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Effect of temperature on reproductive parameters of *Aphidius colemani* and *Aphidius matricariae* (Hymenoptera: Braconidae) on *Aphis gossypii* (Hemiptera: Aphididae) in laboratory conditions

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Abstract: The aphid parasitoids, *Aphidius colemnai* Viereck and *A. matricariae* (Haliday) (Hymenoptera: Braconidae: Aphidiinae) have high potential as the most effective biological control agents for controlling the cotton aphid *Aphis gossypii* Glover (Hemiptera: Aphididae). In this investigation, the effect of five constant temperatures (10, 15, 20, 25 and 30 °C) on the reproductive parameters of the parasitoid was studied at 65 ± 5% relative humidity and a photoperiod of 16L: 8D hours. The newly laid (one-day old) eggs were reared on third instar nymphs of cotton aphid, and the pupal and adult stages of the parasitoids were recorded daily, until the last individual was found dead. The experiments were carried out with 15 replications at each temperature. The results revealed that the gross fecundity and fertility rates were significantly different at all tested temperatures for both species ($P < 0.05$). The highest value for the mean fertile eggs per day were recorded at 25 °C and 30 °C for *A. matricariae* and *A. colemani*, respetively. The results of this research can be used for establishing integrated pest management (IPM) strategies against *A. gossypii* in cucumber greenhouses.

Keywords: *Aphid parasitoids, Aphis gossypii*, reproductive parameters, temperatures

Introduction

Knowledge of the adaptation of insects and mites to climatic conditions plays a vital role to predict the timing of development, dormancy or migration (Nechols *et al.*, 1999), which are useful, too, in the selection of natural enemies so far as details of biological control are concerned. Temperature exerts strong effects on survival and developmental rates of immature stages (Gilbert and Raworth, 1996).

Reproductive parameters have several applications: analyzing population stability and structure, estimating extinction probabilities, predicting life history evolution, predicting outbreak in pest species, and examining the dynamics of colonizing or invading species (Vargas *et al.*, 1997).

Aphis gossypii Glover, (Hemiptera: Aphididae) is a cosmopolitan, polyphagous species widely distributed in tropical, subtropical and temperate regions (Kersting *et al*,. 1999). In many regions, such as Iran, the cotton aphid is an important pest of cucumber in greenhouses. They can cause direct damage, resulting from the search for food, that may induce plant deformation and indirect damage caused either by honeydew or by transmission of viruses (Perng, 2002). Furthermore, due to short developmental period and high fecundity, the

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cotton aphid has the potential for high population growth and rapid appearance of insecticide resistance. Therefore, it is a great interest to explore natural enemies that can be used in the biological control of this aphid species. Few aphelinid species (Hymenoptera: Aphelinidae) and all species of the subfamily Aphidiinae (Hymenoptera: Braconidae) are known to parasitize the various aphid species (Jones *et al.*, 2003). The two aphid parasitoids, *Aphidius colemani* Viereck and *A. matricariae* (Haliday) (Hymenoptera: Braconidae: Aphidiinae), have been considered as good agents for biological control of *A. gossypii* (Bennison, 1992; van Steenis and El- Khawass, 1995; Goh and Yoo, 1997) and their use in biological control of aphids was extensively reviewed (van Lentereen and Wolts, 1988; Goh and Yoo, 1997; Toussidou *et al.,* 1999). The present study was designed with the aim to evaluate the reproductive parameters of *A. colemani* and *A. matricariae* at five different constant temperatures that may be useful for the development of control models of cucumber aphid pests in greenhouses.

Materials and Methods

Insect culture

The cotton aphids and its parasitoids *A. colemani* and *A. matricariae* were obtained from cucumber greenhouses in Tehran, Iran in June, 2007. The cotton aphid was colonized on *Cucumis sativus* cv. Negin at 25 ± 1°C, 65 ± 5% R. H. and a photoperiod of 16L: 8D hours. Seedlings of *C. sativus* were grown to the 4-5 leaf stage in a mixture of sand (33%), clay (33%) and peat mass (33%) in 25 cm pots. The parasitoids were separately reared on *A. gossypii* in leaf cages (30 × 60 × 35 cm). Colonies of parasitoid wasps were replenished with field- collected individuals during spring and autumn. The aphids and parasitoids were reared on cucumber in the laboratory for at least three generations before using in experiments.

Reproductive Parameters

The effect of temperature on reproductive parameters of the parasitoid wasps was determined at five constant temperatures (10, 15, 20, 25 and 30 °C), relative humidity of 65 ± 5% and a photoperiod of 16L: 8D hours. In order to investigate on reproductive parameters, at least 100 third instar nymphs of cotton aphid were exposed to 10 mated female wasps in glass petri dishes (3 × 20 cm^2 containing cucumber leaf disc for less than 24 hours and then exposed aphids were kept in the experimental conditions. Hatching and successive growth stages were recorded daily until emergence of the next generation wasps. Thereafter, 15 newly emerged females were selected and introduced into Petri dishes containing 50 third instar nymphs of *A. gossypii* on cucumber leaf disks. After 24 h, wasps were transferred into new Petri dishes and the exposed aphids were kept in the laboratory conditions. This procedure continued until the death of all female wasps. The number of eggs laid by each female (15 replications at each temperature) was recorded every 24 h.

Data analysis

The effect of temperature on the different parameters was analyzed by one way ANOVA. The following reproduction parameters were calculated using formulae suggested by Carey (1993, 2001):

$$Gross\ \ fecundity\ rate = \sum_{x=\alpha}^{\beta} M_x$$

$$Gross\ \ fertility\ rate = \sum_{x=\alpha}^{\beta} h_x M_x$$

$$Net\ \ fecucdity\ rate = \sum_{x=\alpha}^{\beta} L_x M_x$$

$$Net\ \ fertility\ \ rate = \sum_{x=\alpha}^{\beta} L_x h_x M_x$$

$$Mean\ \ fertile\ eggs\ per\ day = \frac{\sum_{x=\alpha}^{\beta} h_x M_x}{(\varepsilon - \omega)}$$

The Jackknife technique (Maia *et al.*, 2000) was used to calculate the variance of the reproductive parameters. For each parameter, differences among reproduction parameters at different temperatures were determined by Student- Newman- Keuls (SNK) test.

Results

The parameters estimated for the function describing the relationship between temperature and reproductive parameter for *A. matricariae* are shown in Table 1.
The gross fecundity and fertility rates of *A. matricariae* differed significantly at different temperatures (F = 36.14; df = 4, 70; p < 0.01). The parasitoid wasp showed the highest fertility rate at 20 °C (149.23 ± 3.22) and the lowest was recorded at 30 °C (23.38 ± 1.08). There were no significant differences between the net fecundity and fertility rates at 10 and 15 °C (F = 21.36; df = 4, 70; p < 0.01). The maximum values of mean fertile eggs per day and mean eggs per day was recorded at 25 °C (F = 19.77; df = 4, 70; p < 0.0).

The reproductive parameters calculated for *A. colemani* at various temperatures are presented in Table 2. As the table indicates, all reproduction parameters except the mean fertile eggs per day and mean eggs per day, exhibited significant differences at various temperatures (F = 48.12; df = 4, 70; p < 0.01; F = 35.36; df = 4, 70; p < 0.01).According to the data, the maximum rates of gross and net fecundity and fertility were recorded at 25 °C. Whereas, the maximum mean fertile eggs per day and mean eggs per day were observed at 30°C (12.95 ± 0.66).

Table 1 Reproductive parameters of *Aphidius matricariae* at five constant temperatures.

Reproductive parameters	10 °C	15 °C	20 °C	25 °C	30 °C	F
Gross fecundity rate	70.67 ± 1.00^{c}	56.91 ± 0.88^{d}	149.23 ± 3.22^{a}	115.97 ± 2.11^{b}	23.38 ± 1.08^{e}	36.14
Gross fertility rate	70.67 ± 1.00^{c}	56.91 ± 0.88^{d}	149.23 ± 3.22^{a}	115.97 ± 2.11^{b}	23.38 ± 1.08^{e}	36.14
Net fecundity rate	46.00 ± 1.32^{c}	46.11 ± 1.02^{c}	134.32 ± 4.03^{a}	95.14 ± 1.67^{b}	6.70 ± 0.33^{d}	21.36
Net fertility rate	46.00 ± 1.32^{c}	46.11 ± 1.02^{c}	134.32 ± 4.03^{a}	95.14 ± 1.67^{b}	6.70 ± 0.33^{d}	21.36
Mean fertile eggs day	2.08 ± 0.09^{d}	2.19 ± 0.03^{d}	7.46 ± 0.99^{b}	10.54 ± 0.26^{a}	3.34 ± 0.06^{c}	19.77

Means in rows followed by the same letters are not significantly different by SNK multiple comparison (P < 0.05).

Table 2 Reproductive parameters of *Aphidius colemani* at five constant temperatures.

Reproductive parameters	10 °C	15 °C	20 °C	25 °C	30 °C	F
Gross fecundity rate	48.21 ± 0.16^{e}	60.38 ± 0.84^{d}	115.60 ± 1.96^{b}	139.50 ± 2.05^{a}	103.59 ± 3.01^{c}	48.32
Gross fertility rate	48.21 ± 0.16^{e}	60.38 ± 0.84^{d}	115.60 ± 1.96^{b}	139.50 ± 2.05^{a}	103.59 ± 3.01^{c}	48.32
Net fecundity rate	32.41 ± 0.11^{e}	42.85 ± 0.97^{d}	89.91 ± 1.65^{b}	123.55 ± 1.83^{a}	60.41 ± 1.79^{c}	35.36
Net fertility rate	48.21 ± 0.16^{e}	60.38 ± 0.84^{d}	115.60 ± 1.96^{b}	139.50 ± 2.05^{a}	103.59 ± 3.01^{c}	35.36
Mean fertile eggs per day	1.61 ± 0.02^{d}	3.01 ± 0.25^{c}	7.22 ± 1.02^{b}	10.73 ± 0.44^{a}	12.95 ± 0.66^{a}	23.02

Means in rows followed by the same letters are not significantly different by SNK multiple comparison (P < 0.05).

Discussion

Although insects are not subjected to constant or alternating temperatures in nature, controlled laboratory studies can provide a valuable insight into the population dynamics of aphids and their parasitoids (Kersting *et al*., 1999). The results reported here clearly show the effects of temperature on reproductive parameters of *A. matricariae* and *A. colemani*. Also, the previous studies on another aspects of these parasitoids showed that temperature and host species obviously affect their performance (Zamani *et al*., 2006; Jones *et al*., 2003; Vasquez *et al*., 2006; van Emden and Kifel, 2002; Pinto *et al*., 2004). No other study has been carried out about the effect of different constant temperatures on reproductive parameters of *A. matricariae* and *A. colemani* on cotton aphid in greenhouses.

Our results revealed that the optimum temperature for net and gross fecundity and fertility rates of *A. matricariae* and *A. colemani* were 20 °C and 25 °C, respectively. This result differs from 20 °C estimated for *A. colemani* that was recorded by Vasquez *et al*. (2006).

The data presented here provide fundamental information on the effect of temperature on reproductive parameters of *A. colemai* and *A. matricariae*. Our laboratory results suggested that these parasitoids could build up a large population before the first aphids were spotted. Therefore they have been considered as good candidates for biological control of aphids on cucumbers in greenhouses.

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تأثیر دماهای مختلف بر پارامترهای تولید مثل *Aphidius colemani* و *Aphidius matricariae* (Hymenoptera: Braconidae) روی *Aphis gossypii* (Hemiptera: Aphididae) در شرایط آزمایشگاهی

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چکیده: زنبورهای پارازیتوئید *Aphidius colemnai* Viereck (Hymenoptera: Braconidae: Aphidiinae) و*A. matricariae* (Haliday) به عنوان موثرترین عوامل کنترل بیولوژیک پتانسیل بالایی برای کنترل شته *Aphis gossypii* Glover (Hemiptera: Aphididae) دارند. در این تحقیق تأثیر پنج دمای مختلف (۱۰، ۱۵، ۲۰، ۲۵ و ۳۰ درجه سلسیوس) روی پارامترهای تولید مثل زنبورهای پارازیتوئید *A. colemani* و *A. matricariae* در شرایط رطوبت نسبی ۵ ± ۶۵ درصد و دوره نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی با ۲۰ تکرار انجام شد. برای تعیین پارامترهای تولیدمثلی، تخم‌های یک روزه زنبورهای پارازیتوئید روی پوره سن سوم شته *A. gossypii* پرورش داده شد و اطلاعات مربوط به مراحل مختلف رشدی تا مرگ آخرین فرد به‌طور روزانه ثبت گردید. نتایج نشان داد که نرخ های ناخالص باروری و بارآوری هر دو گونه زنبور به‌طور معنی‌داری در دماهای مختلف تغییر کرد ($P < 0.05$). بیشترین میزان میانگین تخم‌های بارور در روز برای زنبورهای *A. matricariae* و *A. colemani* به‌ترتیب در دماهای ۲۵ و ۳۰ درجه سلسیوس مشاهده شد. نتایج این تحقیق برای طراحی برنامه مدیریت تلفیقی(IPM) شته پنبه روی خیار در شرایط گلخانه کاربرد دارد.

واژگان کلیدی: پارازیتوئیدهای شته، *Aphis gossypii*، پارامترهای تولید مثل، دما