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Comparative biology of Australian lady bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions

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Abstract

The present study was conducted to study the biology of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under controlled condition in laboratory at Agriculture Entomology Section, College of Agriculture, Pune (M.S.) during the year 2017. The incubation period, hatching percent, total larval duration, pre-pupal and pupal period *i.e.* total developmental period of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant were slightly higher when fed on mealy bug species, *Maconellicoccus hirsutus* Green than *Phenacoccus solenopsis* Tinsley. It also found that adult of *C. montrouzieri* took more time to complete its pre-mating (7.06 ± 0.48 days), mating, pre-oviposition (7.56 ± 0.41 days) and oviposition (53.49 ± 2.59 days) stages when fed on *M. hirsutus*. Fecundity of *C. montrouzieri* was observed more when fed on *M. hirsutus* (156.26 ± 20.31). Adult longevity of *C. montrouzieri* was slightly higher when fed on *M. hirsutus* than *P. solenopsis*. Further it was also seen that female beetles lived longer than male beetles.

Keywords: Mealy bug, lady bird beetle, biology

Introduction

The success of biological control of mealy bugs on different fruit crops have been achieved by employing a potential predator, the Australian lady bird beetle *C. montrouzieri* as long-term solution because of its self perpetuating ability, persist even when the mealy bug is at low population densities. Continuous attacks on mealy bugs help in keeping their populations below economic injury level. Thus, the Australian lady bird beetle is accepted by most of the fruit growers as a potential bio-agent for the control of mealy bugs on different fruit crops. In India, *C. montrouzieri* @ 20 per plant found solely responsible for the decline of *M. hirsutus* on sapota within two months in Bangalore [6]. As farmers were demanding the *C. montrouzieri* for mealy bug management in various crop ecosystem, it is very important to mass multiply such potent predatory insect on suitable host in the laboratory so as to fulfil the requirement of farmers. Now a days, *C. montrouzieri* reared on mealy bugs under laboratory conditions. Keeping the view in mind, this studies were conducted to know the best species of mealybug for mass multiplication of *C. montrouzieri*.

Materials and Methods:

Mass rearing of mealy bugs, *Maconellicoccus hirsutus* Green on red pumpkins and *Phenacoccus solenopsis* Tinsley sprouts on potato

Mass culturing of host insect, *M. hirsutus* and *P. solenopsis* is one of the basic needs in the laboratory experimentation of *C. montrouzieri*. To generate the culture of mealy bug, the pest infested custard apples were collected from orchards and kept in cages containing red pumpkins (*Cucurbita maxima* Duch.), *P. solenopsis* made available from Central Institute of Cotton Research, Nagpur and released on potato sprouts. Mealy bugs were reared on red pumpkins to obtain the pure laboratory culture throughout the period of research work as per the method used by Singh (1978) [9]. For rearing of *M. hirsutus*, just ripened red pumpkins with prominent ridges and grooves and bearing small stalk for easy handling were selected.

These red pumpkins were cleaned with water to get rid of any dust on them. To prevent rotting, the pumpkins were surface treated with 0.1 percent carbendazim solution (Bavistin 50% WP @ 1 g/ lit water). The wounds, if any, on the pumpkins were plugged with paraffin wax. The ovisacs of *M. hirsutus* obtained from the stock culture of mealy bug and transferred over the pumpkins. The pumpkins infested with mealy bugs were kept on iron stands in the specially designed wooden cages (45× 45× 45 cm) with glass door in front, glass on top and backside and lateral sides fitted with wire mesh (Plate I). These cages were arranged on slotted angle iron racks in the rearing room. In order to maintain darkness at the rearing site, individual racks were completely covered with black muslin cloth. The matured *M. hirsutus* females were developed within 30 to 35 days from the fully infested pumpkins.

For mass rearing of mealy bugs, *P. solenopsis* iron trays 30× 25× 10 cm were used for developing sprouts on potato. Sandy silt soil was filled in the trays with 5 cm layer and 10-15 whole tubers were placed at about 2 cm apart on a layer of soil in the trays which were covered with slightly moist soil. These trays were kept in the racks in the rearing room and watered gently. Temperature in the rearing room was maintained between 21 and 25°C. Ovisacs of the mealy bugs obtained from the stock culture were placed over the sprouts. The culture of mealy bug was developed within 25 days.

Mass rearing of predator, Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant

The predator *C. montrouzieri* was reared after development of sufficient culture of *M. hirsutus* on pumpkins and *P. solenopsis* sprouts on potato. *C. montrouzieri* beetles were released on these pumpkins and potatoes inside the separate cages. Burlaps strips were attached to the fronts of each rack to accommodate pupating *C. montrouzieri* grubs and the racks were again darkened. The emerging adults were collected in plastic vials. The beetles were also fed with honey–agar diet which consisted agar–agar powder 1 g, sugar 20 g, honey 40 cc and distilled water 100 ml intermittently. The diet was prepared by boiling sugar in 50 ml water in a beaker, in which 1 g agar–agar powder was added and again boiled for 30 to 60 seconds. In another beaker, 40 cc honey was diluted with remaining 50 ml water. This honey solution was mixed with the content of first beaker and again boiled for 30 to 60 seconds. Aril sized drops of this mixture were laid on a plastic sheet and allowed to cool for 10 to 15 minutes. After becoming sufficiently hard, these arils were fed to *C. montrouzieri* beetles.

Biology of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions

About 10 newly emerged beetles were transferred in each petri plates (10 x 2 cm) and known number of nymph stages *M. hirsutus* and *P. solenopsis* mealy bugs transferred from red pumpkin and potato cages, respectively by using moist camel hair brush. The beetles besides feeding on the mealy bugs, laid their eggs singly or in groups inside the egg sacs of mealy bugs. Ten eggs laid by each of the ten females were transferred to ten petriplates (10 x 2 cm) separately, using moist camel hair brush. Grub emergence was recorded from those ten petriplates. The average incubation period and hatching percentage were worked out. Full grown grubs pupated on pumpkins, potato sprouts or corner of the breeding

cage. The first beetle emerged within 30 days from the date of exposure of mealy bugs to the beetle; the emerging adults were used for further studies. The beetles and grubs in all petri plates were provided with enough number and same amount of preys during the study period. The pre mating period, pre-oviposition period, oviposition period, incubation period and hatching percentage of eggs, grub period, pre pupal period, pupal period, total developmental period, fecundity and adult longevity of each individuals was recorded on both the species of mealy bugs.

Result and Discussion

Comparative biology of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions Data on Comparative biology of *C. montrouzieri* after feeding on mealy bug *M. hirsutus* and *P. solenopsis* is given in table 1.

Incubation period and hatching percent

The incubation period of *C. montrouzieri* on mealy bugs, *M. hirsutus* and *P. solenopsis* ranged between 5.33 - 8.33 and 4.00 - 7.33 days with an average of 6.56 ± 0.36 and 5.16 ± 0.26 days respectively. The average egg hatching percentage was 83.66 and 78.63 with a range of 80.00 to 90.00 percent and 70.00 - 83.33 percent respectively. From the data on incubation period and hatching percent of *C. montrouzieri*, it could be seen that it was slightly higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*.

The present finding is in close agreement with the study conducted by Shekhar (2001)^[8] who reported the incubation period between 4.6 to 7.55 days. Anil and Jeevan (2008) and Surwase *et al.* (2016)^[2, 11] reported the incubation period of *C. montrouzieri* as 3 - 7 and 4.94 days, respectively.

Hatching percentage of eggs (83.66 and 78.63 percent on *M. hirsutus* and *P. solenopsis* respectively) was noted in the present study is in close agreement with the findings of Bhagat (2004)^[3] who reported the hatching percentage 80 to 90 percent.

Durations of larval instars

The duration of the first instar was 2.66 - 4.66, 2.00 - 3.33 days with an average of 3.36 ± 0.23 , 2.56 ± 0.18 days respectively, when reared on mealy bugs *M. hirsutus* and *P. solenopsis*; whereas, the second instar grub took 3.00 - 4.66, 2.66 - 4.00 days with an average of 3.83 ± 0.19 , 3.12 ± 0.23 days respectively. The third instar grub lasted for 3.66 - 5.00, 3.33 - 4.66 with an average of 4.36 ± 0.22 , 3.99 ± 0.23 days respectively, when reared on mealy bugs *M. hirsutus* and *P. solenopsis* while, the duration of fourth instar grub fed with mealy bugs species was 4.66 - 7.00, 4.00 - 6.33 days, with an average of 5.83 ± 0.31 , 4.86 ± 0.26 days respectively. The total larval period varied from 14.65 - 18.65, 12.98 - 16.32 days with an average of 16.82, 14.45 days, when reared on mealy bugs *M. hirsutus* and *P. solenopsis* respectively. From the data on total larval period of *C. montrouzieri*, it could be seen that it was slightly higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*. As late instar grubs controls mealy bugs more effectively, short duration of larval development is significant for better control of mealy bugs.

This is in agreement with Shekhar (2001)^[8] who reported the duration of grub development was 21.5, 20, 14 to 17, and 13 to 16 and 19.5 days, respectively. The difference in the grub developmental period may be due to difference in quantity

and quality of prey and different ecological factors prevalent during the study period.

Pre-pupal and pupal period

The period of 1 to 2 days with an average of 1.2 ± 0.09 days to complete pre-pupal stage taken by grubs of *C. montrouzieri* on both species of mealy bugs *M. Hirsutus* and *P. solenopsis*, while they take 6.66 - 11.66 days to complete pupal stage with an average of 9.16 ± 0.38 days, when reared on mealy bug *M. hirsutus*; while it take 6.00 - 9.66 days to complete

pupal stage with an average of 7.56 ± 0.35 days, when reared on mealy bug species *P. solenopsis*. From the data on pupal period of *C. montrouzieri*, it could be seen that it was slightly higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*. Whereas, the pre-pupal period recorded in the present study is slightly deviating from the findings of Anil and Jeevan (2008)^[2] who recorded it as 2 to 3 days.

The fully matured grubs undergo pupation preferring mostly the dark and shady places. Pupa was dark brown in colour covered with white waxy filament (Table 1).

Table 1: Biology of immature stages of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions

Pair No.	Incubation period (Days)		Hatching %		Larval period (Days) when fed on										Pre-pupal period (Days)		Pupal period (Days)	
	M.	P.	M.	P.	M. hirsutus					P. solenopsis					M.	P.	M.	P.
	<i>hirsutus</i>	<i>solenopsis</i>	<i>hirsutus</i>	<i>solenopsis</i>	I	II	III	IV	Total	I	II	III	IV	Total	<i>hirsutus</i>	<i>solenopsis</i>	<i>hirsutus</i>	<i>solenopsis</i>
1	7.33	6.66	86.66 (68.85)	83.33 (66.61)	4.00	3.00	3.66	5.00	15.66	2.00	3.66	3.66	4.66	13.98	1.00	2.00	7.33	6.66
2	6.33	7.33	86.66 (68.85)	80.00 (63.90)	3.66	4.33	4.66	5.66	18.31	3.33	2.66	4.33	4.00	14.32	1.00	1.00	7.33	6.00
3	8.33	4.33	80.00 (63.45)	70.00 (56.97)	3.33	3.33	4.33	5.00	15.99	2.33	2.66	3.33	5.00	13.32	1.66	1.00	8.33	9.66
4	6.00	5.33	86.66 (72.11)	83.00 (66.11)	3.66	3.00	4.33	5.00	15.99	2.66	3.66	3.33	4.33	13.98	1.00	1.00	6.66	9.00
5	5.33	5.33	83.33 (66.14)	80.00 (63.40)	3.00	3.33	5.00	7.00	18.33	2.33	2.33	4.66	5.66	14.98	2.00	1.00	6.66	7.00
6	6.00	4.00	76.66 (61.22)	80.00 (63.90)	2.66	3.66	5.00	6.00	17.32	2.00	4.00	3.66	4.66	14.32	1.00	1.33	11.33	8.00
7	7.00	6.00	83.33 (66.14)	80.00 (63.90)	4.66	3.00	4.33	6.66	18.65	3.33	3.00	4.66	5.00	15.99	1.00	1.00	8.33	7.00
8	5.33	4.00	90.00 (71.56)	76.66 (61.19)	3.00	4.66	4.00	4.66	16.32	3.00	3.00	3.66	4.66	14.32	1.00	1.00	6.66	6.33
9	6.66	4.33	83.33 (66.14)	80.00 (63.40)	2.66	3.33	4.00	4.66	14.65	2.00	3.66	4.33	6.33	16.32	1.00	1.66	9.33	7.66
10	7.33	4.33	80.00 (63.43)	73.33 (58.98)	3.33	3.33	4.33	6.00	16.99	2.66	2.66	3.33	4.33	12.98	1.33	1.00	11.66	8.33
Range	5.33	4.00	80.00	70.00	2.66	3.00	3.66	4.66	14.65	2.00	2.66	3.33	4.00	12.98	1	1	6.66	6.00
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8.33	7.33	90.00	83.33	4.66	4.66	5.00	7.00	18.65	3.33	4.00	4.66	6.33	16.32	2	2	11.66	9.66
Mean	6.56	5.16	83.66	78.63	3.36	3.83	4.36	5.83	16.82	2.56	3.12	3.99	4.86	14.45	1.2	1.2	9.16	7.56
	± 0.36	± 0.26			± 0.23	± 0.19	± 0.22	± 0.31		± 0.18	± 0.23	± 0.23	± 0.26		± 0.09	± 0.09	± 0.38	± 0.35

Life stages of adult of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions

Pre-mating and mating period

The data presented in Table 2 revealed that the pre-mating period of *C. montrouzieri* lasted for an average of 7.06 ± 0.48 days with range of 4.33 - 9.00 days on mealy bug *M. hirsutus* while it ranged between 4.33 - 8.33 days with an average of 6.32 ± 0.31 days on *P. solenopsis*. Mating period of *C. montrouzieri* on mealy bug *M. hirsutus* and *P. solenopsis* lasted for 19.09 ± 0.77 and 14.26 ± 0.72 minutes with a range of 13.66 - 23.33 and 9.66 - 20.33 minutes, respectively. From the data on pre-mating and mating period of *C. montrouzieri*, it could be seen that it was slightly higher when *C.*

montrouzieri fed on *M. hirsutus* than *P. solenopsis*.

In the present investigations, the pre-mating period of *C. montrouzieri* lasted for an average of 7.06 ± 0.48 days with range of 4.33 - 9.00 days on mealy bugs *M. hirsutus* while it ranged between 4.33 - 8.33 days with an average of 6.32 ± 0.31 days on *P. solenopsis*. This finding is in agreement with the findings of Shekhar (2001)^[8] who reported 6 days. The variation though not much, may be due to differences in the experimental conditions and climatic conditions.

In the present investigations, the findings on mating period of *C. montrouzieri* is in agreement with Bhagat (2004) and Lad *et al.* (2016)^[3, 5] who reported it as 19.46, 16.30, 14.60 minutes respectively. Ambule (2009)^[1] recorded mating period as 18.63 and 15.03 minutes when reared on *M. hirsutus* and *P. solenopsis* respectively.

Table 2: Life stages of adult of Australian Lady Bird Beetle, *Cryptolaemus montrouzieri* Mulsant on mealy bugs, *Maconellicoccus hirsutus* Green and *Phenacoccus solenopsis* Tinsley under laboratory conditions

Pair No.	On mealy bugs, <i>Maconellicoccus hirsutus</i> Green.						On mealy bugs, <i>Phenacoccus solenopsis</i> Tinsley							
	Pre-mating period (Days)	Mating period (Min.)	Pre-oviposition period (Days)	Oviposition period (Days)	Fecundity (No. of eggs laid)	Adult longevity		Pre-mating period (Days)	Mating period (Min.)	Pre-oviposition period (Days)	Oviposition period (Days)	Fecundity (No. of eggs laid)	Adult longevity	
						Male (Days)	Female (Days)						Male (Days)	Female (Days)
1	5.66	19.00	7.33	56.33	157.00	53.66	61.00	4.33	20.33	8.33	42.66	124.66	48.00	58.33
2	6.33	18.00	6.33	50.66	180.33	56.66	59.33	5.66	13.33	4.00	44.66	97.66	51.66	54.66
3	8.66	23.00	6.66	53.33	180.00	51.33	53.33	7.33	12.66	4.66	54.33	57.66	46.66	61.00
4	9.00	20.00	7.66	58.66	145.66	46.66	54.33	6.66	11.33	6.33	52.66	76.33	42.00	55.33
5	4.33	16.33	8.33	51.33	180.66	47.66	54.33	8.33	15.33	4.00	54.33	106.00	47.00	58.66
6	7.33	16.00	8.33	52.33	133.33	47.66	67.00	6.66	13.33	5.33	46.33	59.00	43.66	66.00
7	7.33	22.33	9.33	51.66	143.00	58.66	57.66	4.33	14.66	7.00	47.00	67.33	52.33	54.33
8	7.66	19.33	6.66	52.33	124.66	47.33	55.66	8.00	13.66	7.66	42.66	55.00	47.33	56.00
9	8.66	13.66	7.33	56.66	197.00	50.33	56.33	5.33	18.33	8.66	56.33	59.33	48.33	56.33
10	5.66	23.33	7.66	51.66	120.99	54.66	57.66	6.66	9.66	3.66	44.33	86.33	53.33	57.00
Range	4.33	13.66	6.33	50.66	120.99	47.33	53.33	4.33	9.66	4.00	42.66	55.00	42.00	54.33
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	7.06	19.09 ±	7.56	53.49	156.26	51.46	57.66 ±	6.32	14.26 ±	5.96	48.52	78.93	48.03	57.76 ±
	± 0.48	0.77	± 0.41	± 2.59	± 20.31	± 2.48	± 2.40	± 0.31	± 0.72	± 0.34	± 2.24	± 17.51	± 1.94	± 2.35

Pre-oviposition and oviposition period

The pre-oviposition period of *C. montrouzieri* on mealy bug *M. hirsutus* and *P. solenopsis* lasted for 7.56 ± 0.41 and 5.96 ± 0.34 days with a range of 6.33 - 9.33 and 4.00 - 8.66 days respectively. The oviposition period lasted for 53.49 ± 2.59 days (50.66 - 58.66) on *M. hirsutus* and 48.52 ± 2.24 days (42.66 - 56.33) on *P. solenopsis*. From the data on pre-oviposition and oviposition period of *C. montrouzieri*, it could be seen that it was slightly higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*.

The present studies of pre-oviposition period of *C. montrouzieri* was comparable with the findings of Shekhar (2001) [8] who reported that the pre-oviposition period of 6 to 7.80 and 4 to 10 days, respectively. The slight variations in the findings of present investigations regarding pre-oviposition period as compared to earlier reports may be due to variations in temperature while conducting the experiment. In present studies, oviposition period was slightly less than the findings of Solangi *et al.* (2012) [10] reported in laboratory oviposition period of *C. montrouzieri* was 76.4 ± 1.30 days. However, the oviposition period reported by Shekhar (2001) [8] and Anil and Jeevan (2008) [2] it as 52 to 84 days, 54 to 83 days respectively. Gosalwad *et al.* (2009) [4] reported that the oviposition period of *C. montrouzieri* was 67.10 and 68.00 on *M. hirsutus* and *P. solenopsis*, respectively.

Adult longevity

Average adult longevity was found to be 51.46 ± 2.48 and 48.03 ± 1.94 days with a range of 47.33 - 58.66 and 42.00 - 53.33 days in male beetles of *C. montrouzieri* and in female beetles it ranged between 53.33 - 67.00, 54.33 - 66.00 days with an average of 57.66 ± 2.40 , 57.764 ± 2.35 days on *M. hirsutus* and *P. solenopsis* respectively. From the data on adult longevity of *C. montrouzieri*, it could be seen that it was slightly higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*. Thus *C. montrouzieri* reared on *M. hirsutus* can control mealy bugs for longer duration as compared to *C. montrouzieri* reared on *P. solenopsis*. From data it also seen that female beetles lived longer than male beetles.

The male could be distinguished from female by colouration

of first pair of legs, having brown and black colour in male and female beetles, respectively. The middle and hind pair of legs were black in both the sexes.

The results of present investigations showed more or less similarity with the observations recorded by Mani (1986) [6] who reported average duration of male and female beetle were 52.2 and 55.90 and 80.2 and 61.40 days, respectively. But, the findings of Shekhar (2001) [8] and Anil and Jeevan (2008) [2] reported contradictory results of 70.3, 69.7 and 77.2, 74.7 days for male and female beetle, respectively.

Fecundity

Number of eggs laid per female beetle of *C. montrouzieri* varied from 120.99 - 197.00, 55.00 - 124.66 with a mean of 156.26 ± 20.31 , 78.93 ± 17.51 fed by *M. hirsutus* and *P. solenopsis* respectively. From the data on fecundity of *C. montrouzieri*, it could be seen that it was higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*. Higher fecundity is needed for fast multiplication of bio-control agent; hence it was good when *C. montrouzieri* fed on *M. hirsutus*. It helps in mass rearing as well as in field to multiply the bio-control agent at faster rate.

The egg laying capacity i.e. fecundity of female beetle was recorded and it was observed as 156.26 ± 20.31 , 78.93 ± 17.51 fed by *M. hirsutus* and *P. solenopsis* respectively when fed with all the stages of mealy bugs.

Total developmental period

The total developmental period i.e. from egg to adult emergence found to be 29.31 - 37.31, 25.65 - 29.99 days with an average of 32.94, 28.37 days, when reared on mealy bugs *M. hirsutus* and *P. solenopsis* respectively. The data on Total developmental period of *C. montrouzieri*, it could be seen that it was higher when *C. montrouzieri* fed on *M. hirsutus* than *P. solenopsis*. Even though *C. montrouzieri* requires more period for its total development, the other parameters like fecundity, hatching per cent and adult longevity were good when fed on *M. hirsutus* than on *P. solenopsis* which were requirements of good bio-control agent. The results of present study corroborate with the findings of Surwase *et al.* (2016) [11] found it as 30, 32.75 and 38.29 days, respectively.

Conclusion

C. montrouzieri required more time to complete its development when fed on *M. hirsutus* than *P. solenopsis*. From overall results it can be concluded that though *C. montrouzieri* required slightly more time to complete its development (32.94 days), it shows higher fecundity (156.26 ± 20.31), hatching percent (83.66%) and adult longevity (51.46 ± 2.48 days in male and 57.66 ± 2.40 days in female) when fed on *M. hirsutus*. So it can be used efficiently for mass rearing and to control mealy bugs the pest of many crops.

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