Comparative life table analysis of chrysopids reared on *Phenacoccus solenopsis* Tinsley in laboratory

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ABSTRACT: Life tables of two chrysopid predators, viz., *Chrysoperla* sp. (carnea-group) and *Mallada desjardinsi* (Navas) on the invasive mealybug, *Phenacoccus solenopsis* (also reported as *P. solani*), were prepared in the laboratory to determine the efficacy of the predators as biocontrol agents of the pest. The rate of mortality ($q_x$) during 0-7 days age interval was higher in *Chrysoperla* sp. (carnea-group) (0.28) than in *M. desjardinsi* (0.22) while it was reverse during 70-77 days age interval when reared on *P. solenopsis*. In fact, $q_x$ was higher in *M. desjardinsi* (2.50) than in *Chrysoperla* sp. (carnea-group) (0.00). The rate of multiplication per day was 0.1159 and 0.1414 females / female for *Chrysoperla* sp. (carnea-group) and *M. desjardinsi*, respectively. The intrinsic rate of increase ($r_m$) was found to be 0.11 for both the predators. *Chrysoperla* sp. (carnea-group) population multiplied 62.80 times in a generation time of 35.72 days on the mealybug, whereas *M. desjardinsi* multiplied 67.12 times in a time period of 29.75 days. Life table assays help in estimating the total number of the natural enemies to be released in biological control programmes. This study would be of paramount importance in estimating the total number of the natural enemies to be released in biological control programmes against the mealybug, which is exotic.

KEY WORDS: Green lacewing, *Chrysoperla* sp. (carnea-group), *Mallada desjardinsi*, *Phenacoccus solenopsis*, life table, fecundity table, intrinsic growth rate

INTRODUCTION

The solanum mealybug, *Phenacoccus solenopsis* Tinsley, an exotic mealybug also reported as *P. solani* Ferris by some workers due to identity opinions in India, is widely distributed on ornamentals, tobacco, and many other plants in the USA, Central America, Latin America, Africa, Hawaiian Islands, Italy, Pakistan and Israel (Gautam, 2007; Gautam et al., 2007; Jhala et al., 2008). During 2005, the sudden appearance of this pest in cotton in some parts of Pakistan destroyed the entire crop within a few days. Control of this pest is gradually becoming difficult with decrease in the efficacy of insecticides and biological control appears to be a more suitable alternative (Gautam, 2008a).

Chrysopids, commonly termed as green lacewings, are known to feed on over 80 species of insects and 12 species of tetranychid mites (Kharizanov and Babrikova, 1978; Zia et al., 2008). The genus *Chrysoperla* is the dominant genus, which contains several important predatory biological control agents that can be used in augmentation programmes (Gautam, 1994; Venkatsan et al., 2008). The green lacewings, *Chrysoperla* (carnea-group) and *Mallada desjardinsi* (Navas) are well recognized and distributed in India, Europe, USSR, North America, South America, and Central Africa. Adults are free living and feed on honeydew and pollen. The larva, which is the predatory stage, feeds on the eggs of different insects and attacks a variety of soft bodied insects like aphids, cicadellids, psyllids, coccids, thrips (Ridgway and Murphy, 1984) and mites (Hagley and Miles, 1987).

Cohort life tables give comprehensive information on the survivorship, development and reproduction of a population and as such are fundamental to both theoretical and applied population ecology (Chi and Yang, 2003). The present study examined the biological attributes of these predators on the exotic mealybug, *P. solenopsis*, focusing on age specific survival $l_x$, age-specific fertility $m_x$ and life table of each predator species in the laboratory.
MATERIALS AND METHODS

The culture of *P. solenopsis* identified by Prof. S. Suresh, TNAU (Gautam et al., 2007) was established in the laboratory from cotton field collected specimens. Mealybug rearing was carried out in glass jars (15 cm x 10 cm) at 25±2°C and 65±5% RH following the method developed by Gautam (1994, 2008b). Black muslin cloth was used to cover the lid of the jars. Sprouted potato tubers were provided as food to the mealybug crawlers. The jar was checked daily for their development and any contamination. Fresh sprouted potatoes were provided to the new generation crawlers for their settlement and healthy colonization so as to get sufficient population.

The green lacewings present in the cotton ecosystem and interacting with the mealybug were collected, identified and maintained in the laboratory to obtain the stock culture. Larvae of *Chrysoperla sp.* (carnea-group) and *M. desjardinsi* were reared in individual vials (6.5 cm x 1.0 cm) at 25±2°C, 65±5% RH, and a photoperiod of 12L:12D (Gautam, 1994). In each vial, a single fertile egg of the predator was placed along with five crawler producing mealybugs as prey. The prey availability was monitored on alternate days and supplemented based on requirement till the larvae entered into cocoon formation. The emerging adults were collected daily and kept in the mating cage (25 cm x 25 cm), supplied with a diet mixture of protein: water: honey: yeast in the ratio of 1:1:1:1 (by volume) glued on the inner side of the rearing cage. Besides, 10% honey solution soaked in absorbent cotton was placed in a separate petri dish as additional food supplement (unpublished).

Fresh sprouted potatoes were provided to the new generation crawlers. The jar was checked daily for their development and any contamination. The adults (8-10 days old) used for the tests were sexed and maintained in the laboratory to obtain the stock culture. Larvae of *Chrysoperla sp.* (carnea-group) were reared in individual vials (6.5 cm x 1.0 cm) at 25±2°C, 65±5% RH, and a photoperiod of 12L:12D (Gautam, 1994). In each vial, a single fertile egg of the predator was placed along with five crawler producing mealybugs as prey. The prey availability was monitored on alternate days and supplemented based on requirement till the larvae entered into cocoon formation. The emerging adults were collected daily and kept in the mating cage (25 cm x 25 cm), supplied with a diet mixture of protein: water: honey: yeast in the ratio of 1:1:1:1 (by volume) glued on the inner side of the rearing cage. Besides, 10% honey solution soaked in absorbent cotton was placed in a separate petri dish as additional food supplement (unpublished).

The adults (8-10 days old) used for the tests were sexed following the morphological characters (Reddy et al., 2004; Sudhida et al., 2008). A total of 100 eggs laid by 10-day-old females were chosen as hatching gets affected with the advancement of age, environmental conditions and food availability (Gautam and Paul, 1988; Gautam, 1994; Adane and Gautam, 2003; Elsiddig et al., 2006a). After hatching, the larvae were fed on the mealybugs. Daily observations on survival and development were taken and recorded till adult emergence. Adults were pooled, provided with the adult food mentioned earlier and were subjected to longevity and fecundity studies.

The fecundity and mortality were recorded for each female till death of last female (Elsiddig et al., 2006b). The experiment was replicated five times wherein each replication had a set of 20 larvae placed in individual vials. The life tables were constructed as described by Andrewartha and Birch (1954), Southwood (1966) and Jervis et al. (2005) with the following columns:

<table>
<thead>
<tr>
<th>Life table</th>
<th>x</th>
<th>numbers dying during the age interval x</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lx</td>
<td>number of individuals alive between age x and x+1 = (Lx + Lx+1)/2</td>
</tr>
<tr>
<td></td>
<td>Tx</td>
<td>total number of individuals of X age units beyond the age x = Lx+Lx+x+1+Lx+2+......+Ln</td>
</tr>
<tr>
<td></td>
<td>ex</td>
<td>expectation of life remaining for individuals of age x = Tx / lx</td>
</tr>
</tbody>
</table>

Fecundity table

x = pivotal age for the class in units of time

l_x = numbers surviving at the beginning of age class x

m_x = number of female eggs laid by female of age class x, i.e., total number of eggs laid by the female/ sex ratio

l.m_x = total number of female eggs laid in age class x

The various parameters calculated were gross reproductive age (GRR=∑m_x), net reproductive age (R=∑m_x), approximate generation time (T=∑x e-r x.lxmx), innate capacity for increase (rc= logeRo/ T), intrinsic rate of natural increase (r=∑exLM_x), rate of increase (λ=exm), mean generation time (T= loge Rm_ / r_m) and doubling time (DT= loge2/ r_m) (Birch 1948, Jervis and Copland 1996).

RESULTS AND DISCUSSION

Mortality of immature stages

Results on stage-specific mortality of immature stages of *Chrysoperla sp.* (carnea-group) and *M. desjardinsi* [Table I(a) and (b)] revealed that the total immature mortality was less (48%) in case of *Chrysoperla sp.* (carnea-group) than *M. desjardinsi* (70%). This included egg, larval and cocoon mortality as well as malformed adults. However, larval mortality was almost similar as it ranged between 33 and 35 per cent. There was no egg mortality in any of the predators, as observed by earlier workers (Gautam and Paul, 1988; Gautam, 1994; Adane and Gautam, 2003). Elsiddig et al. (2006a) reported female lays maximum fertile eggs between 2nd to third week under optimum conditions. Our results indicated that both the predators were able to complete the life cycle on the mealybug indicating that the exotic mealybug is suitable for development. This finding is in conformity with Gautam (2007) who reported these predators feeding on the mealybug and supported by Vij and Gautam (2005). More pupal mortality (35%) was recorded in *M. desjardinsi* as compared to minimum (15%) in *Chrysoperla sp.* (carnea-group), which may be due to variations in food suitability. These predators could be effectively used for controlling the mealybug due to their potential.

Age-specific life tables

The data on the age-specific cohort life tables of *Chrysoperla sp.* (carnea-group) and *M. desjardinsi* on the
Life table of chrysopids on *Phenacoccus solenopsis*

mealybug (Table 1a, b and Fig. 1a, b) indicated similar patterns with regard to log survival and life expectancy. The total life span of the predator at the age interval of seven days was long (more than 80 days). The rate of mortality ($q_x$) indicated that during 0-7 days age interval, the mortality was higher in *Chrysoperla* sp. (carnea-group) (0.28) than in *M. desjardinsi* (0.22) when reared on *P. solenopsis*.

Survivorship curves (Fig. 1(a)) showed that the curves on two predators were more or less type I, which implies relatively lower rate of mortality during immature stages and a relatively high rate during the late 1 stage. The curve is relatively higher for *Chrysoperla* sp. (carnea-group) for the age interval of 0-7 to 28-35 days except during the remaining age, which is slightly higher for *M. desjardinsi*.

### Table 1(a). Life-table analysis of *Chrysoperla* sp. (carnea-group) on *P. solenopsis* in the laboratory

<table>
<thead>
<tr>
<th>Age intervals (days) ($x$)</th>
<th>Number surviving at start of age, $x$ ($L_x$)</th>
<th>Number dying during age interval, $x$ ($d_x$)</th>
<th>Rate of mortality during age interval, $x$ ($q_x$)</th>
<th>Number alive on average during age interval ($L_x$ to $L_{x+1}$) ($L_x$)</th>
<th>Individuals X time units ($T_x$)</th>
<th>Mean expectation of future life $x$: $T_x/L_x$ ($e_x$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-7</td>
<td>100.0</td>
<td>28.0</td>
<td>0.280</td>
<td>86.0</td>
<td>267.0</td>
<td>2.670</td>
</tr>
<tr>
<td>7-14</td>
<td>72.0</td>
<td>24.0</td>
<td>0.330</td>
<td>60.0</td>
<td>181.0</td>
<td>2.513</td>
</tr>
<tr>
<td>14-28</td>
<td>48.0</td>
<td>6.0</td>
<td>0.125</td>
<td>45.0</td>
<td>121.0</td>
<td>2.520</td>
</tr>
<tr>
<td>28-35</td>
<td>42.0</td>
<td>22.0</td>
<td>0.550</td>
<td>31.0</td>
<td>76.0</td>
<td>1.800</td>
</tr>
<tr>
<td>35-42</td>
<td>20.0</td>
<td>8.0</td>
<td>0.400</td>
<td>16.0</td>
<td>45.0</td>
<td>2.250</td>
</tr>
<tr>
<td>42-49</td>
<td>12.0</td>
<td>3.0</td>
<td>0.250</td>
<td>10.5</td>
<td>29.0</td>
<td>2.410</td>
</tr>
<tr>
<td>49-56</td>
<td>9.0</td>
<td>2.0</td>
<td>0.220</td>
<td>8.0</td>
<td>18.5</td>
<td>2.050</td>
</tr>
<tr>
<td>56-63</td>
<td>7.0</td>
<td>4.0</td>
<td>0.570</td>
<td>5.0</td>
<td>10.5</td>
<td>1.500</td>
</tr>
<tr>
<td>63-70</td>
<td>3.0</td>
<td>1.0</td>
<td>0.330</td>
<td>2.5</td>
<td>5.5</td>
<td>1.833</td>
</tr>
<tr>
<td>70-77</td>
<td>2.0</td>
<td>0.0</td>
<td>0.000</td>
<td>2.0</td>
<td>3.0</td>
<td>1.500</td>
</tr>
<tr>
<td>77-84</td>
<td>2.0</td>
<td>2.0</td>
<td>1.000</td>
<td>1.0</td>
<td>1.0</td>
<td>0.500</td>
</tr>
<tr>
<td>84-91</td>
<td>0.0</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Mortality of immature stages (out of 100 eggs) of *Chrysoperla* sp. (carnea-group) reared on *P. solenopsis*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg mortality</td>
<td>0</td>
</tr>
<tr>
<td>Larval mortality</td>
<td>33</td>
</tr>
<tr>
<td>Cocoon mortality</td>
<td>15</td>
</tr>
<tr>
<td>Malformed adults</td>
<td>6</td>
</tr>
<tr>
<td>Total immature mortality</td>
<td>48</td>
</tr>
</tbody>
</table>

In the sixth age interval, $m_x$ for *Chrysoperla* sp. (carnea-group) is higher (79.52) than that for *M. desjardinsi* (56.55). Higher $m_x$ shows more number of eggs being laid in this period in *Chrysoperla* sp. (carnea-group) than *M. desjardinsi* when fed on the mealybug diet and this is responsible for the higher GRR also. Better GRR could be attributed to more predation of the mealybug. According to Huffaker et al. (1976) and Iziquel and Le (1992), high $R_o$ means that these natural enemies can be effective against the pest. Theoretically the natural enemies all have the ability to reproduce faster and in doing so are able to exert some measure of control. The doubling time was shorter (4.90 days) for *M. desjardinsi* than for *Chrysoperla* sp. (carnea-group) (5.98 days). The shorter doubling time of *M. desjardinsi* might be due to the formation of the pupa within the trash carried by larvae, which saves the time for finding a pupation site.

### Age-specific fecundity tables

Results of the age-specific fecundity (Table 2a and b) revealed that the predators reared on the mealybug...
Table 1 (b). Life-table analysis of *M. desjardinsi* on *P. solenopsis* in the laboratory

<table>
<thead>
<tr>
<th>Age intervals (days)</th>
<th>Numbers surviving at start of age, <em>l</em>&lt;sub&gt;x&lt;/sub&gt;</th>
<th>Numbers dying during age interval, <em>d</em>&lt;sub&gt;x&lt;/sub&gt;</th>
<th>Rate of mortality during age interval, <em>q</em>&lt;sub&gt;x&lt;/sub&gt;</th>
<th>No. alive on average during age interval (<em>l</em>&lt;sub&gt;x&lt;/sub&gt; to <em>l</em>&lt;sub&gt;x+1&lt;/sub&gt;)</th>
<th>Individuals X time units</th>
<th>Mean expectation of future life X time units (<em>e</em>&lt;sub&gt;x&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7</td>
<td>100</td>
<td>22</td>
<td>0.22</td>
<td>89.00</td>
<td>252</td>
<td>2.52</td>
</tr>
<tr>
<td>7–14</td>
<td>78</td>
<td>27</td>
<td>0.35</td>
<td>64.50</td>
<td>163</td>
<td>2.09</td>
</tr>
<tr>
<td>14–28</td>
<td>51</td>
<td>8</td>
<td>0.16</td>
<td>47.00</td>
<td>98.5</td>
<td>1.87</td>
</tr>
<tr>
<td>28–35</td>
<td>43</td>
<td>33</td>
<td>0.77</td>
<td>26.50</td>
<td>51.5</td>
<td>1.20</td>
</tr>
<tr>
<td>35–42</td>
<td>10</td>
<td>7</td>
<td>0.7</td>
<td>6.50</td>
<td>25.00</td>
<td>2.50</td>
</tr>
<tr>
<td>42–49</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>18.50</td>
<td>6.17</td>
</tr>
<tr>
<td>49–56</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>15.50</td>
<td>5.17</td>
</tr>
<tr>
<td>56–63</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>12.50</td>
<td>4.17</td>
</tr>
<tr>
<td>63–70</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9.50</td>
<td>3.17</td>
</tr>
<tr>
<td>70–77</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>2.5</td>
<td>6.50</td>
<td>3.25</td>
</tr>
<tr>
<td>77–84</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4.00</td>
<td>2.00</td>
</tr>
<tr>
<td>84–91</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>1.5</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>91–98</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>98–105</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Mortality of immature stages (out of 100 eggs) of *M. desjardinsi* reared on *P. solenopsis*

<table>
<thead>
<tr>
<th>Mortality type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg mortality</td>
<td>0</td>
</tr>
<tr>
<td>Larval mortality</td>
<td>35</td>
</tr>
<tr>
<td>Cocoon mortality</td>
<td>35</td>
</tr>
<tr>
<td>Malformed adults</td>
<td>2</td>
</tr>
<tr>
<td>Total immature mortality</td>
<td>70</td>
</tr>
</tbody>
</table>

started egg laying during the 5<sup>th</sup> age interval of the lifecycle (28-35 days), which corresponds to the first week of adult emergence. The maximum female progeny (*m*<sub>x</sub>) (sex ratio considered 1:1.08 (M:F) for *Chrysoperla* sp. (carnea-group) and 1:1.9 for *M. desjardinsi*) was produced during the 6<sup>th</sup> age interval (35-42 days). The maximum female progeny was 56.55 and 75.92 eggs/female/age interval for *M. desjardinsi* and *Chrysoperla* sp. (carnea-group), respectively. Last surviving females from both stocks died during 63-70 days age interval, which is supported by several workers who reported varying longevity of these predators depending on adult food supplements and the diet intake during larval stage (Joshi and Yadav, 1990; Nehare et al., 2004; Senthilkumar and Gautam, 2007, 2008).

The data (Table 3a,b and 4) showed arbitrary *r*<sub>0</sub> values *r* =0.11 and 0.12 for the predators. The intrinsic rate of increase (*r*<sub>0</sub>) was found to be 0.11 for the two predators. According to these statistics, the populations of *Chrysoperla* sp. (carnea-group) multiplied 62.8 times in a generation time of 35.7 days on the mealybug whereas *M. desjardinsi* multiplied 67.12 times in a time period of 29.75 days. The rate of multiplication per day was 0.1159 and 0.1414 females /female for *Chrysoperla* sp. (carnea-group) and *M. desjardinsi*, respectively. Jervis et al. (2005) stated that prey species can influence the intrinsic rate of natural increase of predators. Lee and Shih (1981) estimated *r*<sub>0</sub>, *R*<sub>0</sub> and *T* for *M. desjardinsi* reared on *Pauropsylla psylliota* as 0.0964,181.5 and 54.2, respectively, but the estimates of Bakthavatsalam et al. (1994) for these statistics for *M. desjardinsi* reared on *C. cephalonica* eggs were different. Their estimates of *r*<sub>0</sub>, *R*<sub>0</sub> and *T* as 0.3329, 191.71 and 17.999 were too low and this period is not sufficient even to complete the developmental period of immature stages of the predator (development from egg to egg is not less than 25 days) and oviposition period of immature stages of the adults can be up to 36.9–46.6 days (Nehare et al., 2004; Joshi and Yadav, 1990).
Life table of chrysopids on *Phenacoccus solenopsis*

Fig. 1(a). Survivorship curve of *M. desjardinsi* and *Chrysoperla* sp. (*carnea*-group) reared on *P. solenopsis*

Fig. 1(b). Life expectancy of *M. de sjardinsi* and *Chrysoperla* sp. (*carnea*-group) reared on *P. solenopsis*
Table 2(a). Fecundity table of *Chrysoperla* sp. (*carnea*-group) reared on *P. solenopsis*

<table>
<thead>
<tr>
<th>Age intervals (days) (x)</th>
<th>Pivotal Age (Days) (x)</th>
<th>Biological attributes of <em>C. carnea</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(lx) Numbers</td>
</tr>
<tr>
<td>0-7</td>
<td>3.5</td>
<td>1</td>
</tr>
<tr>
<td>7-14</td>
<td>10.5</td>
<td>6</td>
</tr>
<tr>
<td>14-21</td>
<td>17.5</td>
<td>4</td>
</tr>
<tr>
<td>21-28</td>
<td>24.5</td>
<td>4</td>
</tr>
<tr>
<td>28-35</td>
<td>31.5</td>
<td>2</td>
</tr>
<tr>
<td>35-42</td>
<td>38.5</td>
<td>2</td>
</tr>
<tr>
<td>42-49</td>
<td>45.5</td>
<td>0</td>
</tr>
<tr>
<td>49-56</td>
<td>59.5</td>
<td>0</td>
</tr>
<tr>
<td>56-63</td>
<td>66.5</td>
<td>0</td>
</tr>
<tr>
<td>63-70</td>
<td>73.5</td>
<td>0</td>
</tr>
<tr>
<td>70-77</td>
<td>80.5</td>
<td>0</td>
</tr>
<tr>
<td>∑</td>
<td></td>
<td>123.13</td>
</tr>
</tbody>
</table>

Table 2(b). Fecundity table of *M. desjardinsi* reared on *P. solenopsis*

<table>
<thead>
<tr>
<th>Age intervals (days) (x)</th>
<th>Pivotal Age (Days) (x)</th>
<th>Biological attributes of <em>M. desjardinsi</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(lx) Numbers</td>
</tr>
<tr>
<td>0-7</td>
<td>3.5</td>
<td>12</td>
</tr>
<tr>
<td>7-14</td>
<td>10.5</td>
<td>8</td>
</tr>
<tr>
<td>14-21</td>
<td>17.5</td>
<td>7</td>
</tr>
<tr>
<td>21-28</td>
<td>24.5</td>
<td>2</td>
</tr>
<tr>
<td>28-35</td>
<td>31.5</td>
<td>2</td>
</tr>
<tr>
<td>35-42</td>
<td>38.5</td>
<td>1</td>
</tr>
<tr>
<td>42-49</td>
<td>45.5</td>
<td>0</td>
</tr>
<tr>
<td>49-56</td>
<td>59.5</td>
<td>0</td>
</tr>
<tr>
<td>56-63</td>
<td>66.5</td>
<td>0</td>
</tr>
<tr>
<td>63-70</td>
<td>73.5</td>
<td>0</td>
</tr>
<tr>
<td>70-77</td>
<td>80.5</td>
<td>0</td>
</tr>
<tr>
<td>∑</td>
<td></td>
<td>104.13</td>
</tr>
</tbody>
</table>

The comparison of life statistics of both the predators on the mealybug (Table 4) suggests that the gross reproductive rate (GRR) was 123.13 females/female/generation for *Chrysoperla* sp. (*carnea*-group) and 104.13 females/female/generation for *M. desjardinsi*. The net reproductive rate ($R_n$) was 62.80 and 67.12 females/female/generation for *Chrysoperla* sp. (*carnea*-group) and *M. desjardinsi*, respectively. Mean generation time ($T$) was 35.72 and 29.75 days for *Chrysoperla* sp. (*carnea*-group) and *M. desjardinsi*, respectively. This is in agreement with Adane and Gautam, (2003) and Elsiddig et al. (2006a).
Table 3(a). Estimation of intrinsic rate of natural increase ($r_m$) *Chrysoperla* sp. (*carnea*-group)

<table>
<thead>
<tr>
<th>Pivotal age (days) (x)</th>
<th>$l_x$</th>
<th>$e^{rx}l_x$ (r = 0.11)</th>
<th>$e^{rx}l_x$ (r = 0.12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5</td>
<td>13.75</td>
<td>0.4300</td>
<td>0.3138</td>
</tr>
<tr>
<td>38.5</td>
<td>37.96</td>
<td>0.5496</td>
<td>0.3740</td>
</tr>
<tr>
<td>45.5</td>
<td>6.10</td>
<td>0.0489</td>
<td>0.0259</td>
</tr>
<tr>
<td>59.5</td>
<td>3.16</td>
<td>0.004 (4.5418 x 10^-03)</td>
<td>0.0025 (2.5050 x 10^-03)</td>
</tr>
<tr>
<td>66.5</td>
<td>1.83</td>
<td>0.001 (1.217 x 10^-03)</td>
<td>0.0006 (6.29 x 10^-04)</td>
</tr>
</tbody>
</table>

Arbitrary values of ‘rm’ are 0.11 and 0.12

Difference

<table>
<thead>
<tr>
<th>Arbitrary ‘rm’</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>1.335</td>
<td>0.7618</td>
</tr>
<tr>
<td>1.336</td>
<td>0.5669</td>
</tr>
</tbody>
</table>

$\sum e^{rx}l_x = 1.335 - 0.7681 = 0.5669, \quad 1.335 - 1.00 = 0.335$

For 0.01, difference is 0.5669, difference will be 0.335 x 0.01 / 0.5669 = 0.0059 (5.909 x 10^-03); therefore, corrected ‘rm’ will be, 0.11 + 0.0059 = 0.1159

Table 3(b). Estimation of intrinsic rate of natural increase ($r_m$) *M. desjardinsi*

<table>
<thead>
<tr>
<th>Pivotal age (days) (x)</th>
<th>$l_x$</th>
<th>$e^{rx}l_x$ (r = 0.11)</th>
<th>$e^{rx}l_x$ (r = 0.12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5</td>
<td>18.61</td>
<td>0.5819</td>
<td>0.4247</td>
</tr>
<tr>
<td>38.5</td>
<td>37.32</td>
<td>0.5403</td>
<td>0.3677</td>
</tr>
<tr>
<td>45.5</td>
<td>7.96</td>
<td>0.05336</td>
<td>0.0338</td>
</tr>
<tr>
<td>59.5</td>
<td>1.16</td>
<td>0.0016 (1.667 x 10^-03)</td>
<td>0.0009 (9.195 x 10^-04)</td>
</tr>
<tr>
<td>66.5</td>
<td>2.07</td>
<td>0.0013 (1.3775 x 10^-03)</td>
<td>0.0007 (7.0843 x 10^-04)</td>
</tr>
</tbody>
</table>

Arbitrary values of ‘rm’ are 0.11 and 0.12

Difference

<table>
<thead>
<tr>
<th>Arbitrary ‘rm’</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>1.1785</td>
<td>0.8278</td>
</tr>
<tr>
<td>1.1785</td>
<td>0.3507</td>
</tr>
</tbody>
</table>

$\sum e^{rx}l_x = 1.1785 - 0.8278 = 0.3507, \quad 1.1785 - 1.00 = 0.1785$

For 0.01, difference is 0.5669, difference will be 0.1785 x 0.01 / 0.05669 = 0.03148; therefore, corrected ‘rm’ will be, 0.11 + 0.03148 = 0.14148

The significantly higher population parameters of the natural enemies, coupled with their shorter doubling times, mean that their population can grow faster and thus exert a controlling effect on pest numbers. Life table assays help in evaluating the future progeny and estimating the total number of the natural enemies to be released in biological control programmes. This study would be of paramount importance due to the fact that the mealybug host is exotic and no information with regard to these predators was available earlier.
Table 4. Life table statistics of the predators reared on *P. solenopsis*

<table>
<thead>
<tr>
<th>Life/ Fecundity table statistics</th>
<th>Formula</th>
<th>Predators</th>
<th>Chrysoperla sp. (carnea-group)</th>
<th>M. desjardinsi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross reproductive rate, GRR (females/female/generation)</td>
<td>$= \sum m_x$</td>
<td>123.13</td>
<td>104.13</td>
<td></td>
</tr>
<tr>
<td>Net reproductive rate, $R_o$ (females/female/generation)</td>
<td>$= \sum l_x m_x$</td>
<td>62.80</td>
<td>67.12</td>
<td></td>
</tr>
<tr>
<td>Approximate generation time, $T_c$ (days)</td>
<td>$= \frac{\sum x l_x m_x}{\sum l_x m_x}$</td>
<td>39.52</td>
<td>38.61</td>
<td></td>
</tr>
<tr>
<td>Innate capacity for increase, $r_i$ (females/female/day)</td>
<td>$= \log R_0$</td>
<td>0.105 = 0.11</td>
<td>0.108 = 0.11</td>
<td></td>
</tr>
<tr>
<td>Intrinsic rate of natural increase, $r_m$ (females/female/day)</td>
<td>$= \sum e^{r_i} l_x m_x$</td>
<td>0.1159</td>
<td>0.1414</td>
<td></td>
</tr>
<tr>
<td>Finite rate of increase, $\lambda$ (females/female/day)</td>
<td>$= e^{r_m}$</td>
<td>1.123</td>
<td>1.152</td>
<td></td>
</tr>
<tr>
<td>Mean generation time, $T$ (days)</td>
<td>$= \frac{\log R_0}{r_m}$</td>
<td>35.72</td>
<td>29.75</td>
<td></td>
</tr>
<tr>
<td>Doubling time, DT (days)</td>
<td>$= \frac{\log 2}{r_m}$</td>
<td>5.980</td>
<td>4.9020</td>
<td></td>
</tr>
</tbody>
</table>

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**REFERENCES**


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