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Effects of temperature on population growth parameters of *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae) reared on *Planococcus citri* (Homoptera: Pseudococcidae)

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Abstract

The effect of temperature on the development, survival, fecundity and population growth parameters of *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) reared on *Planococcus citri* Risso (Hom.: Pseudococcidae) was determined at five constant temperatures (18, 22, 26, 30 and 32±1°C) in the laboratory conditions. Results showed a temperature – dependent development of the coccinellid. The mean total of immature period was estimated 76.6±0.9, 33.9±0.1, 25.8±0.1, 22.6±0.1 and 26.2±1.4 days at 18, 22, 26, 30 and 32°C, respectively. The highest and lowest values of R_0, r_m and λ were obtained 369.9±50.2 and 2.5±0.8 (female/female/generation), 0.07±0.01 and 0.02±0.01 (female/female/day) and 1.08±0.01 and 1.02±0.01 (day^{-1}) at 26 and 32°C, respectively. The lowest values of generation time (T) and doubling time (D_t) were calculated 42.2±0.9 and 8.9±0.5 days at 32 and 26°C, respectively. The lower and higher developmental threshold of total of immature period were obtained 11.5 and 25.5°C, respectively. The thermal requirement for completion of total of immature period of this predator were estimated 400 DD. These results showed that 26°C and /or adjacent temperature is most suitable for mass rearing of this predator.

Keywords development; life table; *Cryptolaemus montrouzieri*; degree day.

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1 Introduction

Citrus mealybugs are pests of many agricultural and horticultural crops. This species of mealybug is a diffuse pest of citrus, occurring primarily in older and shadowy brakes that planted on heavy soils. This pest injects toxic saliva into the tissue of host plant when extracting plant sap that result in defoliation, fruit discoloration, fruit splitting and fruit drop (Mani and Krishnamoorthy, 2007). Information is recorded on the occurrence and

distribution of mealybug species in the north of Iran. For example Maffi (1998) reported the presence of five species of mealybugs on citrus and other host plants, in which *Planococcus citri* (Risso) is known as dominant species (Abbasipour and Taghavi, 2007). Control of this pest with insecticides is difficult because of the mealybug be able to hide in bark sutures and other inaccessible places and to secrete thick layers of protective wax (Joyce et al., 2001). Biological control by predators is stated as most important method of controlling this species (Muştu et al., 2008; Simmonds et al., 2000). Mass rearing and release of parasitoids and predators are among the basic elements of biological control of mealybugs. Also protection of native natural enemies play determinant role in the success of any biological control program (Muştu et al., 2008). Predaceous coccinellids are important biological control agents of aphids, adelgids, mealybugs, scales, white flies, psyllids and mites. They were widely mentioned in important biological control programs and may be used as potential biocontrol agents for management of the pest population (Özgökçe et al., 2006). Important biological control agent of *P. citri* is the predator *Cryptolaemus montrouzieri* (Mulsant) (Frazer et al., 1981; Heidari and Copland, 1992; Hussey and Scopes, 1985). This predator is a native to Australia and is distributed throughout this country. *Cryptolaemus montrouzieri* is unable to overwinter in subtropical regions (Yigit and Canhilal, 1998). Therefore, its use as a biocontrol agent in most non-tropical countries is reliant upon mass rearing and augmentative release (Muştu et al., 2008). The larvae and adults of this predator consume great number of eggs and crawlers of mealybug (Ramesh Babu and Azam, 1987). Considerable researches has been conducted on *C. montrouzieri* reared on mealybugs by Ramesh Babu and Azam (1987), Mani and Krishnamoorthy (1990; 1997), Persad and Khan (2002), Lai (2005), Özgökçe et al. (2006), Mali and Kurtadiker (2008), Elsherif et al. (2010), Ghorbanian *et al.* (2011) and Siddhapara *et al.* (2013), including demographic data on development rates and fecundity. The effects of temperature on laboratory population of *C. montrouzieri* has been studied (Chen et al., 2000). Life tables and fertility tables are powerful tool for analyzing and understanding the effect of an external impact on the growth, survival, reproduction and rate of increase of an insect population (Wittmeyer and Courdon, 2001).

In this study, our purposes was to estimate the major life cycle parameters of *C. montrouzieri* reared on *P. citri* , including development, survival, longevity, reproduction, and population parameters in different constant temperature and also to determine the optimum temperature for development and reproduction, limitation of temperature which predator be able to act and also to estimate the thermal summation that predator require to complete its life cycle. Therefore, we will be able to improve knowledge for biological control of *P. citri* in citrus orchards.

2 Materials and Methods

2.1 Rearing prey and predator

An important requirement for a mass rearing substrate is a long shelf life, which obviated the regular provision of fresh food (Johnson and Giliomee, 2011). In this regard, squash and sprouting potatoes have been found to be suitable substrates for the mass rearing of mealybugs (Johnson and Giliomee, 2011; Meyerdirk et al., 1998; Peña, 2013). Seasonal shortages of produce and difficulties in maintaining of sprouts of potato threaten production and increase costs, wherea the squash is relatively inexpensive and available throughout year in supermarkets and this plant host produce large quantities of females of mealybug with a life cycle and reproductive potential (Serrano and Lapointe, 2002). Therefore, we chose the squash as the host plant substrate. The squashes were placed on cages in rearing chamber (26±2°C, 75±5%RH, L16:D8 h). Then, eggs, crawlers and adults of mealybug were transferred on squashes. After the squashes were infested adequately, predators were transferred to rearing chamber and were released on infested squashes. A primary colony of *C. montrouzieri* was provided from stock colony of Biological Control Researches Laboratory of Amol. Adults

and eggs of the predator that were used for the experiments were obtained after rearing three generations on *P. citri*.

2.2 Experiments

The experiments were conducted by same methods at five temperatures (18, 22, 26, 30 and 32°C), 75±5%RH, and a photoperiod of L16:D8 h. In this study, cohorts were established using 50 same-aged (with 24 hours maximum age). These eggs were put individually in sterilized Petri dishes (10 × 1.5 cm) with a soft brush. The emerged larvae were fed directly by sufficiency of different developmental stages of mealybugs. The presence of exuviae indicated that individuals have moulted. Developmental time and mortality rates were followed for each egg until adults emerge. The data from individual coccinellids were needed to determine rates of development, fecundity, the minimum and maximum temperature for development. After the adult emergence, to determine sex ratio, emerged adults were visually sexed by examination of the first pairs of legs; as in males these legs are reddish brown to yellow while in females they are black (Pang and Gordon 1986). all of adults were placed in a plastic cylindrical container (13 × 14 cm) together to mate for 24 hours. Then, 10 pairs of the adults were selected randomly and each pair was transferred to new sterilized Petri dish with excessive prey. The number of eggs produced by each female was recorded until the females died. The exact boundary between the Oviposition and Post-oviposition periods of female adults was determined when the oviposition of females reaches zero. Also 'The age of female in the first oviposition' term means the day that female adult oviposites for the first time in its longevity. Survival and fecundity data were recorded daily until the death of each individual.

2.3 Satatistical analysis

The obtained data for developmental stages of predator at five temperatures were analyzed by SAS software (Proc GLM, SAS Institute 2007). Tukey-HSD test was used for statistical comparisons. Age – specific survival and fertility tables were constructed using age (x), age specific survival rate (l_x), age – specific fecundity (m_x) (Birch, 1984). The net reproductive rate (R_0), mean generation time (T), doubling time (DT), finite rate of increase (λ) and the intrinsic rate of increase (r_m) were calculated as described by Southwood (1978). The values were then used to obtain initial estimate of (Carey, 2001), r_m=(Ln(r_0))/T.

The estimates of r_m were then used in the first iteration to solve the equation (Carey, 2001),

$\sum_{\alpha}^{\beta} e^{-rmx}.lxmx = 1$; x = 1, 2, 3…., days (1)

Where x = age interval in days, l_x = proportion of females alive at age x and m_x = mean number of crawlers produced by each female during the age interval x. Indexes of α and β means start and end of reproductive period, respectively. Iteration was continued until the left-hand side of the equation was within 0.0001 of the right-hand side.

Net reproductive rate (R_0) = $\sum_{\alpha}^{\beta} lx.mx$ (2)

Mean generation time (T) = $\ln R0 / rm$ (3)

Doubling time (DT) = $\ln 2 / rm$ (4)

Finite rate of increase (λ) = e^{rm} (5)

Jackknife technique (Maia et al., 2000; Zhang, 2010) was used for statistical comparison of population growth parameters.

Analysis of developmental rates of egg, larval, prepupa, pupa, total of immature and adult periods was via simple linear regression model. The inverse of developmental time of each life stage (1/days between molts)

was used to represent developmental rates. The developmental rates were used as the dependent variable and constatnt temperatures as the independent variable in a linear regression model designed to calculate certain developmental parameters (Lamana and Miller, 1998). The minimum temperature for development was then estimated by solving the regression equation 1/Time = 0 (equation 1).

$$Y = ax + b \quad (6)$$

Data obtained at 32°C were not used in these calculation as this temperature was stressful to the Coccinellid (see discussion). The number degree-day (D) required for development was calculating using D = 1/b, where b is the slope of regression of 1/Time on temperature (Campbell et al., 1974). These researchers designed a formula for calculation of degree-day that we used it:

$$^{\circ}D = \frac{1}{n}\sum(Ti - \theta)(ti) \quad (7)$$

n= number of studied temperature, T= experimental temperature, t= necessary time for development, θ= lower developmental threshold

The upper threshold temperature for optimum development was estimated by fitting a quadratic function of 1/Time (equation 2) on temperature to all the data, including 32°C, setting the first iteration derivative equal to zero and solving for X (temperature) (Pedigo, 2004).

$$Y = ax^2 + bx + c \quad (8)$$

3 Results

The results of this study showed that the duration of egg stage decreased as the temperature increased from 18 to 32°C (Table 1). However, there was no significant difference in the duration of egg stage between 26 and 30°C, 30 and 32°C. This trend was observed at developmental time of prepupa, but there was no significant difference in the duration of this stage between 22 and 26°C. The mean duration of first, second and total larval periods decreased as the temperature increased from 18 to 30°C, while the duration of these stages increased from 30 to 32°C (Table 1). This trend was observed at the duration of pupa, total of immature and pre-oviposition periods, as developmental time decreased from 18 to 30°C (Table 1). The developmental time of oviposition period and longevity of female adult increased, as the temperature increased from 18 to 26°C, while the duration of these periods decreased from 26 to 32°C. There was no significant difference in the duration of post-oviposition period at the different temperature (Table 1).

According to figure 1, the day that the maximum oviposition occurred at it, differed based on temperature, but the maximum oviposition occurred in early of oviposition period at all of temperatures. Survival was longest at 26°C (Fig. 1) and decreased rapidly as the temperature increased. The age – specific fecundity (m_x) reached to maximum its value in lower ages, as temperature increased but this trend was varied (Fig. 1). The age of female adults in the first oviposition decreased as the temperature increased except at 32°C (Table 1). The age – specific mortality rate of this predator was calculated in the different developmental stages at the five experimental temperatures (Table 2). This results indicated that the considerable mortality of cohort occurred during post-oviposition period except 32°C, as the maximum mortality occurred during total larval period (64%) at this temperature.

A life table was constructed and the prodictive population parameters estimated that the results of analysis is shown (Table 3). According to the results, there was significant difference between values of all calculated parameters at the different temperatures. The intrinsic rate of natural increase, r_m, reached a peak at 26°C. At 32°C it was the lowest.

The highest value of net reproductive rate (R_0) of *C. montrouzieri* was obtained at 22 and 26°C, that there was no significant difference between them. The R_0 of 2.52 at 32°C indicated that at this temperature there was

near to zero population growth . The mean generation time (T) was also longest at 18C and was lowest at 32°C. The doubling time (D_t) decreased from 18 to 26°C. However, there was no significant difference between the values of this parameter from 18 to 30°C. The value of this parameter increased again from 26 to 32°C. The finite rate of increase (λ) increased as the temperature increased from 18 to 26°C but again decreased from 26 to 32°C.

The estimated minimum threshold temperature for development from egg to the adult emergence (total of immature period) was 11.48°C, in addition, for all of the developmental stages separately were calculated (Table 4) which was also the base for degree day calculations. The maximum rate of development was at 25.5°C (Table 4), while the estimated number of D required to complete development from egg to adult was 400D, and for each stage was calculated (Table 4). The development from egg to adult was not completed at 33°C. Therefore, the upper threshold temperature for development was above 32°C. In addition, the survival and fecundity were the lowest at 32°C (Fig. 1).

4 Discussion

In a study, Ramesh Babu and Azam (1987) reported that at temperatures 20, 25 and 30°C, the mean egg stage, pupa and total of immature periods of *C. montrouzieri* were 6.2, 14.3 and 65.1 days, 6.1, 10.7 and 46.7 days, 3.0, 6.2 and 25.2 days, respectively when reared on *Maconellicoccus hirsutus* (Green). The findings of this study are close with the results of the aforesaid researchers. The observed difference must be due to different prey species and temperature. Mani and Krishnamoorthy (1990) reported that total larval period of *C. montrouzieri* was 17.6±0.9 days when reared on *Chloropulvinaria psidii* (Maskel) at temperatures of 25 - 27°C. In another study, these researchers, the egg stage of this predator calculated 4 – 5 days on *M. hirsutus* at 24 - 28°C. During another study, Mani and Krishnamoorthy (1997) reported that the pre-oviposition period of *C. montrouzieri* was 5 – 7 days when fed on the mealybugs at temperatures of 24 - 28°C.The negligible difference may be observed due to difference in experimental conditions or prey type. Lai (2005) reported that prepupal and pupal periods of *C. montrouzieri* were 4.9 and 12.9 days, 3.7 and 9.3 days at 20 and 28°C, respectively when reared on *M. hirsutus*. Mali and Kurtadiker (2008) reported that at temperatures 25 - 31°C average prepupal and pupal periods of this predator were 2.2±0.2 and 8.3±0.6 days, respectively when reared on *M. hirsutus*. The difference in results of this researchers comparing with results of this study could be due to different prey species and experimental temperature.. Persad and Khan (2002) reported that at laboratory conditions (27±3°C, 58±3%RH) the pre-ovipotion of *C. montrouzieri* was 7.0 days. Özgökçe *et al.* (2006) reported that the pre-oviposition, oviposition and post-oviposition periods of *C. montrouzieri* were 5.1±0.6, 109.3±14.6 and 5.4±0.7 days, respectively when reared on *P. citri* at 25±1°C. Ghorbanian *et al.* (2011) reported that at laboratory conditions (27±1°C, 65±5%RH) the pre-oviposition, oviposition and post-oviposition of this ladybird were 5.6±0.2, 70.4±2.9 and 2.9±0.4 days, respectively when reared on *P. citri*. Siddhapara *et al.* (2013) reported that the pre-oviposition and oviposition periods of *C. montrouzieri* were 5.7±1.1 and 41.0±2.3 days, respectively when fed on *Phenacoccus solenopsis* (Tinsley) at laboratory conditions (26.4±0.7°C, 52.6±2.5%RH). This difference must be due to different prey species or experimental conditions.

Persad and Khan (2002) reported that under laboratory conditions (27±3°C and 58±3%RH) average longevity of *C. montrouzieri* was 98.1±1.6 days on *M. hirsutus*. Özgökçe *et al.* (2006) reported that at laboratory conditions (25±1°C, 45±5%RH) the mean longevity of this predator was 120.8±17.4 days when reared on *P. citri*. Mali and Kurtadiker (2008) reported that the mean longevity of this ladybird was 74.7 days when reared on *M. hirsutus* at 25 - 31°C. Ghorbanian *et al.* (2011) reported that under laboratory conditions (27±1°C, 65±5%RH) average longevity of *C. montrouzieri* was 79.0±2.9 days when reared on *P. citri*.

Siddhapara *et al.* (2013) reported that the mean longevity of this predator was 51.9±2.7 days when fed on *P. solenopsis* at laboratory conditions (26.4±0.7°C, 52.6±2.5%RH). However, the present findings differ from the observations of the aforesaid researchers, that must be due to different prey species or experimental conditions.

Table 1 Development time (days) of *Cryptolaemus montrouzieri* reared on *P. citr*i at the different temperatures

Development stage	Mean±SE [min. – max.] (sample size)				
	18°C(50)	22°C(50)	26°C(50)	30°C(50)	32°C(50)
Egg	11.2±0.2*a*[10-1](29)	6 ±0.1*b*[5-7](43)	4.5±0.1*c*[4-5](43)	4.1±0.1*c*[4-5](36)	4±0.0*c*(9)
Larva I	9.3±0.3*a*[7-13](29)	4.2±0.1*b*[3-6](43)	3.2±0.1*c*[2-6](43)	2.6±0.1*c*[2-3](36)	3.4±0.6*bc*[2-8](9)
Larva II	6.9±0.2*a*[5-10](29)	2.9±0.1*bc*[1-4](43)	2.5±0.1*c*[1-4](43)	2±0.1*d*[1-3](36)	3±0.2*b*[2-4](9)
Larva III	8.1±0.2*a*[5-12](29)	3.7±0.1*b*[3-4](43)	2.6±0.1*c*[1-4](43)	2.8±0.1*c*[2-3](36)	2.3±0.5*c*[1-6](9)
Larva IV	16.7±0.6*a*[13-25](29)	4.7±0.1*c*[4-6](43)	3.2±0.1*d*[2-5](43)	3.4±0.1*d*[3-4](36)	6.3±0.3*b*[5-7](9)
Total larval period	41±0.9*a*[34-54](29)	15.7±0.1*b*[15-17](43)	11.4±0.1*c*[10-13](43)	10.8±0.1*c*[10-11](36)	15.1±1.3*b*[13-25](9)
Prepupa	6.3±0.3*a*[4-10](29)	3.7±0.1*b*[2-5](43)	3.5±0.1*b*[1-5](43)	2.5±0.1*c*[2-4](36)	1.9±0.1*c*[1-2](9)
Pupa	18.1±0.2*a*[16-20](29)	8.6±0.1*b*[8-9](43)	6.4±0.1*c*[5-7](43)	5.2±0.1*d*[5-6](36)	5.3±0.2*d*[5-6](9)
Total of immature	76.6±0.9*a*[68-92](29)	33.9±0.1*b*[32-36](43)	25.8±0.1*c*[24-28](43)	22.6±0.1*d*[22-24](36)	26.2±1.4*c*[24-37](9)
Pre-oviposition	11.3±1.9*a*[4-24](12)	4.6±0.7*b*[1-16](22)	0.6±0.3*c*[0-7](24)	0.5±0.2*c*[0-3](19)	5.8±2.9*b*[0-17](5)
Oviposition	96.9±13.2*bc*[22-168](12)	134.8±9.9*ab*[49-208](22)	177.8±13.6*a*[65-264](24)	165.2±13.9*a*[1-200](19)	22±6.4*c*[0-34](5)
Post-oviposition	22.6±5.2*a*[1-49](12)	23.2±4.4*a*[5-77](22)	11.6±2.6*a*[0-49](24)	13.8±3.4*a*[2-64](19)	8.6±4.1*a*[0-24](5)
Longevity	130.8±15.6*a*[42-188](12)	162.6±11.8*a*[73-237] (22)	190.1 ±15.3*a*[65-287](24)	179.5±12.7*a*[8-233] (19)	36.4±8.8*b*[4-57](5)
Total Life span	211.1±15.9*a*[123-280](12)	196.3±11.7*a*[107-270](22)	215.9±15.3*a*[90-313](24)	202.1±12.7*a*[31-255](19)	64.2±9.3*b*[30-81](5)
The age of female in the first oviposition	95.8±1.6*a*[87-107](12)	42.7±1.1*b*[40-52](22)	32.6±0.3*c*[32-39](24)	28.5±0.2*d*[28-31](19)	33±1*c*[30-34](4)

*The occurrence of different letters in the each row indicate significant difference ($p<0.01$)

Table 2 The age - specific mortality rate of developmental stages of *C. montrouzieri* reared on *P. citri* at different constant temperatures

Stage	The actual numbers of individual (Precentage)				
	18°C	22°C	26°C	30°C	32°C
Egg	0	0	7(14%)	6(12%)	1(2%)
Total larval period	19(38%)	6(12%)	0	8(16)%	32(64%)
Pupal period	1(2%)	0	0	0	0
Pre-oviposition	0	1(2%)	0	0	5(10%)
Oviposition	10(20%)	13(25%)	19(39%)	5(11%)	3(5%)
Post-oviposition	20(40%)	30(61%)	24(47%)	31(61%)	9(19%)

Table 3 Comparison of life table parameters of *C. montrouzieri* reared on *P. citri* at five different temperature

Parameter	Mean ± SE				
	18°C (n=12)	22°C (n=22)	26°C (n=24)	30°C (n=19)	32°C (n=10)
R_0 (f/f/generation)	26.3±6.8b*c*	324.9±31.7*a*	369.9±50.2*a*	100.5±23.5*b*	2.5±0.8*c*
R_m (f/f/day)	0.03±0.01*c*	0.06±0.01*a*	0.07±0.01*a*	0.04±0.01*b*	0.02±0.01*c*
T (days)	112.5±2.2*a*	84.6±2.9*b*	75.5±4.5*c*	87.4±3.9*b*	42.2±0.9*d*
D_t (days)	23.1±1.6*b*	10.1±0.2*b*	8.9±0.5*b*	13.1±0.8*b*	31.6±23.6*a*
λ ($days^{-1}$)	1.03±0.01*c*	1.07±0.01*a*	1.08±0.01*a*	1.05±0.01*b*	1.02±0.01*c*
Sex ratio (male:female)	1:1.14	1:0.95	1:1.26	1:0.89	1:0.72

*The occurrence of different letters in the each row indicate significant difference ($p<0.01$), n= number of ladybird used, f= female.

Table 4 Developmental thresholds (D_{th}) and degree – day requirements (DD) of life stages of *C. montrouzieri* reared on *P. citri*

Stage	D_{th}(°C)		Equation	R^2	Degree day
	Lower	Higher			
Incubation	10.3	31.3	$Y= -0.0009x^2+0.0563x-0.632$	0.9993	77.5
Larva I	12.4	23.9	$Y= -0.0054x^2+0.2583x-2.8174$	0.9117	45.1
Larva II	11.7	32.3	$Y= -0.0016x^2+0.1034x-1.2022$	0.9817	35.2
Larva III	10.4	27.5	$Y= -0.0027x^2+0.1486x-1.6968$	0.9801	47.4
Larva IV	13.1	27.4	$Y= -0.0027x^2+0.1477x-1.7405$	0.9942	49.5
Prepupa	8.6	19.6	$Y= -0.0005x^2+0.0196x-0.1736$	0.9261	55.3
Pupa	12.5	38.5	$Y= -0.0004x^2+0.0308x-0.3671$	0.9991	88.5
Preadult	11.5	25.5	$Y= -0.0002x^2+0.0102x-0.1192$	0.9914	400
Adult	14.7	24	$Y= -0.00005x^2-0.0024x+0.0365$	0.9895	1111.1

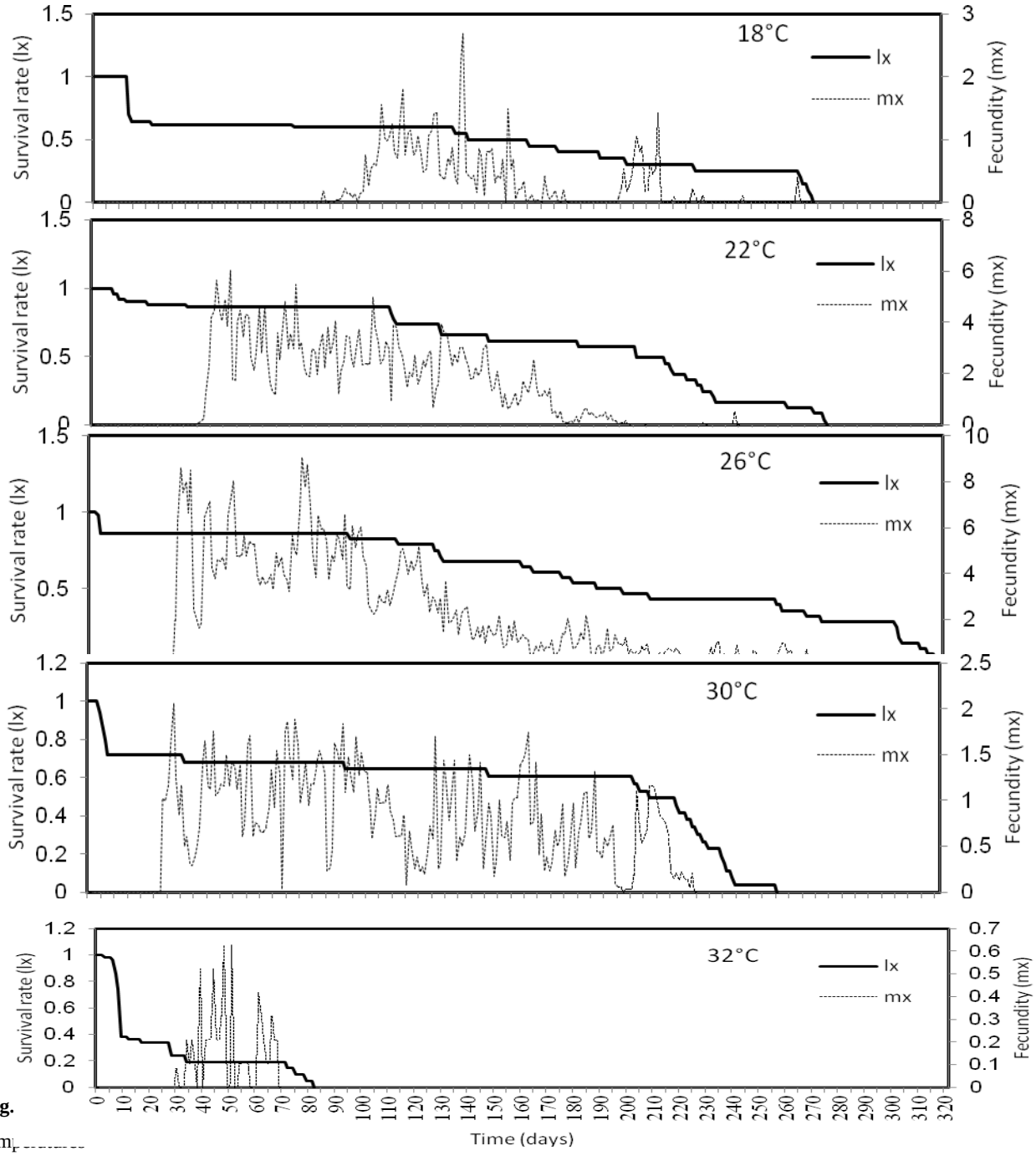

Fig.

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In specific environmental condition, it is practical to use the intrinsic rate of increase (r_m), an important demographic parameter, for predicting the potential of population growth of an animal (Ricklefs and Miller, 2000). Persad and Khan (2002) reported that the r_m of *C. montrouzieri* was 0.14 when reared on *M. hirsutus* at 27±3°C. Özgökçe *et al.* (2006) reported that under laboratory conditions (25±1°C, 45±5%RH) the r_m of this predator was 0.1±0.01 when fed on *P. citri*. Lai (2005) indicated that the highest intrinsic rate of increase (r_m) of *C. montrouzieri* was 0.052 at 28°C, comparing with 0.049 at 25°C and 0.035 at 20°C when reared on *M. hirsutus*. The results of this study correspond to results of this researcher, because show the value of r_m increase as temperature increase. Elsherif *et al.* (2010) stated that under laboratory conditions (28±2°C, 44±5%RH) the r_m of *C. montrouzieri* was 0.08 when fed on *Phenacoccus madeirensis*. Ghorbanian et al. (2011)

indicated that the r_m of this ladybird was 0.09±0.01 after rearing on *P. citri* at 27±1°C. The slightly lower value of r_m obtained in this study maybe due to the lower temperature (26°C) which this experiment was conducted. The r_m value is progressively applied for selecting hopeful biological control candidates based on their reproductive potential and in order to predict the outcome of pest – natural enemy intractions in biological control practices(Ghorbanian et al., 2011; citation from Jervis and Copland, 1996). Persad and Khan (2002) reported that the net reproductive rate (R_0), generation time (T), doubling time (D_t) and finite rate of increase (λ) of *C. montrouzieri* was 227.2 (female/female/generation), 40.1 and 5.1 days and 1.14 day^{-1}, respectively when reared on *M. hirsutus*. Özgökçe *et al.* (2006) stated that R_0, T, D_t and λ of this predator was 340.703(female/female/generation), 59.4 and 7.2 days and 1.101 day^{-1}, respectively when reared on *P. citri*. Elsherif *et al.* (2010) indicated that R_0, T, D_t and λ of this ladybird was 363.60 (female/female/generation), 76.7 and 9.01 days and 1.08 day^{-1}, respectively. Ghorbanian *et al.* (2011) reported that R_0, T, D_t and λ of *C. montrouzieri* was 125.3±5.1 (female/female/generation), 52.4±1.3 and 7.5±0.2 days and 1.1±0.01 day^{-1}, respectively. The obtained values of population growth parameters in this study are in close agreement with the findings of Elsherif *et al.* (2010). The negligible differences between the findings of this study and the results of other researchers may be observed due to difference in experimental conditions or prey type. In a study, Saljodi *et al.* (2014) evaluated the effect of temperature on life table parameters of *C. montrouzieri* fed on *P. solenopsis*. Their results showed that the values of T and D_t was decreased as temperature increased from 24 (91.2 and 13.1 days) to 32°C (57.0 and 8.1 days), respectively, while the values of R_0 and r_m was increased from 24 (124.1 and 0.02) to 28°C (203.1 and 0.04) and afterward, was decreased from 28 to 32°C (135.1 and 0.03), respectively. The findings of these researchers almost correspond with the results of the present study. Based on the data of life span and population growth parameters, 26°C and /or adjacent temperature was the most suitable temperature for mass rearing of this predator.

Chen et al. (2000) reported that the development threshold temperature and the effective accumulated temperature of *C. montrouzieri* generation were 11.9°C and 452.3 DD, respectively. This difference must be due to different prey species or temperature. The several studies were conducted related to effect of temperature on the development, fecundity and population growth parameters. For example, Atlihan and Chi (2008) reported that the thermal summation of *Scymnus subvillosus* (Goeze) were 77.5, 145.8 and 300 DD for egg, larval and total preadult stages, respectively when reared on *Hyalopterus pruni*. Also, Stathas *et al.* (2011) reported that the lower developmental threshold and thermal summation of *Harmonia axyridis* (Pallas) were 10.2°C and 47.8 DD, 11.17°C and 258.3 DD and 11.8°C and 357.1 DD for egg, total pre-immaginal periods and life cycle, respectively when reared on *Aphis fabae* (Scopoli).

Hodek and Honek (1996) believed that the thermal summation and thermal threshold of species is determined in their emergence, development and seasonal abundance in given habitats. Therefore, the thermal summation is useful tool for the prediction of the coccinellid's phenology. The temperature, photoperiod, food abundance and their interaction affect coccinellid's phenology. If the climate conditions in the release area aresimilar to desirable conditions that the biocontrol agent is adapted to it, then probability of its establishment increase. In addition, those parameters are useful tools for the prediction of the phenology of an insect pest and/ or its natural enemy, as coexistence of a predator and its prey in field condition is often desirable (Papanikolaou et al., 2013).

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