatures and thermal constant for different developmental stages of cotton mealybug, *P. solenopsis*

<table>
<thead>
<tr>
<th><em>P. solenopsis</em> development stages</th>
<th>Regression equation</th>
<th>Thermal constant (K)</th>
<th>Temperature threshold (To)</th>
<th>R(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>y = 0.041x - 0.521</td>
<td>24.40</td>
<td>12.70</td>
<td>0.92</td>
</tr>
<tr>
<td>1(^{st}) instar</td>
<td>y = 0.019x - 0.301</td>
<td>52.63</td>
<td>15.80</td>
<td>0.88</td>
</tr>
<tr>
<td>2(^{nd}) instar</td>
<td>y = 0.017x - 0.154</td>
<td>58.82</td>
<td>9.05</td>
<td>0.84</td>
</tr>
<tr>
<td>3(^{rd}) instar (Female)</td>
<td>y = 0.016x - 0.142</td>
<td>62.50</td>
<td>8.87</td>
<td>0.91</td>
</tr>
<tr>
<td>Male (Pre-pupal and pupal stage)</td>
<td>y = 0.007x - 0.054</td>
<td>142.85</td>
<td>7.71</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Regression equations between development rate and temperature were found to be \( y=0.041x - 0.521 \) (R\(^2\) = 0.92) for egg; \( y = 0.019x - 0.301 \) (R\(^2\) = 0.88) for 1\(^{st}\) instar nymph; \( y = 0.017x - 0.154 \) (R\(^2\) = 0.84) for 2\(^{nd}\) instar nymph; \( y = 0.016x - 0.142 \) (R\(^2\) = 0.91) for 3\(^{rd}\) instar female nymph \( y = 0.007x - 0.054 \) (R\(^2\) = 0.96) for male pre-pupal and pupal stage, respectively (Figures 1-3). Development threshold was determined to be 12.70, 15.80, 9.05, 8.87 and 7.10 °C for egg, nymphs (I to III instar) and male pre-pupal and pupal stage, respectively with corresponding thermal constant being 24.40, 52.63, 58.82, 62.5 and 142.85 DD. Total thermal constant requirement to complete a generation was thus 341.2 DD. It may also be noted that temperature threshold decreased after 1\(^{st}\) instar stage.

**Figure 1** Regression between different temperatures and mean duration of *P.solenopsis* (I instar nymphs, female)
Figure 2 Regression between different temperatures and mean duration of *P. solenopsis* (male pre-pupal stage)

Figure 3 Regression between different temperatures and mean duration of *P. solenopsis* (pupal stage of male)

**Conclusion**

A linear approximation of relationship between developmental rate and temperature gives the most appropriate fit within the quasi-linear range of temperatures [13]. Entomologists have strong interest on this kind of relationships, since they are prerequisite to predicting timing and phenology of insect life cycle events and to initiating management actions [14, 15], while application of temperature driven models are also essential in epidemiology modeling, development of effective vector control programmes [16] and prediction of biological invasions [17]. From an agronomical standpoint, empirical models are often used to predict specific population events and provide means for precisely applied control methods, reducing costs as well as insecticide use [18, 19]. Furthermore, the determination of insect-specific vital thermal requirements provides evidence to infer on observed geographical distributions and predict future dynamics [20].

**Acknowledgement**

The authors acknowledge Department of Science and Technology, Government of India, New Delhi for providing financial assistance in the form of INSPIRE Fellowship and Chairman, Department of Plant Protection, Aligarh Muslim University for providing facilities to conduct the present study.

**References**