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The Impact of Temperature on Biological and Life Table Parameters of *Cryptoleamus montrouzieri* Mulsant (Coleoptera: Coccinellidae) Fed on Cotton Mealy Bug, *Phenococcus solenopsis* Tinsley

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Abstract.- The impact of temperature on biological and life table parameters of *Cryptoleamus montrouzieri* Mulsant (Coleoptera: Coccinellidae) fed on cotton mealy bug were evaluated at three different temperatures *i.e.* 24, 28 and 32±1°C with 65 ±5% relative humidity and 16:8 (L:D) photoperiod under growth chamber. Results showed that rearing of *C. montrouzieri* at 28°C, resulted in optimum developmental and reproductive characteristics and life table parameters. It was inferred from the present findings that rapid development of *C. montrouzieri* at 32°C can be useful if quick development is desired in laboratories. At 28°C, the recorded total female fecundity was highest, as females tend to oviposit a total of 235.1±0.08 eggs per female. Highest survival rate (92%) from egg to adult emergence was recorded at 28°C as compared to all other temperatures. Highest survivorship rate (Lx) (0.905), maximum oviposition rate per female per day (Mx) (235.1) and highest values of R_0 (203.1), r_m (0.0374) were obtained by rearing of *C. montrouzieri* at 28°C. The longest mean generation time (T) (91.2) and doubling time (DT) (13.11) of *C. montrouzieri* was achieved by rearing at 24 °C, while highest death rate (Dx) (24.60) was recorded at 32°C.

Key words: *Cryptoleamus montrouzieri,* cotton mealy bug, temperature, biological characteristic, life table parameters.

INTRODUCTION

Cotton mealy bug, *Phenococcus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is an emerging threat to the cotton crop (Gautam, 1996). The cotton mealy bug appeared as a major pest of commercial cotton (Tanwar *et al*., 2011; Hameed *et al*., 2013) and yield losses due to this pest were estimated up to 50% (Joshi *et al*., 2010). The female of cotton mealy bug is parthenogenetic and can produce between 128-812 crawlers (Vennila *et al*., 2010). It is an invasive polyphagous pest in Pakistan (Abbas *et al*., 2005) and it was first reported in 2005 damaging cotton crop and other plants at Agriculture Research Station, Vehari. In 2006-07 about 12 and 40% of the crop was damaged by mealy bug and it spread almost throughout Pakistan and became a major pest of cotton in Southern Punjab, which resulted in huge economic loss of 3.1 million bales (Kakakhel, 2007; Abdullah, 2009; Hameed *et al*., 2012). Its potential distribution expanded dramatically, indicating that this presented a great economic threat to cotton in Asia including Pakistan and other parts of the world (Wang *et al*., 2010).

Cryptoleamus montrouzieri Mulsant species of Coccinellidae (Coleoptera) native to Australia and commonly known as mealy bug destroyer is a small blackish beetle highly voracious predator of mealy bug in both immature and adult stages. It can be easily mass reared under laboratory conditions. Mass rearing techniques were developed in USA for releases in groves during warmer months (Luck and Forster, 2003). Since that time, it has been introduced into 50 countries of the world for control of several mealy bug species (Olivero *et al*., 2003; Garcia *et al*., 2009).

In Pakistan *C. montrouzieri* was first imported in December, 2007 through Center for Agricultural Biosciences International (CABI), under the project "Mass production of native and introduced predators of mealy bug and other cotton pests (Mahmood, 2008). The initial results of trials were quite promising and it was hoped that the

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establishment of this predator will greatly contribute to the management of cotton mealy bug (Aijun *et al*., 2004). In Pakistan no such information are available on the biology of *C. montrouzieri*, therefore it was thought imperative to investigate its biology and potential.

The activities of insects are affected by change in environmental conditions. Temperature is one of the major key factors in environment that influences the rate of particular insect species and can also effect its seasonal population (Babu and Azam, 1987a). The study of relationship between temperature and developmental rate therefore, becomes an important aspect of ecological studies and is necessary for the development of pest management strategies (Kitching, 1977).

Considering the recent introduction of *C. montrouzieri* into Pakistan, the objective of this work was to study the impact of temperature on its biological and life table parameters. This information could be usefully employed for mass and quality production of *C. montrouzieri* under local environmental conditions.

MATERIALS AND METHODS

Maintenance of cotton mealy bug, P. solenopsis *culture*

The culture of cotton mealy bug was reared on different vegetables *i.e.,* lady's finger, potato sprouts and also on pumpkin, under controlled conditions of 30±1°C in insect rearing rooms in wooden cages of 4′x6′ size and also in plastic jars of different sizes. Fresh vegetables were provided every morning to maintain continuous culture of cotton mealy bug throughout the whole experimental duration. The mealy bug colonies were renewed by replacing the older vegetables with new infested.

Rearing of predator, Cryptoleamus montrouzieri

The adults were reared under controlled conditions of (28±1°C) in insect rearing rooms. The adults were kept in plastic container of 10″ x 15″ size and diets were provided on potato leaves, fresh okra and pumpkin infested with *P. solenopsis* crawlers every morning. The diets were replaced daily with new crawlers. The plastic containers were covered with fine muslin cloth at the top. Leaves of potatoes, okra and pumpkin were provided as an oviposition substrate for the collection of eggs. The *C. montrouzieri* adults usually gave eggs singly and the eggs were collected daily early in the morning during the time of observations. The eggs were kept in another plastic container of 3″x4″ size and moist tissue paper was provided at the bottom to avoid desiccation. Upon hatching, the larvae were fed mealy bug crawlers in the same container till adult emergence. The adults were shifted to stock colony to maintain the culture continuously. The rearing jars were checked every morning for collection of eggs. Eggs were collected with camel hair brush and also on respective vegetable leaves. The stock culture of both *C. montrouzieri* and its host *P. solenopsis* was maintained throughout the experimental period.

Developmental durations of immature stages and survival rate of Cryptoleamus montrouzieri *fed on cotton mealy bug*

Different sets of experiments were conducted on developmental durations and percent survival of immature stages of *C. montrouzieri* at three different temperatures ***i.e.***, 24±1, 28±1 and 32±1°C with 65±5% relative humidity and 16:8 (L:D) photoperiod under growth chamber. Freshly laid eggs of *C. montrouzieri* were collected from already established culture at Insectary/biological control laboratories. A total of 100 eggs were separated under binocular microscope and 10 eggs per Petri dish were kept with 10 replications. Moist filter paper was placed at the bottom to avoid desiccation. The Petri dishes were kept in growth chamber at each required temperature. Data on developmental durations, incubation period and percent hatching of eggs were daily recorded.

Upon hatching, 50 newly emerged first instar grubs were transferred with camel hair brush singly to other plastic vials of 3″ x 6″ size covered with muslin cloth at the top and were kept at three different temperatures *i.e.* 24±1, 28±1 and 32±1°C. *P. solenopsis* crawlers were provided daily as diet by replacing the old one, every morning. The predators were observed for molting frequently and the durations between each molting were recorded.

Number of larval instars and time of each instar and their survival rate was recorded. The procedure was followed till predators pupated. Pupae were collected, counted and kept in other plastic vials covered with muslin cloth at the top and were kept in growth chamber at three constant temperatures. The data was recorded on the incubation period, survival rate, molting time, developmental duration, pre-pupal and pupal period, total duration from egg to adult emergence and survival rate from egg to adult emergence. The data collected was statistically analyzed and used for construction of life table.

Biological parameters of adult C. montrouzieri *fed on cotton mealy bug*

The adult biology of *C. montrouzieri* was studied at three different temperatures *i.e.,* 24±1, 28±1 and 32±1°C with 65±5% Relative Humidity and 16:8 (L:D) photoperiod under growth chamber. One day old male and females were paired and kept in plastic vials of 4″x12″ size. Vegetables, twigs and leaves infested with mealy bug crawlers were provided inside the jars for feeding. Jars were covered by muslin cloth at the top and were kept in growth chamber at required constant temperature. The experiment was replicated 20 times. The adults were observed daily to record pre-oviposition, oviposition and post oviposition periods.

During ovi-position period the eggs laid by each female were collected daily during the time of observations every morning, and kept in plastic vials for hatching under the same temperature. Deposited eggs from each pair were monitored daily and kept for hatching separately. Upon hatching grubs were separated and provided crawlers as a food. The crawlers were replaced with fresh food daily till pupation and adult emergence. The observations were recorded on pre-oviposition period, oviposition period, post-oviposition period, fecundity, and male and female longevity. The experiments were continued till the death of all pairs at each respective temperature under growth chamber. Basic data was used in the construction of life table.

The life tables of *C. montrouzieri* were constructed at three constant temperatures *i.e.*, 24±1, 28±1 and 32±1°C from already collected data with the following parameters:

Lx (survivorship of female from the beginning of age interval T) = Total adults emerged/ total number of eggs.

T is mean generation time from egg to adult emergence, calculated in days.

Dx is mortality rate, the number of individual dying during the age interval T

R_o (the net reproductive rate, the number of female offspring that left during her lifetime by one female) = Σ Lx.Mx

Mx is mean fecundity rate which is total eggs produced per female at age interval T.

r_m (the maximum population growth, the intrinsic rate of increase) = $\log_e$ Ro/T

DT (oubling time, the number of days required by a population to double) = $\log_e 2/ r_m$

RESULTS AND DISCUSSION

Developmental durations of immature stages and survival rate of C. montrouzieri *fed on cotton mealy bug at different temperatures*

Results of the comparative study to evaluate effective rearing temperature for *C. montrouzieri* on the developmental parameters at eggs, larvae and pupae stages are shown in Table I. It revealed significant differences among the tested rearing temperatures. The results indicated that incubation periods 4.16±0.24, 3.26±0.18 and 2.84±0.14 days were recorded at 24, 28 and 32°C, respectively. Same trend of decrease in the incubation period of *Chrysoperla carnea* with the increase of temperature was also recorded by Nadeem *et al*. (2012). They recorded 10.3±0.31, 5.9±0.39, 4.5±0.57, 4.0±0.00, 4.0±0.01 days incubation period at 20±1, 25±1, 28±1, 31±1 and 35±1°C, respectively. Oncuer and Koldas (1981) also supported the present findings. They reported same trend of decrease in the incubation period of *C. montrouzieri* with the progressive increased temperature.

The insect passed through four larval instars before transforming into pupal stage.

The results showed that with increasing temperature developmental duration for different instars of *C. montrouzieri* significantly decreased (Table I). Previous workers reported different developmental periods for different instars. Gosalwad *et al.* (2009) reported developmental

Table I.- Developmental periods in days (Mean±SE) of *C. montrouzieri* fed on *P. solenopsis* at three different constant temperatures.

Developmental duration	Temperature (°C)		
	24±1	28±1	32±1
Incubation period	4.16±0.24a	3.26±0.18b	2.84±0.14b
1st instar	3.31±0.19a	2.63±0.14b	2.92±0.18ab
2nd instar	2.63±0.14a	2.56±0.19a	2.73±0.20a
3rd instar	2.88±0.21a	2.70±0.16a	1.99±0.17b
4th instar	4.08±0.31a	4.15±0.24a	2.80±0.27b
Total larval d	12.7±0.91a	11.9±0.68a	8.56±0.84b
Pre-pupal	1.21±0.10a	1.14±0.08a	0.66±0.07b
Pupal	5.47±0.44a	5.28±0.37a	3.84±0.41b
Total duration from egg to adult emergence	19.38±0.04a	18.32±0.03b	13.06±0.04c

Means followed by same letters (rows wise) are non significant at P≤ 0.05.

periods for 1st, 2nd, 3rd and 4th instars of *C. montrouzieri* as 5.14, 3.88, 6.84 and 8.04 days, respectively on *M. hirsutus* and 5.52, 4.58, 7.42 and 8.20 days on *P. solenopsis*. Total period from egg to adult emergence was higher at 24°C and decreased significantly with increasing temperatures. Some previous workers also reported same trend of developmental durations (days) in relation to different temperatures (Al-Humiari *et al*., 2011; Solangi *et al*., 2013).

Total larval developmental at 24°C lasted 12.7±0.91 days and this duration decreased with the increase of temperature. (Table I). Jalali *et al.* (1999) supported the same trend for *C. montrouzieri*. Same trend of decrease in the pre-pupal and pupal developmental durations with increase of temperature was also observed. The developmental traits of *C. montrouzieri*, in our findings, gradually decreased with the increase in rearing temperature which is in agreement with the work reported by Mali and Jeevan (2008), who studied the biological parameters of *C. montrouzieri* feeding on grapevine mealy bug. The results indicated that with the increasing temperatures there was significant decrease in developmental durations including pre-pupal and pupal durations. Babu and Azam (1987b) reported that at temperatures of 20, 27.5 and 30ºC, the average pupal period was 14.3, 6.1 and 6.2 days, respectively reared on *M. hirsutus* Green of grapevine. The trend of their work was also in agreement with the present findings.

The results of the present study showed that temperature has significant effect on the survival rate of immature stages of *C. montrouzieri*. The recorded average survival rate from egg to adult emergence was 80%, 92% and 86% at 24, 28 and 32°C, respectively (Fig. 1). These results agreed with the findings of Solangi *et al*. (2013) who reported significant effects of the different temperatures on the % survival rate from egg to adult emergence of *C. montrouzieri.*

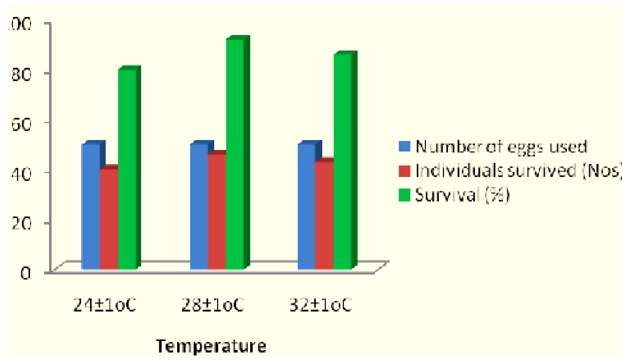

Fig. 1. Percentage of *C. montrouzieri* survived from eggs to adult fed on *P. solenopsis* at three different constant temperatures

Longevity and reproductive capacity of C. montrouzieri *fed on cotton mealy bug*

Table II shows the longevity and reproductive parameters of the adults of *C. montrouzieri* at different temperatures. All these durations decreased with the temperature increase and lowest figures were recorded for the durations of these parameters at the highest temperature (32°C).

The highest pre-oviposition period (11.62±0.03 days), oviposition duration (73.85±0.02 days), post-oviposition duration (7.32±0.03 days), male longevity (82.2±0.01 days) and female longevity duration (91.2±0.01 days) was recorded at 24°C. The shortest pre-oviposition duration (5.43±0.04 days), oviposition duration (48.58±0.03 days), post-oviposition duration (4.08±0.03 days), male longevity period (38.5±0.02 days) and female longevity period (57.0±0.01 days) was recorded at the highest temperature (32°C). All the temperatures had a significant effect on the fecundity of *C. montrouzieri*. Highest number of eggs, 235.5±0.02 were recorded at 28°C, which were followed by

Table II.- Pre-oviposition, oviposition, post- oviposition periods and longevity (Days) (Mean ±SE) of adults of *C. montrouzieri* fed on *P. solenopsis* at three different constant temperatures

	Temperature (°C)		
	24±1	28±1	32±1
Pre-oviposition	11.62±0.03a	9.47±0.03b	5.43±0.04c
Oviposition	73.85±0.02a	60.65±0.03b	48.58±0.03c
Post-oviposition	7.32±0.03a	5.93±0.03b	4.08±0.03c
Fecundity	137.1±0.07c	235.1±0.08a	166.2±0.09b
Male longevity	82.2±0.01a	60.6±0.01b	38.5±0.02c
Female longevity	91.2±0.01a	74.8±0.01b	57.0±0.01c

Means followed by same letters (rows wise) are non significant

166.2±0.09 and 137.1±0.07 number of eggs recorded at 32°C and 24°C, respectively. These findings suggest that 28 °C proved to be the best for egg laying and also proved to be overall best suited for the reproductive parameters of *C. montrouzieri* as compared with the other temperatures (Table II). Results of our present findings agree to the work carried by Al-Humiari *et al*. (2011) who have reported that rearing at 28°C proved to be the best temperature for the reproductive parameters of *C. montrouzieri*.

Life table parameters

Table III shows life table parameters of *C. montrouzieri* which showed that mean generation time (T) decreased as the temperature increased. The value of mean generation time was longest (91.2 days) at 24°C, while it was shortest (57.0 days) at 32°C. Results indicated highest survivorship of female (Lx) (0.905%) recorded at 28°C, while lowest (0.813%) at 32°C. Maximum oviposition rate per female per day (Mx) 235.1 at 28°C, while minimum oviposition was recorded at 24±1˚C. Results indicated that the death rate (Dx) was recorded 23.15, 22.09 and 24.60 at 24, 28 and 32°C, respectively. Death rate was found highest at 32°C, while lowest at 28°C. The highest net reproductive rate (R0=203.1) was recorded at 28°C, while the lowest value (R0=124.1) was recorded at 24°C. The intrinsic rate of increase (r_m) is a perfect indicator at which the growth of population is most favorable because it reflects the overall effects on development, reproduction and survival characteristics of a population (Tsai and Wang, 1999). Intrinsic rate of increase was highest at 28°C, where as lowest (r_m) was obtained at 24°C. Results showed that population of *C. montrouzieri* could be doubled every 13.11, 9.76 and 8.05 days at 24, 28 and 32°C, respectively. The shortest time for doubling population (DT) was achieved at 32°C, while the longest (DT) was recorded at 24°C. The trend of the current findings is in conformity with the previous work of Ozgokce *et al*. (2006).

Table III.- Life table parameters of *C. montrouzieri* fed on *P. solenopsis* at three different constant temperatures

Parameters*	Temperature (°C)		
	24±1	28±1	32±1
T	91.2	74.8	57.0
Lx	0.864	0.905	0.813
Mx	137.1	235.1	166.2
Dx	23.15	22.09	24.60
R_o	124.1	203.1	135.1
r_m	0.0231	0.0374	0.0308
DT	13.11	9.76	8.05

*For definitions of parameters see “Materials and Methods”

It is clear from the results obtained on all Life Table parameters that at 28°C, *C. montrouzieri* showed best performance as compared with the recorded results at all other temperatures (Table III). There are no published data on the effect of three different temperatures *i.e.,* 24, 28 and 32°C on the life table parameters of *C. montrouzieri* fed on cotton mealy bug.

CONCLUSIONS

It is concluded from the present study that *C. montrouzieri* can be easily mass reared in laboratory at different temperatures. Our findings suggest that among the tested temperatures, 28°C is effective for rearing as indicated by developmental, reproductive characteristics and life table parameters of *C. montrouzieri*.

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