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Life Cycle and Population Growth Parameters of *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) Reared on *Planococcus citri* (Risso) (Hem.: Pseudococcidae) on Coleus

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ABSTRACT

Life cycle parameters were estimated for development, longevity, fecundity and oviposition period, of the mealybug predator, *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) fed on *Planococcus citri* (Risso) (Hem.: Pseudococcidae) reared on coleus plant, *Solenostemon scutellarioides* (L.) Codd.. All experiments were conducted in laboratory at temperature 27 ± 1ºC , 65 ± 5% RH and a photoperiod of 16:8 (L:D) hours. The incubation period, total larval period, pre-pupal and pupal period of *C. montrouzieri* were 3.945 ± 0.047, 12.993 ± 0.498, 2.432 ± 0.071 and 7.791 ± 0.103 days, respectively. The pre-oviposition, oviposition and post-oviposition period of *C. montrozieri* were 5.60 ± 0.187, 70.375 ± 2.920 and 2.875 ± 0.360 days, respectively. Population growth parameters calculated from the data are: the intrinsic rate of increase (r_m) = 0.092 ± 0.002, the finite rate of increase (λ), the net reproduction rate (R_0), the mean generation time (T) and the doubling time (DT) of *C. montrouzieri* were, 1.097 ± 0.002 d–1, 125.339 ± 5.136 females / female, 52.356 ± 1.306 days and 7.511 ± 0.161 days, respectively.

Keywords: Cryptolaemus montrouzieri, *Planococcus citri*, Coleus, life cycle, population growth parameters.

INTRODUCTION

Recently, the citrus mealybug, *Planococcus citri* (Risso) (Hem.: Pseudococcidae), has become a serious pest on ornamental plants grown in greenhouses as a permanent planting including the common bedding plant *Solenostemon scutellarioides* (L.) Codd. Permanent growing of ornamental plants permits the pests to easily overwinter. Mealybugs make injury on plant vigor and cause yellowing of the foliage. In some cases, the damage of the pest caused deformation and defoliation of the host plant (Hussey and Scopes, 1985).

The body of the mealy bugs is covered by wax, which protects it from contact with chemical sprays; thus, biological control seems to be a better method (Lester *et al.*,

2000) than insecticides. *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) is native to Australia, but now has a worldwide distribution because of its widespread use in biological control (Clausen, 1978). This predator is a very efficient natural enemy of the mealybugs, with both adults and larvae of these beetles eat the mealy bug completely (Clausen, 1978). The success control of the mealybug species by this predator are reported in many control programs (Bartlett, 1978). Substantial research has been conducted on *C. montrouzieri* feeding on mealybugs by Babu and Azam (1987), Mani and Krishnamoorthy (1998; 1999; 2001), Parabal and Balasubramanian (2000), Al-Khateeb and Raie (2001), including demographic data on development rates and fecundity by Persad and Khan (2002) and Özgokce *et al*. (2006). The predation rates of *C. montrouzieri* on *P. citri* on leaves of ornamental plant *S. scatellarioides* have been studied (Garcia and O'Neill 2000).

Age specific life and fertility tables have been effective tools for analyzing and realizing the impact of an external effect on the growth, survival, reproduction and intrinsic rate of increase of an insect population (Wittmeyer and Coudron, 2001). The main objective of this study was to estimate the major life cycle parameters of *C. montrozieri* feeding on *P.citri* on *S. scatellarioides* leaves, including survival, development, longevity, reproduction, and population growth parameters in an environment similar to a greenhouse, but precisely controlled to ensure accurate estimation.

MATERIAL AND METHODS

Culture of plants, pests and predators in the greenhouse

A greenhouse located in Abureihan University, maintained at 25±5 ºC, 30-90% RH, and a natural photoperiod, was used for the culture of host plants, mealybugs and lady beetles. The red variegated coleus, *Solenostemon scutellarioides* (L.) Codd [previously *Coleus blumei* (Bentham)], was used for this study because it is very susceptible to the citrus mealybug, and most greenhouse producers of coleus have need to control it. The red coleus plants used in current study were originally obtained from a greenhouse located in Tehran, during the winter of 2009.

Adults and nymphs of *P. citri* were collected from greenhouses located in University of Abureihan, Iran; during Feb. 2009. It was reared on *S. scutellarioides* for several generations on the coleus before use in the experiments.

Male and female adults of *C. montrouzieri* were obtained from Biological Control Research Department of Iranian Research Institute of Plant Protection, Tehran, at July, 2009. Adult and larval stages of the predator were reared on *P. citri* in the greenhouse.

Study of the biology and life table

The study of biology and life table of *C. montrouzieri*, was conducted in a growth chamber, at 27 ± 1ºC, 65 ± 5% RH and a photoperiod of 16:8 (L:D) hours. An age-specific life table is based on the fate of a real cohort; conveniently the members of a population belonging to a single generation (Southwood and Henderson 2000).

Computational methods for constructing life tables and estimating key reproductive parameters date back several decades (Birch 1948). In current study, cohorts were established using 100 same-aged (< 24 h old) eggs, taken from the colony of *C. montrouzieri*. These eggs were put individually in Petri dishes with an artist brush No. 000. Newly emerged larvae were individually transferred to coleus leaves infested by mealybug kept in the Petri dish for development until pupation. Development and survival of immature stages of *C. montrouzieri* were monitored at 8 h intervals and any developmental changes and mortality were recorded. All stages of the lady beetle were kept in Petri dishes (9 mm diameter) covered by a piece of fine net (2-mm mesh) to provide air ventilation. After the emergence of adult, 24 pair of the adults was selected and each pair transferred to a new Petri dish with excessive host. The Petri dishes were checked daily and the number of laid eggs was recorded. The pre-oviposition, oviposition and post-oviposition periods of the adult stage were recorded.

Statistical analysis

Age-specific survival and fertility tables were constructed using age (x), age specific survival rates (l_x), age specific fecundity (m_x) (Andrewartha and Brich, 1954). Several population growth parameters including net reproductive rate (R_0), finite rate of increase (λ), mean generation time (T), doubling time (DT), and intrinsic rate of increase (r_m) were estimated based on the recorded data in fertility and survival schedules (Carey, 2001):

Intrinsic rate of increase (r_m), from the solution of the Euler equation:

$$\sum_{\alpha}^{\beta}(e^{-r_m x}\, l_x\, m_x) = 1$$

Net reproductive rate $(R_0) = \sum_{á}^{â} l_x\, m_x$

Finite rate of increase $(\lambda) = e^{r_m}$

Mean generation time $(T) = \dfrac{l_n R_o}{r_m}$

Doubling time $(DT) = \dfrac{l_n 2}{r_m}$

Jackknife technique (Maia *et al*., 2000) was applied for estimating the variance for all stable population growth parameters. One-Way analysis of variance (ANOVA) was conducted to analyze differences in means of developmental time, longevity, and fecundity. The estimation of r_m, R_0, λ, T and DT was carried out by using Proc GLM of SAS statistical package (SAS Institute, 1988).

RESULTS AND DISCUSSION

Development times of immature stages (Table 1)

Egg development ranged from 3 to 5 days with an average of 3.945±0.047 days. Mani and Krishnamoorthy (2001) observed that the incubation period of *C. montrozieri* was 4 to 5 days on *Maconellicoccus hirsutus* at 24-28 ºC. This negligible difference may be observed due to difference in experimental condition or prey type.

The duration of the first, second, third, fourth instars and entire stage of *C. montrouzieri* larvae were 3.042±0.061, 2.397±0.078, 2.867±0.1, 4.686±0.097, and 12.993±0.498 days, respectively. However, Mani and Krishnamoorthy (1990) reported that larvae completed their development in 17.60±0.89 days when reared on eggs of *Chloropulvinaria psidii* (Maskel) at temperatures of 25-27ºC and 13.92 days when reared on *Chloropulvinaria polygonata* Cockerell (Mani and Krishnamoorthy, 1998). During another study, Mani and Krishnamoorthy (1999), reported that under laboratory condition at temperature 25±5°C, the average duration of the fourth instar and entire larval stage were 6.4 and 17.2 days, respectively, for *C. montrouzieri* reared on *Aleurodiecus disperses* Russell*.* Baskaran *et al.* (1999) reported that biology of *C. montrouzieri* was different on *P. citri* and *Doctylopious tomentasus* as completed incubation and larval period in 4.00 and 12.42 days on *P. citri* whereas completed 4.23 and 17.67 days when reared on *D. tomentasus*. Parabal and Balasubramanian (2000) reported that larvae completed their development in 13.92 days when reared on *M. hirsutus.* This difference must be due to different prey species or temperature.

The pre-pupal and pupal period of *C. montrouzieri* reared on *P. citri* under laboratory conditions was 2.432±0.071 and 7.791±0.103 days respectively. These findings are close with Babu and Azam (1987) reported that at temperatures of 20, 27.5 and 30 ºC, the average pupal period was 14.3, 6.1 and 6.2 days, respectively When reared on *M*. *hirsutus* Green of grapevine.

Table 1. Development time (means±SE) of *C. montrouzieri* fed by *P. citri* reared on *S. scutellarioides* at 27±1ºC

Incubation period (Mean±SE)	Larval instars duration (Mean ± SE)					Pre-pupal stage (Mean±SE)	Pupal stage (Mean±SE)	Total Immature stages (Mean±SE)
	1st	2nd	3rd	4th	Total			
3.945±0.047	3.042±0.061	2.397±0.078	2.867±0.1	4.686±0.097	12.993±0.498	2.432±0.071	7.791±0.103	27.162±0.6

Reproduction periods and fecundity parameters (Table 2)

The time between the date of adult emergence and first egg deposition was considered as pre-oviposition period. The pre-oviposition period of *C. montrouzieri* was 5.60±0.187 days. Mani and Krishnamoorthy (1997) observed that the pre-oviposition period was 5 to 7 days on mealybugs under natural conditions. Heidari and Copland (1999) reported that the pre-oviposition period of *C. montrouzieri* was 5.50±0.5 days on *P. viburni* at 26 ºC. Persad and Khan (2002) studied that under laboratory conditions (27±3 ºC and 58±3% relative humidity), the pre-oviposition period of *C. montrouzieri* was 7.00 days on *M. hirsutus* as a prey. Özgokce *et al*. (2006) observed that under lab temperature (25±1 ºC and 45±5% RH) the pre-oviposition period of *C. montrouzieri* was 2 to 8 days with an average of 5.1±0.64 days when reared on *P. citri* that are close with findings of these study.

Oviposition period was the duration between first and last egg laying and post-oviposition period was the duration between last egg laying until the death of adult. Oviposition period in the present study was 46 to 109 days with an average of 70.375±2.920 days and post-oviposition period was 2.875±0.360 days. Özgokce *et al*. (2006) reported that oviposition and post-oviposition period of *C. montrozieri* averaged 109.3±14.61 and 5.4±0.73 days respectively when provided the mealybug, *P. citri,* as prey and under lab temperature (25±1ºC and 45±5% RH).

The adult period of *C. montrouzieri* was 79.041±2.895 days. The mean number of eggs per female and mean eggs per day was 433.073±0.221 and 3.832±0.001 respectively.

Mani *et al*. (1997) and Al-Khateeb and Raie (2001) reported that adult period of *C. montrouzieri* was 52 to 80 and 70.6±6.7 days under natural conditions respectively. Mani *et al.* (1997) observed that adult period of *C. montrouzieri* was 121 to 138 days on *P. citri* as a prey under lab conditions. Persad and Khan (2002) reported that under laboratory conditions (27±3 ºC and 58±3% RH) average longevity and total fecundity of *C. montrouzieri* was 98.08±1.6 days and 118.68±1.82 eggs on *M. hirsutus.* Özgokce *et al*. (2006) reported that under laboratory conditions (25±1ºC and 45±5% RH) average longevity of *C. montrouzieri* was 39 to 159 days with an average of 120.8±17.4 days and the mean number of eggs per female and mean eggs per day was 805±92.07 and 7.0±0.58 respectively when reared on *P. citri*.

Table 2. Oviposition, longevity and fecundity parameters (mean±SE) of *C. montrouzieri* fed by *P. citri* reared on S. scutellarioides at 27±1ºC

Pre-oviposition period (days)	Ovipositio period (days)	Post- oviposition period (days)	Longevity (days)	Total fecundity (eggs/female)	Daily reproduction (eggs/female)
5.60±0.187	70.375±2.920	2.875±0.360	79.041±2.895	433.073±0.221	3.832±0.001

Life history parameters

In specific environmental conditions, it is practical to use the intrinsic rate of natural increase (r_m); an important demographic parameter, for predicting the potential of population growth of an animal (Ricklefs and Miller, 2000). The r_m of 0.092±0.002 for *C. montrouzieri* on *P. citri* (Table 3) was less than 0.135 measured for *C. montrouzieri* on *M. hirsutus* under similar laboratory conditions (27±3 ºC and 58±3% RH) (Persad and Khan 2002), and 0.098±0.003 for *C. montrouzieri* at lower laboratory conditions (25±1 ºC and 45±5% relative humidity) on *P. citri* reared on potato shoots as a host plant (Özgokce *et al*., 2006). 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 interactions in biological control practices (Jervis and Copland, 1996).

The r_m value of *C. montrouzieri* was lower than that of its prey, *P. citri* on coleus at 28ºC (0.14±0.005; Goldasteh *et al.,* 2009). Nevertheless, the voracious *C. montrouzieri* consistently suppressed populations of *P. citri*. A similar situation was observed by Persad and Khan (2002) and Özgokce *et al*. (2006). It is possible that under favorable conditions, *C. montrouzieri* can eliminate prey more rapidly than they can reproduce. The net reproductive rate (R_o) of *C. montrouzieri* was estimated as 125.339±5.136 females /female, generation time (*T*) 52.356±1.306 days, doubling time (*DT*) 7.511±0.161 days and finite rate of increase (λ) 1.097±0.002 day^{-1} (Table 3). Persad and Khan (2002) reported that the net reproductive rate (R_o), generation time (*T*), doubling time (*DT*) and finite rate of increase (λ) was 227.18 females / female, 40.13 and 5.13 days and 1.14 day^{-1} respectively when reared on *M. hirsutus*. Özgokce *et al*. (2006) observed that R_o, *T*, *DT* and λ was 340.703 females /female, 59.350 and 7.2 days and 1.101 day^{-1} respectively when reared on *P. citri*.

Table 3. Comparison of life history parameters of *C. montrouzieri* fed by *P. citri* reared on *S. scutellarioides* at 27±1ºC

R_0 females/female	r_m females/female/day	T days	D_t days	λ days^{-1}
125.339±5.136	0.092±0.002	52.356±1.306	7.511±0.161	1.097±0.002

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