EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE BIOLOGY OF COTTON MEALY BUG (PHENACOCCUS SOLENOPSIS TINSELEY)

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ABSTRACT

A study on biology of cotton mealy bug (Phenacoccus solenopsis Tinsley) was conducted in the laboratory of Entomological Research Institute, Faisalabad, Pakistan during 2007-2008. Adult females were released in petri-dishes (9 cm dia) containing fresh leaves of cotton crop. Egg laying duration was checked after 8 hour intervals to record the hatching time. Biology of pest was studied at seven different temperatures and relative humidities viz. 20°C with 75 ± 5% RH; 25°C with 70 ± 5% RH; 27°C with 65 ± 5% RH; 30°C with 60 ±5% RH; 32°C with 55 ± 5% RH; 35°C with 40 ±5% RH and 40°C with 40 ± 5% RH. The results revealed that incubation period significantly decreased from 32 hours to zero hour with increase in temperature from 20°C to 40°C. Life period of first, second and third instar was decreased from 8.31 to 3.0 days, 8.61 to 2.71 days, and 4.6 to 3.00 days (female), 7.4 to 2.4 days (male), respectively at 20°C with 75 ± 5% RH and 40°C with 40 ± 5% RH, respectively. Pupae duration decreased from 9.57 days at 20°C to 3.78 days at 35°C, while no male emerged from pupae at 40°C. Total male life decreased from 25.21 days at 20°C to 11.0 days at 35°C, while no male emerged at 40°C. Total female life decreased from 90.57 days at 20°C to 12.71 days at 40°C. There was significant effect of temperature on fecundity of adult female. Total adult life (both male and female) was prolonged at lower temperatures and shortened at higher temperatures. Optimum temperature for growth and development of the pest was 32°C with 55 ±5% RH.

KEYWORDS: Gossypium hirsutum; Phenacoccus solenopsis; temperature; relative humidity; Pakistan.

INTRODUCTION

Cotton (Gossypium hirsutum L.) is important cash and fibre crop of Pakistan. During 2005, a new menace, cotton mealy bug, Phenacoccus solenopsis Tinsley...
Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae)), an exotic spp. appeared in Sindh (Sanghar, Mirpur Khas and Tando Allahyar districts) and in Punjab (Multan, Vehari and other cotton growing areas of Southern Punjab) (6, 22). During 2006, pest appeared in Gujrat (India) and during 2009 in Bangladesh (18, 24, 28). The pest feeds on more than 154 plants belonging to six different families (3, 4). Cotton production in Pakistan is facing a steady decline from 2.194 million tons during 2005 to 2.09 million tons during 2009 due to incidence of sucking pest complex and high cost of fertilizer and pesticides (13, 20, 21). During 2006, 3.1 million bales have been ruined by cotton mealybug in Pakistan and 17 percent of yield declined in Punjab during 2007 (5).

Damage to host crop is due to sucking of twigs and leaves. Sooty mould appears on the twisted twigs and leaves due to which young plants die and elder plants are weakened. Damage in Pakistan started from the hot regions of provinces, it might be due to hot weather and lack of rainfall that encouraged development of pest. In India, Dhawan et al. (11) reported positive correlation existed between increase in temperature while negative correlation existed between rainfall and population of pest under natural conditions. In conclusive way, hot weather and lack of rainfall encourage development and spread of pest.

The work so far conducted on biology of cotton mealybug (1, 2, 3, 22) was not on a very précised manner. So, the present study was conducted to determine the effect of temperature and relative humidity on the biology of cotton mealy bug at different sets of climatic conditions.

**MATERIALS AND METHODS**

**Collection of insects**

Adults of cotton mealy bug were collected from different host plants in Faisalabad, Pakistan through scissor and plant cutter by cutting 15-cm of host plant twigs containing culture of adult cotton mealy bug. These were placed in cool box and brought into the laboratory of Entomological Research Institute, AARI, Faisalabad during the year 2007-08.

**Rearing of insects**

Rearing of adult insect was done in glass petri dishes of 9 cm diameter containing fresh China rose twigs. First nymphal (crawlers) instars, appeared
from the bodies of adult females, were transferred in plastic vial size 1.5 x 0.5 cm covered with a plastic cover having sieve of 90-mesh size. The plastic vials contained moist soaked sand on which China rose twigs were placed. One individual of 1st instar of cotton mealy bug was released in each rearing cell/vial.

**Data collection**

**Egg stage:** Mated females were kept in glass petri-dishes for formation of ovi-sac. Development of eggs and filling of sac with eggs was checked after 8 hour intervals. Complete development of ovi-sac was standardized when 1st nymph appeared from the ovi-sac.

**Hatching time:** Hatching time was standardized i.e. time duration between 1st nymph appeared from the ovi-sac to last nymph appeared from the ovi-sac.

**Nymphal instars duration:** Nymphs on hatching were placed in rearing cells. Nymphal duration was recorded twice a day. Data on morphological characters and duration for relative development at various sets of temperature and humidity were recorded.

**Pupal stage duration:** Pupal stage duration, shape, color and size was recorded twice a day.

**Adult stage:** Adult characteristics viz. size, colour, shape, duration, longevity, fertility, fecundity, pre-ovipositional period and post ovipositional period were observed and recorded twice a day. The experiment was laid out in completely randomized design consisting of 7 treatments and 14 replicates. The temperature and humidity were maintained by the use of environmental growth chamber. The temperatures and relative humidities is included were: 20°C with 75 ± 5% RH, 25°C with 70 ± 5% RH, 27°C with 65 ± 5% RH, 30°C with 60 ± 5% RH, 32°C with 55 ± 5% RH, 35°C with 40 ± 5% RH and 40°C with 40 ± 5% RH.

Data were statistically analyzed for analysis of variance and means were compared by DMR test (P = 0.05) using Mstat-C software. Growth chamber was used to maintain temperature and RH of experimental units.

**RESULTS AND DISCUSSION**

Cotton mealy bug (CMB) during its growth passed through different stages. In male insects, the egg, 1st instar, 2nd instar, pupae and adult male
appeared, while in female, egg, 1st instar, 2nd instar, 3rd instar and adult female stages were appeared. There was no pupal stage in female specimens.

**Eggs**

CMB eggs were small having yellowish green colour with 0.3 x 0.1 mm size. The eggs were present in the pouch made up of silken thread in the last abdominal segments of female insect.

Egg duration differed at different temperatures. It was 32 hours at 20°C with 75% RH; 30.07 hours at 25°C with 65±5% RH; 28.07 hours at 27°C with 65±5% RH; 24.00 hours at 30°C with 60±5% RH; 22.00 hours at 32°C with 55±5% RH; 19.07 hours at 35°C with 40% ± 5% R.H and no egg hatched at 40°C with 40±5% RH (Table).

These results are partially similar to those of Aheer et al. (3) who reported that eggs of CMB were orange in colour (yellowish green in the present study), elongate in shape and were found in clusters in ovi-sac. The hatching time was 30-45 minutes as reported by the same scientists without mentioning the conditions. In broader sense the results of Child (8) are in conformity who reported that high ambient temperature increased the incidence of pest attack and damage.

The data revealed the decrease in incubation period from 32.00 hours to 19.00 hours from 20°C to 35°C, respectively while no egg survived at 40°C (Table). Similar results were also reported by Chong et al. (9), Emana (15) and Rees and Walker (27) who found prolonged duration at lower temperature and shortened at higher temperature. The present findings cannot be compared with those of Despines (10) who reported that lower hatching percentage at 35°C in horse tick is due to increase in temperature. Similarly Punzo and Mutchmor (26) reported that decrease in humidity played a significant role in hatching percentage than temperature, however, combination of two factors increased mortality due to desiccation. Similarly, results reported by Fokunang et al. (16), Hodgson et al. (19) and El-Minshawy et al. (14) cannot be compared due to different ecological conditions and their methodologies.

**First instar**

First instars of CMB were small and yellowish green in colour. Their size varied from 0.5 mm to 0.1 mm. There was no wax coating on the first instar.
The first instar were very fast crawlers. They quickly searched the food and settled on the host. The duration of 1\textsuperscript{st} instar of CMB differed at different temperatures and relative humidities. However, it declined with increase in temperature and decrease in relative humidity.

The duration of 1\textsuperscript{st} instar was 8.31 days at 20\degree C with 75 \pm 5\% RH; 7.57 days at 25\degree C with 65\pm5\% R.H; 6.89 days at 27\degree C with 65\pm5\% R.H; 4.36 days at 30\degree C with 60\pm5\% R.H; 4.11 days at 32\degree C with 55\pm5\% RH; 3.32 days at 35\degree C with 40\% \pm 5\% R.H and 3.00 days at 40\degree C and 40\% \pm 5\% RH. The present findings are in conformity with those of Aheer \textit{et al.} (3) who reported that 1\textsuperscript{st} instars of CMB were yellowish green in colour and fast crawler.

The data indicated that survival of 1\textsuperscript{st} instar was decreased at higher temperatures as compared to the lower temperatures. The present findings are partially in conformity with those of Aheer \textit{et al.} (3) who reported that duration of 1\textsuperscript{st} instar was 7-9 days at 25\degree C. The present findings can also be compared with those of Duale (12) who reported a decreased survival at extremes temperature above 35\degree C and prolonged duration at low temperature. Similarly, Piesik (25) and Torrent and McCoy (29) reported a decrease in survival of neonates from 60 days to 30 days at 30\degree C. They further concluded that temperature and photoperiod significantly affected larval body weight. The present findings in broader sense can be compared with those of Gandolfo \textit{et al.} (17) and Child (8) who reported that increase in damage to agricultural crops was observed due to increased environmental temperature.
Table. Effect of various temperatures and relative humidities on different stages of cotton mealy bug.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration (days) at various temperatures and RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20°C; 75 ± 5% R.H</td>
</tr>
<tr>
<td>Egg (LSD = 0.628)</td>
<td>32.0±0.22a</td>
</tr>
<tr>
<td>1st instar (LSD = 0.29)</td>
<td>8.31 ± 0.17a</td>
</tr>
<tr>
<td>2nd instar (male) (LSD = 0.50)</td>
<td>8.61 ± 0.18a</td>
</tr>
<tr>
<td>2nd instar (female) (LSD = 0.10)</td>
<td>4.6 ± 0.18a</td>
</tr>
<tr>
<td>Pupae (LSD = 0.32)</td>
<td>7.42 ± 0.18a</td>
</tr>
<tr>
<td>Adult female (LSD = 12.43)</td>
<td>60.57±0.53a</td>
</tr>
<tr>
<td>Fecundity (LSD = 5.28)</td>
<td>227.1±1.85a</td>
</tr>
<tr>
<td>Adult male (LSD = 1.24)</td>
<td>1.929±0.15a</td>
</tr>
<tr>
<td>Total nymphal stage duration (LSD = 0.89)</td>
<td>23.64±0.31a</td>
</tr>
</tbody>
</table>

Means in rows sharing similar letters are not significantly different by DMR test at P = 0.05.
Second instar

Second instar of CMB was green in colour. Its size varied from 0.75-mm to 0.33-mm. Two black dots on the thorax and abdomen were present. They usually sticked to the twigs of host plants and waxy layer developed on the body surface one hour after moultng. The duration of 2\textsuperscript{nd} instar cotton mealy bug varied at different temperatures and relative humidities. The duration of 2\textsuperscript{nd} instar (male) was 8.61 days at 20°C with 75\% ± 5\% RH which reduced to 3.14 days at 35°C with 40 \% ± 5\% R.H and 2.71 at 40°C with 40±5\% RH (Table).

The duration of 2\textsuperscript{nd} instar (female) was 4.6 days at 20°C with 75 \% ± 5\% RH which gradually reduced to 3.0 days at 40°C with 40±5\% RH. These results revealed that life duration of 2\textsuperscript{nd} instars both male and female, decreased as the temperature increased. Thus increase in temperature resulted in rapid growth of cotton mealy bug at 2\textsuperscript{nd} instar stage of both the sexes.

These findings are in conformity with those of Aheer \textit{et al}. (3) who reported light green colour of 2\textsuperscript{nd} instar and variation in duration of both sexes i.e. 4 to 9 days in males and 3 to 4 days in females. Similar results were also obtained by Hodgson \textit{et al}. (19).

Third instar

Third instars of CMB were light green in colour. Two black dots were present on the thorax and abdomen. White waxy layer appeared on 2\textsuperscript{nd} day. Third instars appeared only in the female specimens while in male specimens pupae were formed. They remained stick to the twigs and suck the sap from twigs of host plants. The duration of 3\textsuperscript{rd} instar was 7.42 days at 20°C with 75 \% ± 5\% RH and 6.92 days at 25°C with 70±5% RH. It gradually decreased to 2.42 days at 40°C with 40±5\% RH (Table). The data depicted that life period of 3\textsuperscript{rd} instar female ranged from 2.42 to 7.42-days at temperature range of 20 °C to 40 °C, respectively. Thus lower temperatures prolonged life span of the pest as compared to the higher temperatures.

Aheer \textit{et al}. (3) also reported that third instar female was light green in colour and completed its life in 6.5 to 8.0 days at 25°C and 70% RH. Hodgson \textit{et al}. (19) conducted studies on \textit{P. solenopsis} and found similar results. Duale (12) reported that low temperature resulted in longer development period.
Pupae

Pupae were white in colour enclosed in silken sac made up of white threads. Internal colour of pupae was light green when dissected. The size of pupae was 1.80 x 0.50 mm. Pupae in field were present on the twigs of host plants when attack was abundant. However, when attack was not abundant, the pupae were found on the leaves of host plants particularly in tomato and sunflower. In laboratory conditions, pupae were mostly found on the lid. Pupae exposure at maintained temperatures and relative humidities showed different durations.

The duration of pupae was 9.57 days at 20°C with 75 ± 5% RH; which gradually decreased to 3.78 days at 35°C with 40 ± 5% RH and pupae died at 40°C with 40±5% RH. The present findings are similar to Aheer et al. (3) who reported that male pupae were formed after 2\textsuperscript{nd} instar and pupal duration was 7 to 8 days at 25°C. The results clearly revealed that pupal stage duration decreased from 9.57 days to 3.78 days at 20°C and 35°C, respectively. No male emerged at 40°C with 40 ± 5% RH due to high temperature and low humidity. According to Punzo and Mutchmor (26) high temperature and low RH resulted in increased mortality in young ones and pupal stage at extreme of temperature and relative humidity due to desiccation and inability to moult.

Adult female

Adult female size varied from 1.75-mm to 2.0-mm. Colour was light green which converted into dark brown when died. The adult specimen had two black dots each on thorax and abdomen. Duration of adult female differed at reached different temperatures and relative humidities. It was 60.57 days at
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20°C with 75 ± 5% R.H; which continued to decrease with rise in temperature and reached to 7.0 days at 40°C and 40 ± 5% RH (Table).

**Adult male**

Adult male of CMB was blackish brown in colour and had four abdominal filaments and winged. Wings were transparent. Size of adult male was 1.0 mm x 0.20 mm. The duration of adult male was 1.92 days at 20°C with 75 ± 5% RH, 1.85 days at 25°C with 70±5% R.H and it gradually decreased to 0.78 days at 35°C with 40 ± 5% RH. It did not emerge from pupae at 40°C with 40±5% RH (Table). Further, adult male taken from field population, was paired at this temperature. The adult died without successful mating to female specimen. Aheer et al. (3) also reported that adult male are blackish brown in colour, with transparent wings and four abdominal segments. They further reported that adult survived 1-2 days at 25°C with 75% RH.

![Adult female](image1.png) ![Adult male](image2.png)

**Fecundity**

The results revealed that fecundity was significantly reduced with increase in temperature and at 40°C with 40 ± 5% RH no egg was produced due to high temperature. Fluid inside pouch was desiccated and insects died due to non-availability of suitable conditions and liquid availability. The faster development was at 35°C.

These findings contradict to those of Chong et al. (9) where the development of *M. hirsutum* was the fastest at 27°C, and mealy bugs completed development in 29-days. The lower (T\text{min}) and upper (T\text{max}) developmental
thresholds and optimal developmental temperatures \(T_{\text{opt}}\) were estimated at 14.5, 35, and 29°C, respectively.

**Total nymphal stage duration**

Total nymphal stage duration varied significantly with increase in temperature and relative humidity. At 40°C only ten days were required to complete the development of insects. The duration of total nymphal stage was 23.64 days at 20°C with 75 ± 5% RH, 22.14 days at 25°C and decreased to 10.0 days at 40°C with ± 40% RH. These results confirm the findings of earlier workers (3, 9, 19, 26, 29) who reported that decrease in temperature increased the longevity and increase in temperature decreased the duration of nymphal stage.

**Total male life**

Total male life duration varied significantly with increase in temperature and relative humidity. At 40°C male did not emerge from pupae. However, duration of total male life was 25.21 days at 20°C with 75 ± 5% RH, 20.14 days at 25°C and it decreased to 11.00 days at 35°C with 40 ± 5% RH. Some earlier scientists (3, 9, 19, 23, 26, 29) also reported that decrease in temperature increased the longevity while increase in temperature resulted in decreased duration of insect.

**Total adult female life**

Total female life duration varied significantly with increase in temperature and relative humidity. The duration of female was 90.57 days at 20°C with 75±5% RH and 82.85 days at 25°C with 70±5% R.H. It reduced to 12.71 days at 40°C with 40±5% RH. The results showed that life duration of adult female reduced on increasing temperature and vice versa. Similar findings have also been reported earlier (3, 9, 26, 29).

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