Bio-ecology of Coccinellid Beetle, *Cryptolaemus montrouzieri* Mulsant on Grapevine Mealy Bug, *Maconellicoccus hirsutus* (Green) under Laboratory Condition

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Abstract

The present study was conducted at the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad, Karnataka, India under laboratory conditions. The mealy bug, *Maconellicoccus hirsutus* (Green) is major and hard to kill pest of grape vines because of its protected waxy filaments, which are almost impossible to be penetrated with insecticidal sprays. The predatory coccinellid beetle, *Cryptolaemus montrouzieri* Mulsant has been proved as a voracious feeder and best biological control agent on different mealy bugs. In this study an effort was made to know the developmental period taken by the predator to complete its life cycle on feeding second and third instars mealy bugs. The predatory grub took 3.83 ± 0.53, 4.83 ± 0.65, 6.03 ± 0.85 and 5.67 ± 0.66 days and 3.53 ± 0.51, 4.53 ± 0.51, 5.57 ± 0.50 and 5.50 ± 0.51 days to complete its first, second, third and fourth instar, respectively when supplemented with second and third instar mealy bugs with an average of 3.68 ± 0.36, 4.68 ± 0.33, 5.80 ± 0.57 and 5.58 ± 0.46 days. The results clearly indicated that the duration taken by the predator feeding on second instars mealy bugs was little more than feeding on third instars mealy bugs. The total developmental period of grubs was 20.37 ± 1.29 and 19.13 ± 0.86 with an average of 19.75 ± 0.77 when supplemented with second and third instar mealy bug preys, respectively. The predator grubs recorded pre-pupal duration of 1.73 ± 0.52 and 1.67 ± 0.55, with a mean of 1.70 ± 0.39 days feeding on second and third instar mealy bug. The pupal period recorded was 8.70 ± 0.88 and 8.53 ± 1.22 days, respectively when fed on second and third instar mealy bugs with an average of 8.62 ± 0.82 days. The duration of male beetle when reared on second and third instar mealy bugs was 55.80 ± 3.19 and 60.59 ± 3.73 days, respectively with an average of 58.18 ± 2.13 days. Similarly, the longevity of female beetle was 63.83 ± 1.91 and 61.28 ± 2.21 with a mean of 62.48 ± 1.42 days.

Keywords Instar; Developmental period; Pre-pupal period; Pupal period, Longevity

Introduction

Grape (*Vitis vinifera* L.) is one of the most important commercial fruit crops of sub-tropical, tropical and temperate regions of the world. The prevailing sub-tropical and tropical climatic condition of India is well suited for higher sucrose level and berry yield. In India, the major grape growing states include Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Punjab, Madhya Pradesh and Haryana. As per the reports of Butani (1979) over 85 species of insect pests are known to occur on grapes in India. Balikai and Kotikal (2003) recorded 26 pests infesting grapevines in northern Karnataka. Among these, two insects viz., flea beetle, *Sceledonta strigicollis* Mots. and mealy bug, *Maconellicoccus hirsutus* (Green) were recorded as major pests on this crop. Lower (1968) described the mealy bug as “hard to kill pest of fruit trees” because mealy bugs are protected by waxy filaments, and almost impossible to be penetrated by insecticidal sprays. In recent years, *M. hirsutus* has become very severe in grape vine yards.

The biological control is one of the effective means of achieving insect control (Pedigo, 2004). The researches so far done regarding bio-control have proved that most of the major pests of important agricultural and horticultural crops would be suppressed by bio-agents. About 60 percent of the pests are controlled naturally by entomophages occurring in nature, provided, they are not destroyed by the use of chemicals. The coccinellid beetles are...
considered to be of great economic importance in agro-ecosystem as they can be successfully employed in the biological control of many injurious insects (Agarwal et al., 1988).

In India the coccinellid beetle, Cryptolaemus montrouzieri Mulsant (Coleoptera: Coccinellidae) has provided spectacular control of heavy infestations of sucking pests, especially mealy bugs (Mani, 1990; Mani and Krishnamoorthy, 2008) and some soft scales (Kumar and Prakasam, 1984; Mani and Krishnamoorthy, 1990). The predator was also reported to feed on citrus mealy bug, Planococcus citri (Risso) (Singh, 1978) and pink mealy bug, M. hirsutus (Mani and Thontadarya, 1987; Reddy and Narayan, 1986). Cryptolaemus montrouzieri was found to be almost efficient predator among coccinellids in India (Fandi et al., 2010). Despite the frequent use of different predators, only the coccinellid, C. montrouzieri can be considered successful (Moore, 1988). The coccinellid beetle, C. montrouzieri can be effectively utilized in the management of pink hibiscus mealy bug M. hirsutus and papaya mealy bug (Mishra et al., 2012). Keeping in mind the efficacy of C. montrouzieri on mealy bug species, the present study was conducted to estimate the biology of C. montrouzieri on different stages of M. hirsutus a pest of grape vine in India.

Results

Bio-ecology of Cryptolaemus montrouzieri

The studies on bio-ecology of C. montrouzieri revealed that, the pre-mating and pre-oviposition period was found with an average of $6.00 \pm 2.06$ and $8.70 \pm 1.64$ days, respectively. Whereas, oviposition period lasted for $73.80 \pm 13.02$ days. The male and female adult lived with an average of $78.00\pm 10.83$ and $88.50\pm 14.86$ days, respectively (Table 1). The freshly laid eggs were pale yellowish white, smooth and cylindrical in shape. At the time of hatching the shining of egg disappeared and a longitudinal depression was seen on the eggs. The egg laying capacity of female beetle was recorded with a mean of $550.30 \pm 62.68$ eggs when fed with all the stages of mealy bugs. The grubs emerged out through eggs by breaking at the weak point of this longitudinal depression. The incubation period lasted for $5.75 \pm 0.72$ days with egg hatching percentage of 95.

Table 1 Mating period, oviposition period, adult longevity, fecundity, incubation period and hatching percentage of Cryptolaemus montrouzieri

| Particulars                        | Pre-mating period (Days) | Pre-oviposition period (Days) | Oviposition period (Days) | Adult longevity (Days) | Total number of eggs laid | Incubation period (Days) | Hatching (%) |
|------------------------------------|--------------------------|-------------------------------|---------------------------|------------------------|--------------------------|--------------------------|--------------|
| Range                              | 4-9                      | 6-11                          | 58-89                     | 61-91                  | 72-109                   | 472-652                  | 3.6-7.9      | 80-100       |
| Average                            | $6.00 \pm 2.06$          | $8.70 \pm 1.64$              | $73.80 \pm 13.02$        | $78.00 \pm 10.83$     | $88.50 \pm 14.86$        | $550.30 \pm 5.75$        | $62.68 \pm 0.72$ | $95$         |

Note: Observations on 10 adults per replication

Developmental period of Cryptolaemus montrouzieri

Results on the developmental period of grubs and adults on different stages of M. hirsutus indicated that the grub period was extended when reared on second instar mealy bugs compared to rearing on third instar mealy bugs. The newly hatched grubs were smooth and pale greyish in colour. They were devoid of wax strands at the time of hatching but exhibiting four instars. This difference in the developmental period of grubs and adults reared on different stages of the mealy bug may be due to the quality and quantity of the prey offered to the predator. The predatory grub took $3.83 \pm 0.53$, $4.83 \pm 0.65$, $6.03 \pm 0.85$ and $5.67 \pm 0.66$ days to complete its first, second, third and fourth instar, respectively (Table 2) when supplemented with second instar mealy bugs while, $3.53 \pm 0.51$, $4.53 \pm 0.51$, $5.57 \pm 0.50$ and $5.50 \pm 0.51$ days when fed on third instar mealy bugs with an average of $3.68 \pm 0.36$, $4.68 \pm 0.33$, $5.80 \pm 0.57$ and $5.58 \pm 0.46$ days, respectively (Figure 1).

The total developmental period of grubs was $20.37 \pm 1.29$ and $19.13 \pm 0.86$ with an average of $19.75 \pm 0.77$ when supplemented with second and third instar mealy bug preys, respectively. The predator grubs recorded pre pupal
Table 2 Developmental period of *Cryptolaemus montrouzieri* fed on 2\(^{nd}\) and 3\(^{rd}\) instar mealy bug, *Maconellicoccus hirsutus*

| Particulars | Duration (Days) | (Mean ± S.D) |
|-------------|-----------------|--------------|
| Egg Period  |                 |              |
| Grub Period | Feeding on 2\(^{nd}\) Instar Mealybug | Feeding on 3\(^{rd}\) Instar Mealybug | Mean |
| I Instar    | 3.83 ± 0.53     | 3.53 ± 0.51  | 3.68 ± 0.36 |
| II Instar   | 4.83 ± 0.65     | 4.53 ± 0.51  | 4.68 ± 0.33 |
| III Instar  | 6.03 ± 0.85     | 5.57 ± 0.50  | 5.80 ± 0.57 |
| IV Instar   | 5.67 ± 0.66     | 5.50 ± 0.51  | 5.58 ± 0.46 |
| Total       | 20.37 ± 1.29    | 19.13 ± 0.86 | 19.75 ± 0.77 |
| Pupa        |                 |              |
| Pre-pupa    | 1.73 ± 0.52     | 1.67 ± 0.55  | 1.70 ± 0.39 |
| Pupa        | 8.70 ± 0.88     | 8.53 ± 1.22  | 8.62 ± 0.82 |
| Male        | 55.80 ± 3.19    | 60.59 ± 3.73 | 58.18 ± 2.13 |
| Female      | 63.83 ± 1.91    | 61.28 ± 2.21 | 62.48 ± 1.42 |

Note: *Cryptolaemus montrouzieri* - ten numbers of grubs per replication were used.

duration of 1.73 ± 0.52 and 1.67 ± 0.55, with a mean of 1.70 ± 0.39 days feeding on second and third instar mealy bug (Figure 1). Pupa was dark brown in colour covered with white waxy filament. The pupal period recorded was 8.70 ± 0.88 and 8.53 ± 1.22 days, respectively when fed on second and third instar mealy bugs with an average of 8.62 ± 0.82 days. The male could be distinguished from female by colouration of first pair of legs, having brown and black colour in male and female beetle, respectively. The middle and hind pair of legs were black in both the sexes. The duration of male beetle when reared on second and third instar mealy bugs was 55.80 ± 3.19 and 60.59 ± 3.73 days, respectively with an average of 58.18 ± 2.13 days. Similarly, the longevity of female beetle was 63.83 ± 1.91 and 61.28 ± 2.21 with a mean of 62.48 ± 1.42 days.

Discussion

The pre-mating period of *C. montrouzieri* is in agreement having 6.2 and 6 days on grapevine mealy bug (Bhat et al., 1981; Shekhar, 2001, respectively). In some studies pre-mating period lasted for 8 to 11 days (Rao and David, 1958), which is slightly higher than the recorded in the present study. The pre-oviposition period in present study is comparable with the findings of Gokuldas Kumar and Vijayalaxmi (1986) and Shekhar (2001) who reported 6 to 7.80 and 4 to 10 days on coffee and grape mealy bug, respectively. However, it is shorter than that reported by Rao and David (1958) as 9 to 13 days at temperature of 24 to 29.5°C on grapevine mealy bug. In contrast, it is greater than what was observed by Mineo (1967) *i.e.* 3 to 4 days at 25°C and observed around 5 days for beginning for egg laying (Anon., 2006a) on citrus mealy bug. The ambient temperature have influence on pre-oviposition period (Babu and Azam, 1987) which got extended (9.6 days) when the predator, *C. montrouzieri*
was maintained at constant temperature of 20°C. Whereas, pre-oviposition period of *C. montrouzieri* was 3.6 days at 30°C compared with the maintenance at ambient temperature (2.4 days). Thus, the slight variations in the findings of present investigations regarding pre-oviposition period as compared to earlier reports is because of variation in temperature while conducting the experiment.

The oviposition period of *C. Montrouzieri* was reported 75 and 69.5 days (Rao and David, 1958; Shekhar, 2001, respectively). It was also observed that the female predator prefers wax filaments of mealy bugs for egg laying. The same was stated by Merlin et al. (1996) that female delay oviposition and with held mature eggs in absence of wax filament produced by the prey on grapevine mealy bug. The longevity of predator was recorded 52.2, 76.7 and 70.3 days for male and 80.2, 77.8 and 77.2 days for female *C. Montrouzieri* (Rao and David, 1958; Bhat et al., 1981; Shekhar, 2001) which show more or less similarity with present observations. The fecundity of predator female is quit deviating from the earlier record of 207 and 210.5 eggs (Rao and David, 1958; Mani, 1986, respectively). However, Fisher (1963), Shekhar (2001) and Anon. (2006a) recorded fecundity of female *C. montrouzieri* in the range of 194 to 729, 370 to 682 and 400 to 500 eggs, respectively. The female *C. montrouzieri* laid on an average of 476.2 eggs in it life time (Anil and Jeevan, 2008). The present finding is in close agreement with the study conducted by Shekhar (2001) who reported the incubation period ranged between 4.6 to 7.55 days on grape mealy bug. Bishop (1931) and Anil and Jeevan (2008) reported the incubation period of *C. montrouzieri* as 8 to 10 and 3 to 7 days on citrus mealy bug and grapevine mealy bug, respectively. Babu and Azam (1987) concluded that higher temperature shortened and lower temperature increased the incubation period of eggs. The egg hatching percentage is closely in agreement with the findings of Mineo (1967), Bhat et al. (1981) and Shekhar (2001) who recorded 93, 97 and 100 per cent, respectively on citrus mealy bug and grapevine mealy bug.

In the present study, the results clearly indicated that the duration taken by the predator feeding on second instars mealy bugs was little more than feeding on third instars mealy bugs. It is because of the sufficient nutritional requirement by the predator to pass to next higher stage might have delayed the developmental period. Hence, it is good to release the predatory grubs or adults at early stage of mealy bugs which will lead to good management of mealy bug population build up and extended period of development will consumes more number of mealy bugs to meet its nutritional requirements.

The developmental period of *C. montrouzieri* having close conformity with the findings of Mani (1986) who reported 5.25, 4.40, 6.35 and 6.85 days on mealy bug eggs, 3.50, 2.20, 4.10 and 4.95 days on nymphs and 3.05, 2.25, 3.86 and 4.30 days on adult mealy bug taken to complete its first, second, third and fourth instar by *C. montrouzieri*, respectively. In the present study the developmental period of grub is supported by Shekhar (2001), Van Der Goot (1920) and Bhat et al. (1981) who reported the duration of 21.5, 20 and 19.5 days, respectively on grapevine mealy bug. However, it differs from the observations of Liotta and Mineo (1965), Mani (1986) and Murthy and Narayana (1986) who recorded it as 14 to 17, 13 to 16 and 31.6 days on citrus mealy bug (*P. citri*) and grapevine mealy bug, respectively. Ambule et al., (2014) reported that the feeding potential of *C. montrouzieri* on grubs and adults of mealy bugs jointly revealed that the total consumption of grub was much higher on *M. hirsutus* i.e. 144.4±15.64 with their longevity of 12.10±2.1 days than *Phenacoccus solani* Ferris and custard apple mealy bugs. The difference in the grub developmental period reported by several workers may be due to difference in quantity and quality of prey and different ecological factors prevalent during the study period.

The pre-pupal period is in conformity with the findings of Murthy and Narayana (1986) and Shekhar (2001) who reported it as 1 to 2 days which prefers mostly the dark and shady places. But, it slightly deviated from the findings of Mani (1986) and Anil and Jeevan (2008) on grapevine mealy bug and Hanchinal (2010) on cotton mealy bug (*Phenacoccus solenopsis* Tinsley) who recorded 2 to 3 days. The pupal period in the study is having corroboration with the findings of Rao and David (1958), Liotta and Mineo (1965), Mani (1986), Shekhar (2001), Anon. (2006a), Anil and Jeevan (2008) on grapevine mealy bug and Hanchinal (2010) on cotton mealy bug who reported as 7 to 8, 6 to 13, 7 to 9, 7 to 11, 6 to 10 and 8 to 9 days, respectively. In the present investigations in the day duration of male and female beetle when fed with second and third instar mealy bugs, may be
due to quantity and quality and stage of the prey. These results of present investigations show more or less similarity with the observations recorded by Rao and David (1958), Mani (1986) on grapevine mealy bug and Hanchinal (2010) on cotton mealy bug who reported average duration of male and female beetle as 52.2, 55.90 and 56.45 and 80.2, 61.40 and 62.56 days, respectively. However, the findings of Shekhar (2001) and Anil and Jeevan (2008) reported contradictory results of 70.3, 69.7 and 77.2, 74.7 days for male and female beetle, respectively on grapevine mealy bug, which may be due to variation in the experimental conditions.

Materials and Methods
Laboratory multiplication of mealy bug, *Maconellicoccus hirsutus*

The grapevine mealy bug, *M. hirsutus* was used as prey throughout the study period. The mass production of mealy bugs was done on medium sized ripened red pumpkin (*Cucurbita maxima* Duch.) under laboratory conditions at 25 ± 5°C temperature and 75 ± 5 per cent relative humidity as suggested by Chacko et al. (1978) and Singh (1978).

Mass rearing and biology of the predator, *Cryptolaemus montrouzieri*

The method adopted by Chacko et al. (1978) and Singh (1978) was followed for rearing the predator after sufficient development of mealy bugs on pumpkins. About 8-10 pairs of predators were released into the cage. The beetles besides feeding on the mealy bugs, female adults laid their eggs singly or in groups among the mealybug colonies. Full-grown grubs pupated on pumpkins 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 pre-mating, pre-oviposition, oviposition period, incubation, hatching percentage and adult longevity studies. The beetles were provided with enough number of preys during the study period.

Studies on feeding potential of *Cryptolaemus montrouzieri* on various bio-stages of mealybugs

In order to determine the feeding potential of both the stages (grub and adult) of the predator, known number of nymphs (2nd instar) and adults of mealybugs were supplied separately. For the test, newly hatched 1st, 2nd, 3rd and 4th instar grubs and emerged adults of *C. montrouzieri* were taken at the rate of ten numbers per replication with following treatment details.

| Stage of predator | Stage of prey               |
|-------------------|-----------------------------|
| 1st Instar *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| 1st Instar *C. montrouzieri* | 3rd Instar *M. hirsutus* |
| 2nd Instar *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| 2nd Instar *C. montrouzieri* | 3rd Instar *M. hirsutus* |
| 3rd Instar *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| 3rd Instar *C. montrouzieri* | 3rd Instar *M. hirsutus* |
| 4th Instar *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| Adult male *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| Adult male *C. montrouzieri* | 3rd Instar *M. hirsutus* |
| Adult female *C. montrouzieri* | 2nd Instar *M. hirsutus* |
| Adult female *C. montrouzieri* | 3rd Instar *M. hirsutus* |

Petriplates (10 x 2 cm) were used for grubs while the adults were confined to transparent glass container (vials) with muslin cloth. Feeding potential of male and females were studied separately.

Observations were recorded at an interval of 24 hours on number of preys consumed by the grubs and adults. It was computed by subtracting the number of mealybugs left out from total number of insects provided. Fresh preys were supplied daily to the grubs and adults until the grubs pupated and the adults died. The total number of bio-stages consumed by different larval instars as well as by male and female and also the total development period of grub and longevity of adults were recorded. The data were subjected to statistical analysis.
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