Effect of Eggplant Varieties and Temperatures on Development and Fertility Life Tables of Chrysoperla carnea (Steph.) (Neuroptera: Chrysopidae)

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ABSTRACT

An experiment was conducted at the Experimental farm, Faculty of Agriculture, Mansoura University, to evaluate the effect of three eggplant (Solanum melongena L.) varieties (Classic, 0111 and Anan) on development and age-specific fertility life table of the green lacewing predator, Chrysoperla carnea (Steph.) that fed upon the cotton aphid, Aphis gossypii Glover reared at three various temperatures (20, 25 and 30 ± 1°C) and 60 ± 5% R.H. The results showed that a significant difference among the larval developmental times at the three temperature regimes within each eggplant variety. Similarly, the entire development (egg-adult) of C. carnea was significantly differed among host varieties, hosting aphids, within each temperature regime. For the life table parameters, the highest value of gross reproductive rate (GRR) for C. carnea was obtained when provisioned with aphids reared on Classic variety at 30°C. Moreover, the lowest mean generation time (T) and doubling time (DT) were achieved when the predator fed upon prey that reared on Anan and 0111 varieties, respectively. Further, the lowest and highest values of the net reproductive rate (Rn) were obtained when the predator provided with prey from Classic and 0111 varieties, respectively. Additionally, the highest value of the intrinsic rate of increase (rmax) was obtained when the A. gossypii fed on Classic variety at 30°C. It can be concluded that both eggplant varieties and temperature had significant effects on the developmental time and life table parameters of the predator. Hence, to optimize the mass rearing of A. gossypii as a preferred prey for C. carnea, Classic variety of eggplant has to be considered. As well, the range of temperature between 25-30°C would maximize the performance of predator under rearing conditions. This information on tritrophic interactions and subsequent life table estimates of C. carnea improves IPM programs of aphids.

Keywords: aphids, green lacewing, eggplant, temperature, tri-trophic interactions

INTRODUCTION

The green lacewing, Chrysoperla carnea (Steph.) (Neuroptera: Chrysopidae), is considered one of the most efficient predators that found in several corps around the world (Abdel-Salam, 1995). This predator is successfully employed to control population of aphid species in various agroecosystems (Easterbrook et al., 2006; Jokar and Zarabi, 2012). It is a successful predator in mass rearing programs especially in hot spot areas (e.g. greenhouses), because they have high consumption rate and searching activity than that of any other predator (Shaukat, 2018). To use these predators in biological control systems, it is required to understand their life table parameters before releasing them in the farms. C. carnea is a generalized predator that preyed a wide range of insects and appeared in the same time and space to feed upon populations of the prey. One of the main preys of the C. carnea is the cotton aphid, Aphis gossypii Glover (Hemiptera: Aphididae). A. gossypii is a cosmopolitan species highly distributed in tropical, subtropical and warm regions. It attacks several species host plants (Blackman and Eastop, 1984).

Life table parameters are fundamental component in ecological studies and general biology (Alasady et al., 2010; Jokar and Zarabi, 2012). Information regarding the growth, survival, and reproduction of an insect at various environmental conditions is fundamental to its management (Mandour, 2010). In addition, the prey that maximizes these biological parameters of a natural enemy has to be considered in future mass production programs. Population growth rate is a vital ecological parameter of the growth of an organism under given conditions that expressed as the intrinsic rate of increase, rmax (Southwood and Henderson, 2009). In biological control, it is not only helpful for comparing between beneficial species, but also for comparing the efficiency of a natural enemy at different environmental conditions (Orhanides and Gonzales, 1971; Nechols et al., 1989).

The influence of aphid species on biology and life parameters of chrysopid species is discussed by several authors (El-Serafi et al., 2000; Sattar et al., 2011; Jokar and Zarabi, 2012; Khuho et al., 2012; Hameed et al., 2013). The effect of temperature is also discussed in many researches works of temperature and varieties on the life table (Saljoqi et al., 2015; Pathan et al., 2016). Several studies in Brazil have evaluated the efficiency of lacewings in controlling aphids on grasses, such as Schizaphis graminum (Rondani) on sorghum (Fonseca et al., 2001; Figueira et al., 2002) and Rhopalosiphum maidis (Fitch) on corn (Maia et al., 2004). These studies have revealed that this predator can develop at temperatures ranging from 12 to 30°C. However, the current knowledge on the fertility life tables of predators with respect to host plant varieties and climatic conditions has not yet fully explored. Only, Farrokhli et al. (2017) investigated the effect of four host plants (peach, almond, pepper, and potato) on Myzus persicae (Sulzer) - C. carnea interactions. The importance of eggplant and the threat to its production has led to increased interest in alternative control methods. Integrated Pest Management (IPM) is an applicable alternative, depends on the complementary use of host plant, chemicals, and biocontrol agents. Several tactics, including host plant resistance (Reddy and Baskaran, 2006), C. carnea (Sharanabasava and Manjunatha, 1998a, b) and neem oil (Sharanabasava et al., 1999), have been proven to be effective in controlling spider mite populations on other vegetable crops. Therefore, this study aims to study the effect of three eggplant varieties (Classie, 0111 and Anan) and three temperature regimes on development and the life table parameters of C. carnea that preyed A. gossypii.

MATERIALS AND METHODS

1. Aphid culture

Seedlings of eggplant (Solanum melongena L.) varieties namely Classic, 0111 and Anan were sown in the greenhouse. The experimental area of the green house was 360 m² located at the Experimental field, Faculty of Agriculture, Mansoura University. The cotton aphid, Aphis gossypii Glover, was collected from heavily infested crops (squash and cucumber) growing at the Experimental farm. Once the seedlings inside the greenhouse reached 10 cm in height, the infestation was started using the nymphs of A. gossypii that transferred using hair brush to each host plant variety. These plants were watered and fertilized in the due time as required. After one month from plantation. These infestations were used either in rearing predators or in feeding experiments of predators.
2. Predator culture

Adult *C. carnea* were aspirated from ficus trees heavily infested with scale insects and mealybugs in the morning (7 AM). In the laboratory, these adults were divided into two transparent containers (15 cm diam × 30 cm ht) (ca. 20 adults each). The container tops were covered with black mesh screens (to serve as an oviposition substrate) fixed in place with a rubber band. Adult of lacewings in the containers were supplied every 48 hours with a fresh diet of honey and brewey's yeast (1:1) which offered on small pieces of sponge, and water on other sponges. These containers were kept at 25 ± 1.0 °C, 60.0 ± 5% RH, and a 14:10 (L:D) day length. Eggs holders that deposited on the mesh screens were removed daily using fine scissors into Petri-dishes and kept at 25 ± 1.0 °C, 60.0 ± 5% RH, and a 14:10 (L:D). Upon eclosion, first-instar was isolated in Petri-dishes (5.5 cm in diameter) to prevent cannibalism and fed upon *Sitotroga* eggs that supplied *ad libitum* and water on a small sponge, both refreshed every 24 h, until pupation occurred. Upon emergence, adults of *C. carnea* were placed in jars (ca. 20 per jar) to ensure mating and reared as described above.

3. Development

Development of *C. carnea* was monitored at three different temperatures (20, 25 and 30 ± 1 °C) with a relative humidity of 60.0 ± 5.0% and a photoperiod of 14 L:10 D. The aphids were provided as a diet in each trial for each predator species was collected from the three eggplant varieties. Upon eclosion, three groups of larvae, each consisted of 20 neonate larvae isolated in Petri-dishes (each 5.5 cm in diam.). As the predator’s instar grew, the aphid amount was gradually increased. Every day, the number of aphid consumed by each individual larva, died individuals were counted and recorded.

4. Fertility life tables

Life table parameters of *C. carnea* were estimated using a MATLAB computer program. This program is constructed based on Birch's method (1948). To estimate these parameters, the age-specific survival (Lx), age-specific fecundity (Mx), and female age (x) were used for the green lacewing which reared in each temperature on each plant variety. The parameters were as follows; Net reproductive rate (Ro= Σl *mx*), The generation time [T = (Σl *mx*)/(Σl *rm*)], the intrinsic rate of increase (r = In (R _n_ /T)), the finite rate of increase (λ= e^r ), and the growth reproductive rate [GRR = (2^zn*)] were calculated according to Carey (1993). The population doubling time (In 2/λ) is estimated according to Mackauer (1983).

5. Statistical analysis

One-way ANOVA was performed to analyze the data of developmental time of *C. carnea* using temperature and eggplant varieties as independent variable. In case of significant, the means were separated using Student-Newman-Keuls Test (Costat Software, 2004).

RESULTS AND DISCUSSION

Developmental time

At 30 °C, *A. gossypii*-eggplant varieties did affect the incubation period of *C. carnea* (F2,57 = 3.87, P = 0.03), but did not at 20 and 25 °C (F2,57 = 1.49, P = 0.23; and F2,57 = 1.22, P = 0.303, respectively). The larval development of *C. carnea* significantly differed among the three eggplant varieties, hosting aphid, at 20, 25, and 30 °C with the shortest duration for larvae fed aphids from Classic variety (F2,57 = 18.11, P < 0.001; F2,57 = 12.72, P < 0.001; and F2,57 = 12.54, P < 0.001, respectively). Aphid-eggplant varieties did not affect the duration of pupal stage of *C. carnea* at 20 °C (F2,57 = 0.93, P = 0.404), 25 °C (F2,57 = 1.18, P = 0.318), and 30 °C (F2,57 = 3.35, P = 0.043). In addition, the entire development (egg-adult) was significantly differed at 20 °C (F2,57 = 3.75, P = 0.03), 25 °C (F2,57 = 5.46, P < 0.001), and 30 °C (F2,57 = 14.24, P < 0.001). On the other hand, developmental periods of egg, larval, pupal, and the entire development decreased significantly as temperature increased within each host plant variety.

Saljoqi *et al.* (2015) estimated the developmental parameters of *C. carnea* under four different temperatures (20±1, 24±1, 28±1 and 32±1 °C). They noted that a significant difference in the developmental times of different life stages among the tested temperatures. The results also showed that the developmental times for larval instars of *C. carnea* were significantly decreased, when the temperature is increased. Similar results are also reported by Mannan *et al.* (1997). *Chrysoperla carnea* exhibited a shorter development when fed upon aphids which reared on the classic variety of eggplant than other the two eggplant varieties. This might be because the nutritional value of classic is high or chemical defense levels are low, or/and the physical structure of the host plant variety is not impeded the aphid feeding, resulting in aphids with bigger sizes (Walde 1995; Kos *et al.*, 2012). When aphids are exposed to increasing levels of toxicity, these prey are known to have negative impacts on their feeders (Birch *et al.*, 1999). There are various levels of toxicity sequestered by the herbivorous aphids, which create differing factors that could affect the overall tritrophic interaction between the host plants, aphids, and *C. carnea*, since *C. carnea* developing a preference for one host plant aphid species over others (Chaplin-Kramer *et al.*, 2011; Kos *et al.*, 2012). This is why plants can impact the biological characteristics and predation efficiency of a predator (Price *et al.*, 1980).

2. Fertility life table parameters

The optimum life table parameters of *C. carnea* were obtained using herbivorous aphids from eggplant variety of Classic variety at each of the three temperature tested. Further, the parameters obtained for *C. carnea* at 30 °C were better than the other two temperatures for the three varieties of eggplant (Table 2). As temperature increased, the values of T and DT were decreased on each of the three eggplant varieties, whereas the values of GRR, r, and λ were increased. In respect to Rn, as the temperature increased the value of Rn was increased on Classic and 0111 varieties but decreased on Anan variety.

At 20 °C, the survivorships (Lx) for female age intervals of *C. carnea* were 0.75, 0.6, and 0.7 on classic, 0111, and Anan varieties. At 25 °C were 0.75, 0.65 and 0.6 on classic, 0111, and Anan varieties. At 30°C (Lx) were 0.8, 0.85,0.8 respectively. This implies that most of eggs had developed to maturity using aphids from Classic variety especially at 20 and 25 °C, and mortality happened gradually during the ovipositional period. At 20 °C, the maximum oviposition rate per female per day (Mx) was 3.53 on 22th day, 3.3 on 9th day and 3.7 on 7th day on classic, 0111, and Anan varieties, respectively. At 25 °C, these values were 3.811 on 30th day, 3.23 on 34th day and 3.5 on (7 and 14th) day at the three tested varieties, respectively, and at 30 °C, these values were 4.94 on 18th day, 3.29 on 14th day and 3.43 on 16th day at the three host plant varieties respectively (Figures 1, 2, and 3).
Table 1. Developmental times (±SEM) (in days) of immature stages of *Chrysoperla carnea* when fed upon *Aphis gossypii* that reared on three eggplant varieties under three different temperatures.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Temperature (°C)</th>
<th>Incubation Period</th>
<th>1st Larval Instar</th>
<th>2nd Larval Instar</th>
<th>3rd Larval Instar</th>
<th>Total</th>
<th>Pupal Stage</th>
<th>Egg-Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic</td>
<td>20</td>
<td>5.1±0.16 a</td>
<td>4.4±0.16 a</td>
<td>3.7±0.16 a</td>
<td>4.57±0.16 a</td>
<td>12.73±0.27 a</td>
<td>14.4±0.71 a</td>
<td>32.17±0.98 a</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>3.6±0.16 b</td>
<td>3.7±0.16 b</td>
<td>3.25±0.16 b</td>
<td>3.88±0.21 b</td>
<td>10.83±0.28 b</td>
<td>9.5±0.32 b</td>
<td>23.93±0.47 b</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.5±0.16 c</td>
<td>3.2±0.16 c</td>
<td>2.9±0.16 c</td>
<td>3.33±0.15 c</td>
<td>9.3±0.25 c</td>
<td>6.83±0.19 c</td>
<td>19.07±0.49 c</td>
</tr>
<tr>
<td>0111</td>
<td>20</td>
<td>5.2±0.32 a</td>
<td>5.2±0.16 a</td>
<td>4.2±0.16 a</td>
<td>5.11±0.29 a</td>
<td>14.53±0.45 a</td>
<td>15.84±0.64 a</td>
<td>34.5±1.49 a</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>3.8±0.15 b</td>
<td>4.1±0.07 b</td>
<td>3.95±0.18 b</td>
<td>4.17±0.16 aAB</td>
<td>12.22±0.24 b</td>
<td>9.81±0.36 b</td>
<td>25.83±0.37 b</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>3.2±0.06 c</td>
<td>3.4±0.17 c</td>
<td>3.2±0.10 bAB</td>
<td>3.7±0.16 bAB</td>
<td>10.3±0.26 c</td>
<td>6.94±0.37 c</td>
<td>20.24±0.45 b</td>
</tr>
<tr>
<td>Anan</td>
<td>20</td>
<td>5.4±0.17 a</td>
<td>5.8±0.09 a</td>
<td>4.45±0.11 a</td>
<td>5.35±0.24 a</td>
<td>15.6±0.28 a</td>
<td>16.05±1.0 a</td>
<td>37.0±1.16 a</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>3.9±0.13 b</td>
<td>4.2±0.12 b</td>
<td>4.3±0.13 a</td>
<td>4.47±0.12 b</td>
<td>13±0.23 b</td>
<td>10.4±0.43 b</td>
<td>27.29±0.47 b</td>
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<tr>
<td></td>
<td>30</td>
<td>3.3±0.11 c</td>
<td>3.8±0.09 c</td>
<td>3.6±0.11 b</td>
<td>3.95±0.17 b</td>
<td>11.35±0.26 c</td>
<td>7.7±0.14 c</td>
<td>22.35±0.26 c</td>
</tr>
</tbody>
</table>

Means followed by the same small lowercase letters in a column among temperatures in each variety and the same uppercase capital letters among Varieties in each temperature are not significantly different at the 5% level of probability (Student-Newman-Keuls Test).

Table 2. Life table parameters of *Chrysoperla carnea* females at three constant temperatures when provided with herbivorous aphids reared from three eggplant varieties.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Temp. (°C)</th>
<th>Mean generation time (T) (in days)</th>
<th>Doubling time (DT) (in days)</th>
<th>Gross reproductive rate (GRR)</th>
<th>Net Reproductive rate (R₀)</th>
<th>Intrinsic rate of increase (λ₀)</th>
<th>Finite rate of increase (λ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic</td>
<td>20</td>
<td>53.75±18</td>
<td>9.93±05</td>
<td>59.25</td>
<td>42.6</td>
<td>0.06980</td>
<td>1.9723</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>41.45±28</td>
<td>7.27±19</td>
<td>77.84</td>
<td>52.0</td>
<td>0.09532</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>34.65±26</td>
<td>5.90±79</td>
<td>85.91</td>
<td>58.3</td>
<td>0.11732</td>
<td>1.1245</td>
</tr>
<tr>
<td>0111</td>
<td>20</td>
<td>55.11±58</td>
<td>11.41±69</td>
<td>49.60</td>
<td>28.4</td>
<td>0.06071</td>
<td>1.0626</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>42.6±35</td>
<td>8.41±59</td>
<td>64.88</td>
<td>33.6</td>
<td>0.08236</td>
<td>1.0858</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>34.49±06</td>
<td>6.23±54</td>
<td>68.33</td>
<td>46.3</td>
<td>0.11116</td>
<td>1.1176</td>
</tr>
<tr>
<td>Anan</td>
<td>20</td>
<td>58.62±07</td>
<td>10.96±77</td>
<td>61.98</td>
<td>40.7</td>
<td>0.06320</td>
<td>1.0652</td>
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<td>25</td>
<td>44.35±77</td>
<td>8.42±22</td>
<td>70.68</td>
<td>38.5</td>
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<td>1.0858</td>
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<tr>
<td></td>
<td>30</td>
<td>35.92±43</td>
<td>6.75±71</td>
<td>82.44</td>
<td>39.9</td>
<td>0.10258</td>
<td>1.108</td>
</tr>
</tbody>
</table>

Means followed by the same small lowercase letters in a column among temperatures in each variety and the same uppercase capital letters among Varieties in each temperature are not significantly different at the 5% level of probability (Student-Newman-Keuls Test).

Figure 1. Age-specific fecundity (Mₓ) and survivorship (Lₓ) of *Chrysoperla carnea* when fed upon *A. gossypii* that collected from Classic variety of eggplant at three constant temperatures.

Figure 2. Age-specific fecundity (Mₓ) and survivorship (Lₓ) of *Chrysoperla carnea* when fed upon *A. gossypii* that obtained from 0111 variety of eggplant at three constant temperatures.
Potato and peach, respectively. Moreover, it can be realized that the maximum and minimum values of gross reproductive rate (GRR) were obtained when the prey is rearing on 0111 and Classic varieties, respectively, indicating that the type of the variety can affect the life table parameters.

It can be concluded that both eggplant varieties and temperature had significant effects on the developmental time and life table parameters of the predator. Hence, to optimize the mass rearing of A. gossypii as a preferred prey for C. carnea, Classic variety of eggplant has to be considered. As well, the range of temperature between 25-30 °C would maximize the performance of predator under rearing conditions. This information on tritrophic interactions and subsequent life table estimates of C. carnea can optimize IPM programs.

REFERENCES


تأثر أصناف البذور ودرجات الحرارة على حياة لمفترس أسد المemploi

أجريت دراسة في مزرعة كلية الزراعة جامعة المنصورة لقياس تأثير ثلاثة أصناف من نبات البذور (الكلاسيكي، و111، غمان) على النمو ومقايسات جداول الحياة لمفترس أسد الم emploi، وذلك بتغذية على حبوب من القطن وثلاثة درجات حرارة مختلفة (20، 25 و30°C). أشار النتائج أن هناك اختلاف معنويًا خلال التطور النمو لمفترس على درجات الحرارة المختلفة لكل صنف من أصناف البذور. وكان هناك اختلاف معنويًا للأصناف الثلاثة العائلة المتنوعة في فترة التطور من البكاء إلى المرحلة الكامنة لمفترس داخل كل درجة حرارة، وبالتالي لمعاملات جدول الحياة فإنه لم يتغير معنويًة على قيمة معلم الكائن (GRR) مع درجة حرارة. كانت درجة حرارة 30°C كانت أعلى قيمة على من القطن على صنف الكلاسيكي على درجة حرارة 30°C. وكان متوسط فترة الجيل (T) والزمن اللازم لتصاعد الجيل (DT) كانت على صنف غمان و111 بالترتيب. والنتائج أيضاً أن أقل وأعلى قيمة معامل صافي الخصوبة (Rc) لمفترس كانت عندما تم تربية الفراولة (ببرد) من القطن على صنف غمان وكلاسيكي بالترتيب. بالإضافة إلى ذلك كانت أعلى قيمة لمعامل زيادة الطيني (r) كانت عند درجة حرارة 30°C على من القطن. ومن النتائج يمكن استنتاج أن كل من أصناف البذور ودرجات الحرارة لها تأثير معنوي على فترة النمو وجاودة الحياة للمفترس. ومن خلال النتائج يظهر أن تعليمات الانتقاء سهلة لمن القطن كفية مضادة لمفترس أسد الم emploi، فهناك استخدام صنف البذور كلاسيكي في عملية الانتقاء الكمية الممتدة. كما يصدر تربية الفراولة في الفراولة المحايدة لحل התداخل.

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