Some Biological Attributes of *Trichogrammatidae bactrae*, Hymenoptera: 
Trichogrammatidae, at High Temperatures in Pink Bollworm (*Pectinophora gossypiella*, Lepidoptera: Gelechiidae) Eggs

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Abstract: The peak of development, (Egg to adult emergence) of *Trichogrammatidae bactrae* ranged from 7.273 to 6.532 days between temperatures 30 to 40 °C. Immature mortality was maximum (71.88 %) at 40 °C and minimum (39.77 %) at 30 °C. More females than males were found at all tested temperatures. Fecundity was 31 per female at 30 °C and 19 per female at 40 °C. Females lived longer than males at all tested temperatures. The net reproductive rate (R0), intrinsic rate of increase (r) and finite rate of increase (λ) were maximum at 30 °C. From these results, 30 °C is the best temperature for rearing *T. bactrae* in the laboratory with 45 % RH and 14/10 photoperiod. At 30 °C parasitoid can produced about 33 generations in a year. Upper threshold temperature for *T. bactrae* looks around 46 °C.

Key words: *T. bactrae*, parasitoid, mortality, fecundity, speed of development, net reproductive rate, intrinsic rate of increase, finite rate of increase, Balochistan, Pakistan

Introduction
Parasitic Hymenoptera are very effective and environmentally safe for the control of agricultural pests (Bhatti et al., 2000). Pink bollworm (PBW) is a key pest of cotton. Due to the absence of native biological agents the pest has got a level of economic importance (Anonymous, 1978). Egg is the first stage in the life cycle of PBW. By using an egg parasitoid it may be possible to biologically control PBW (Hutchison et al., 1990). *T. bactrae*, Hymenoptera, Trichogrammatidae is an egg parasitoid of PBW. *T. bactrae* is widely distributed in the orient. It is adapted to hot and humid habitats and is known to attack various pests of cotton, sugarcane, fruits and vegetables (Nagaraja, 1978). There is a need to understand its life history and behavior in detail at high temperature and low humidity. Nagaraja (1978) first described *T. bactrae* from the specimen collected from India. Hutchison et al. (1990) reported that *T. bactrae* completes its immature stages within the host (*Pectinophora gossypiella*) egg. *T. bactrae* may prove to be a good parasitoid for PBW in hot and semi humid climatic conditions. It could be used in an IPM program for PBW control in cotton growing areas of Balochistan, Pakistan which are hot and semi humid like New Mexico State, USA. So to determine different biological attributes, like speed of development, mortality, sex ratio, fecundity, net reproductive rate (R0), intrinsic rate of increase (r) and finite rate of increase (λ) of *T. bactrae* at hot and semi humid conditions in PBW eggs in the laboratory, the project was assigned.

Materials and Methods
To determine different biotic parameters like speed of development, immature mortality, sex ratio, fecundity, net reproductive rate (R0), intrinsic rate of increase (r) and finite rate of increase (λ) of *T. bactrae* at four different temperatures (30, 35, 40 & 45 °C), with constant 45% relative humidity (RH) and 14/10 photoperiod, an experiment was conducted in the Post Graduate’s Laboratory, Department of Entomology, Plant Pathology and Weed Science, New Mexico State University, USA. Environmental chambers (Atmar & Ellington, 1972) were used for control conditions. PBW eggs and *T. bactrae* were obtained from the colonies maintained locally in the department.

Development, Immature Mortality and Sex Ratio: To determine development, immature mortality and sex ratio, two hundred PBW eggs were placed in an air tight petri dish (60 x 9 mm) with ten pairs of *T. bactrae* adults and diet (100% natural honey) at 23 °C, 55% RH and 11/13 photoperiod (Malik, 2000). After parasitization, eggs were placed in another air tight petri dish (60 x 9 mm) at the same temperature for emergence. Soon after emergence, ten males and ten females *T. bactrae* adults were placed in an air tight petri dish (60 x 9 mm). Development was noted twice a day. Because egg and larval stages could not be distinguish therefore these two stages were combined for data collection (Malik, 2000). Blackening of the vitelline membrane of the host egg occurs at the onset of the pre-pupal stage (Hutchison et al., 1990). Therefore, the time from adult release to blackening was considered to be the egg/larval stage while blackening of host egg to emergence of the parasitoid was considered to be the pupal stage. After the emergence of all adults the speed of development of males and females, immature mortality and sex ratio were counted.

Fecundity: To determine the fecundity of female *T. bactrae*, two male and female *T. bactrae* with diet and about 100 PBW host eggs were placed in an air tight petri dish (60 x 9 mm) at 23 °C, 55% RH and 11/13 photoperiod. PBW eggs were replaced every eight hours until the death of the last female. After the death of all the females, the total number of parasitized eggs were counted in each replication.

Life Table Parameters: A computer program Life43 (Abou-Selte, 1986) was used to calculate life table parameters like net reproductive rate (R0), intrinsic rate of increase (r) and finite rate of increase (λ) of the parasitoid, *T. bactrae*.

Statistical Analysis: Each temperature regime was considered a treatment and each small air tight petri dish a replication. Egg/larval and pupal development, male/female longevity, egg/larval and pupal mortalities, fecundity, reproductive rate (R0), intrinsic rate of increase (r) and finite rate of increase (λ) of the parasitoid were the different variables in this experiment. Treatments were replicated eight times for four generations in a split plot design. Data were analyzed by Statistical Analysis System (SAS) Statistical Procedure Program (SAS Institute, 1990). ANOVA was used to test for
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Table 1: "Mean Egg/Larval, Pupal Speed Of Development and Percent Immature Mortality of T. bactrae at Different Temperatures.

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Egg/Larval Stage (Days)</th>
<th>Pupal Stage (Days)</th>
<th>Total Time From Egg To Emergence (Days)</th>
<th>Egg/Larval Mortality (%ag)</th>
<th>Pupal Mortality (%ag)</th>
<th>Total Immature Mortality (%ag)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>4.731 a³</td>
<td>2.542 a</td>
<td>7.273a</td>
<td>22.34 c</td>
<td>17.43 c</td>
<td>39.77 c</td>
</tr>
<tr>
<td>35</td>
<td>4.812 b</td>
<td>2.421 b</td>
<td>6.933 b</td>
<td>31.78 b</td>
<td>18.67 b</td>
<td>50.45 b</td>
</tr>
<tr>
<td>40</td>
<td>4.324 c</td>
<td>2.208 b</td>
<td>6.532 c</td>
<td>41.89 a</td>
<td>29.89 a</td>
<td>71.88 a</td>
</tr>
</tbody>
</table>

¹Means are from eight replications. * Total time from egg to adult emergence is the sum of egg/larval and pupal stages. ³Total Immature Mortality is the sum of Egg/Larval and Pupal Mortalities. ⁴Lower case letters indicate significant difference down the column using the LSD test. LSD for egg/larval stage 0.185, pupal stage 0.132, total immature stage 0.187, egg/larval mortality 0.345, pupal mortality 0.592, total immature mortality 0.468 at significance level of 0.05.

Table 2: "Mean Male, Female Longevity, Sex Ratio, and Fecundity of T. bactrae at Different Temperatures.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Male Longevity (Days)</th>
<th>Female Longevity (Days)</th>
<th>Female/Male Ratio</th>
<th>Fecundity/Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.52 a</td>
<td>5.22 a</td>
<td>55/48b</td>
<td>31a</td>
</tr>
<tr>
<td>35</td>
<td>1.31 a</td>
<td>5.14 a</td>
<td>55/48b</td>
<td>26b</td>
</tr>
<tr>
<td>40</td>
<td>1.20 a</td>
<td>4.23 a</td>
<td>55/48b</td>
<td>19c</td>
</tr>
</tbody>
</table>

¹Means are from eight replications. * Lower case letters indicate significant difference down the column using the LSD test. LSD for male longevity 0.232, female longevity 0.22, female/male ratio 0.537 and fecundity/female 0.413 at significance level of 0.05.

Table 3: Life Table Parameters of T. bactrae at Different Temperatures.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Net Reproductive Rate (R₀)</th>
<th>Intrinsic Rate of Increase (rₘ)</th>
<th>Finite Rate of Increase (λ)</th>
<th>Total Generation Time (T) (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>16.98 a²</td>
<td>0.30 a</td>
<td>1.430 a</td>
<td>11.95 a</td>
</tr>
<tr>
<td>35</td>
<td>16.11 b</td>
<td>0.29 b</td>
<td>1.321 b</td>
<td>10.55 b</td>
</tr>
<tr>
<td>40</td>
<td>8.97 c</td>
<td>0.09 c</td>
<td>1.001 c</td>
<td>10.07 c</td>
</tr>
</tbody>
</table>

²Lower case letters indicate significant difference down the column using the LSD test. LSD values for R₀, rₘ, λ, and T were 0.064, 0.005, 0.007 and 0.863 respectively at significance level of 0.05.

Results and Discussion

Development, Immature Mortality and Male/Female Longevity: Temperature had a significant effect on immature mortality as observed by Sharma & Chaudhry (1988) in Haltimis amigera and Marco et al. (1997) in Aebunonymus mariaeaceae. More mortality was observed in egg/larval stage than pupal stage (Table 1). Same is reported by Shipp & Houten (1997) in the study of Anulysseus cucumeris. Total immature mortality was maximum at 45 °C (> 6%). Thus was not considered in further analysis. This indicates that the upper threshold temperatures for T. bactrae might be around 45 °C. As temperatures went towards upper threshold level the mortality increased as reported by Sharma & Chaudhry (1988). The lowest percent mortality occurred at 30 °C (39.77%) (Table 1). Temperature also had an inverse relation with the mean development time of the parasitoid (Sharma & Chaudhry 1988, Phoolio et al. 1991, Marco et al. 1997). It took T. bactrae a minimum 6.532 days from eggs to emergence at 40 °C and a maximum of 7.273 days at 30 °C. Pupal stage respond less to the temperature than the egg/larval stage. Based on these results, the speed of development of T. bactrae, from sting to adult death, was 7.273 days at 30 °C (Table 1) which is about the same as reported Naranjo (1993) 7.3 days at 25.6 °C. Immature mortality was 35.77% to 79.8% at 30 & 40 °C respectively (Table 1). Hutchison et al. (1990) reported 34.3% at 27.5 °C and Naranjo (1993) observed 39% at 26 °C. Females at any temperature lived longer than males. Both male and female longevity decreased as temperature increased (Table 2). Same response was observed by Hutchinson et al. (1990) and Naranjo (1993).

Sex Ratio and Fecundity: T. bactrae female/male ratio ranged from 62.38 to 64.65 between 30 & 40 °C temperatures (Table 2). Hutchison et al. (1990) got 64.36 at 27.5 °C. A maximum of 31 eggs/female at 30 °C were obtained (Table 2). Hutchinson et al. (1990) got 19 and Naranjo (1993) got 34 eggs/female at 27.5 °C. These differences might be due to differences in diet, temperature, relative humidity and density of parasitoid. Hutchinson et al. (1980) and Naranjo (1993) used 10% honey solution while 100% pure natural honey was used in this study. Diluted honey was not used because it reduces the osmotic concentration and allows mold growth (Malik, 2000). Relative humidities were also different in this study from the studies of Hutchinson et al. (1990) and Naranjo (1993). Hutchinson et al. (1990) and Naranjo (1993) used high relative humidity (75%) for hot and humid areas like Sindh and Punjab (Pakistan), Arizona and California (USA). In this study high temperatures of 30 to 45 °C with constant low relative humidity (45%) was used like cotton areas of Balochistan (Pakistan) and New Mexico State (USA). Hutchinson et al. (1990) used 1:10 and Naranjo (1993) 1:25 female/host eggs while in this study the ratio was 1:80.

Life Table Parameters: To compare biotic potential under conditions of the experiment (Table 3), net reproductive rates (R₀) at 30 °C was 16.26 while Naranjo (1993) got 16.23 at 27.5 °C, intrinsic rate of increase (rₘ) was 0.30 at 30 °C while Naranjo (1993) got 0.31 at 27.5 °C, finite rate of increase (λ), 1.43 was maximum at 30 °C and minimum total time for a generation (T), 10.07 at 40 °C. From these results, 30 °C is the best temperature for rearing
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*T. bactrae* in the laboratory at 45% RH and 14/10 photoperiod. At 30 ºC about 33 generations of *T. bactrae* can be produced in a year. The result indicated that the above said combination of environmental conditions suits *T. bactrae* to establish in the cotton growing areas of Balochistan, Pakistan and New Mexico State, USA.

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References