

**BIOLOGICAL STUDIES OF
CRYPTOLAEMUS MONTROUZIERI MULSANT.
AND IT'S SUSCEPTIBILITY TO SOME
INSECTICIDES**

By

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DISSERTATION



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PARBHANI - 431 402 (M.S.) INDIA**

2001

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**I, hereby declare that the entire work embodied
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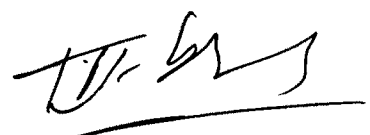
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This is to certify that **Shri. KULKARNI CHANDRASHEKHAR GOVIND** has satisfactorily prosecuted his course credits and research for a period of not less than two years and the dissertation entitled. "**BIOLOGICAL STUDIES OF CRYPTOLAEMUS MONTROUZIERI MULSANT. AND IT'S SUSCEPTIBILITY TO SOME INSECTICIDES** " submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination for the award of the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL ENTOMOLOGY**. I also certify that the dissertation or part there of has not been previously submitted by him for a degree of any University.

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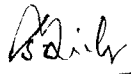


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CERTIFICATE - II


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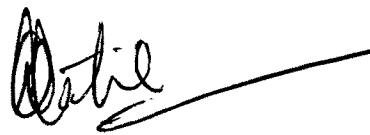
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INTRODUCTION

CHAPTER - I

INTRODUCTION

The disaster phase of pesticide use initiated, in India, with simultaneous launching of biological control. Bio-agents will be key tool of IPM in twenty first century. The researches so far done regarding bio-control have proved that most of the major pests of important agronomical and horticultural crops would be suppressed by bio-agents (Khaire *et al.*, 1998). Regarding natural control, the entomophages occurring in nature bring near about 60 per cent of the natural control of pest, provided, they are not destroyed by the use of chemicals (Puri *et al.*, 1998).

Mealybug is a sucking pest and has become a serious problem of horticultural crops. Occasionally, it causes havoc in citrus, grape, custard apple, guava, mango, mulberry gardens and ornamentals, like hibiscus. It affects their most cherished and highly priced yields throughout the tropical and subtropical regions of the world. In India, it is of regular occurrence in states like Maharashtra, Andhra Pradesh, Karnataka, Punjab etc.

In recent years, the fruits and flowers have a great demand in foreign market. For achieving the international qualitative and quantitative standards, the fruit production from the orchards should be free from pests and pesticide residues. Among such pests, mealybugs assured status of major pest (Ayyar, 1938). Mealybugs infest leaves, shoots, buds and also gets conglomerated at the stalk end. As a result, the affected plant parts get deformed in shape and reduced in size

So far, various chemical pesticides have been attempted for the control of mealybugs either singly or in combinations but did not give the desired control of the pest (Anonymus, 1995). The reason is that only those mealybugs are controlled which are exposed on the shoots, while those sheltering in the crevices of the bark, escape and re-establish their population quickly (Manjunath, 1985). Rao and David (1958) stated that, because of presence of waxy coating over the body of mealybugs, it is difficult to control them by insecticides. Even when effective chemicals are available, the usually extensive host range of the pest afford them facilities for taking shelter on wild hosts while such measures are instituted and reinfesting the field later. Hence, it is essential to integrate biological and chemical control strategies. In the changing scenario of pest management, there is need to exploit the bio-agents as the foremost component of IPM for efficient control of mealybugs.

The Australian lady bird beetle *Cryptolaemus montrouzieri* Mulsant (Coleoptera : Coccinellidae) is a general predator of a wide range of mealybugs, at all stages of development. It is commonly referred as mealybug destroyer. It has been employed as the possible solution for combating the menace of the pest, around the world. It is native of Australia and was introduced in India in 1898 in an attempt to control the coffee green scale by H.O. Newport (Mayne, 1953). Though the predator did not establish on green scale, it was responsible to check mealybugs in coffee growing zones (Chacko *et al.*, 1978). The biological suppression of mealybugs through this potent predator in

India was well documented (Rao *et al.*, 1971; Babu and Azam, 1989; Mani *et al.*, 1995). In the other countries, *C. montrouzieri* had proved effective as it is evident from the study of Smith and Armitage (1931) who succeeded in keeping under check the destructive mealybugs in California by large scale multiplication of the beetles.

Though the predator is now well established in South India, there is no proper information available on successful multiplication and establishment of *C. montrouzieri* under agroclimatic conditions of Marathwada region of Maharashtra. Hence to use the predator successfully against mealybugs, studies on biology, habits, feeding potential and susceptibility to some insecticides of *C. montrouzieri* under agroclimatic condition of Marathwada region, the present studies were taken up.

The life history, fecundity, longevity and feeding potential of *C. montrouzieri* were studied on grapevine mealybug *Maconellicoccus hirsutus*. Laboratory experiment was also conducted to find out safe insecticides to the predator. The results of these investigations are presented in this dissertation.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

Among the pests of fruit crops and ornamentals, mealybug posed serious threat. A predator *Cryptolaemus montrouzieri* M. has been tried successfully against this pest. For taking accurate decisions on control of the pest using *C. montrouzieri*, its detailed study have been done by several workers in India and abroad. The available literature pertinent to the present studies is reviewed in the following pages.

2.1 Biology and habits of *C. montrouzieri*

Biology and habits of the coccinellid predator has been studied earlier by several workers (Van der Goot 1920; Hall 1926; Bishop 1931; Rao and David 1958; Fisher 1963; Liotta and Mineo 1965; Mineo 1967; Bhat *et al.* 1981).

2.1.1 Pre-mating period

Rao and David (1958) described pre-mating period ranged between 8 to 11 days. Liotta and Mineo (1965) noticed the pre-mating period of 1 to 2 days, while it was observed as 3 to 4 days at temperature of 25°C by Mineo (1967), Bhat *et al.* (1981) could record pre-mating period 6.2 days while Mani (1986) studied biology of *C. montrouzieri* and he found pre-mating period between 5 to 17 days.

2.1.2 Mating period

Bhat *et al.* (1981) reported the mating period between 30 to 40 minutes and further observed the copulation up to age of 58th days of female.

2.1.3 Pre-oviposition period

According to Rao and David (1958), the pre-oviposition period ranged between 9 to 13 days. Bhat *et al.*, (1981) observed it as 14 to 15 days.

Gokuldas Kumar and Vijayalaxmi (1986) recorded pre-oviposition period as 6.0 to 7.8 days while Babu and Azam (1987a) found it to be 9.6 days at temperature of 20°C.

2.1.4 Oviposition period

Oviposition of *C. montrouzieri* was reported to extend up to 93 days in one case with an average of 75 days (Rao and David, 1958). However, the oviposition period reported by Bhat *et al.* (1981) and Mani (1986) was 47.91 and 42.50, respectively.

Marlin *et al.* (1996) studied the ovipositional behaviour of *C. montrouzieri* under laboratory conditions. The results showed that the females delay oviposition and withheld mature eggs in their lateral oviducts in absence of wax filament produced by the prey.

2.1.5 Incubation period and hatching percentage

Hall (1926) reported the incubation period of 3 to 4 days while Bishop (1931), reported it for 8 to 10 days. Rao and David (1958) observed incubation period in the range of 2-4 days while studying the biology of *C. montrouzieri*. Mani (1986) reported it for 4 to 5 days.

According to Babu and Azam, (1987a) higher temperature shortened the incubation period and it was 52 per cent longer at 20°C (6.2 days) than at 30°C (3.0 days)

The egg viability in *C. montrouzieri* reported by Mineo (1967) was 97 per cent while Bhat *et al.* (1981) found it to be 100 per cent.

2.1.6 Grub development

Van der Goot (1920) studied the biology of *C. montrouzieri* in Java and indicated that the larval period ranged from 13 to 23 days with an average of 20 days.

According to Bishop (1931), the grub development was completed within 8 to 10 days. Rao and David (1958) suggested that the temperature range of 75 to 85°F was favourable for rearing *C. montrouzieri* and they noted the developmental period for grubs as 14 to 16 days.

The studies made by Liotta and Mineo (1965), Bhat *et al.* (1981), on biology of *C. montrouzieri* when reared on *M. hirsutus*, revealed that the grub completed development within 14 to 17 and 18 to 21 days, respectively.

The grub of the predator have four instars in their life and the duration of first, second, third and fourth instars were found to be 3 to 4, 4, 4 to 5 and 7 to 8 days, respectively as reported by Bhat *et al.* (1981).

Mari (1986) indicated that the total grub development was completed in 13 to 16 days.

Batu and Azam (1987a) studied the effect of temperature on development of grubs of *C. montrouzieri* and they reported that the duration of each instar was 2.7, 3.5, 4.1 and 5.5 days at temperature of

30°C and 6.2, 7.0, 13.5 and 17.7 days at temperature of 20°C, respectively.

The duration of each instar was reported as 8.90, 4.05, 5.25 and 9.45 days, respectively and grub completed development in 27.20 days when fed on eggs of mango mealy bugs (*Rastrococcus iceryoides*) (Anonymous, 1994).

2.1.7 Pre-pupal period

The results of the biology studies conducted by Bhat *et al.* (1981), Murthy and Narayana (1986a) revealed the pre-pupal period of 3 to 4 days and 1 to 2 days, respectively.

2.1.8 Pupal period

The studies were made on biology of *C. montrouzieri* by Van der Goot (1920), Hall (1926), Bishop (1931), Rao and David (1958), Liotta and Mineo (1965), Bhat *et al.* (1981), and Mani (1986). They reported that pupal period of *C. montrouzieri* was ranged from 6 to 9, 6 to 9, 14 to 20, 7 to 8, 6 to 13, 7 to 8 and 7 to 9 days, respectively.

Babu and Azam (1987a) reported it to be 6.2 and 14.3 days at constant temperatures of 30°C and 20°C, respectively.

2.1.9 Total development period

According to Van der Goot (1920), Hall (1926), Bishop (1931); Rao and David (1958), the development of *C. montrouzieri* from egg to adult emergence was completed in 22 to 35, 21 to 35, 32 to 36 and 24 to 28 days, respectively.

Fisher (1963) attempted mass multiplication of *C. montrouzieri* and found that the development from egg to adult was

completed in 43 to 47 days at 70°F and 28 to 29 days at 80°F and 60 per cent relative humidity.

Liotta and Mineo (1965) and Bhat *et al.* (1981) reported that the development was completed within 22 to 27 and 33 to 39 days, respectively.

Babu and Azam (1987a) observed that when the predator was subjected to controlled conditions of temperature, there was extension in life cycle (65.1 days) at lower temperature of 20°C than higher temperature of 30°C (25.2 days).

Srinivasan (1994) attempted the mass multiplication of *C. montrouzieri* and found that the development from egg to adult was completed in about 30 days.

2.1.10 Fecundity

Studies conducted by Vander Goot (1920), Rao and David (1958), Fisher (1963), Liotta and Mineo (1965) and Mineo (1967), indicated that the fecundity was 64 to 176, 207, 194 to 729, 90 to 100 and 60 to 120 eggs, respectively.

Bhat *et al.* (1981) noted fecundity in the range of 85 to 336 eggs with an average of 164.1, when the females reared on mealy bugs plus honey agar while 66 to 367 eggs with an average of 229.2 when reared on mealy bugs only.

Gokuldas Kumar and Vijayalaxmi (1986) observed that the mean total fecundity of the beetle was significantly high when *P. citri* was the prey. It was ranged from 864 to 1235 with an average of 1062.6.

Shirke and Salunkhe (1996). reported that. fecundity of *C. montrouzieri* were greater when fed on *M. hirsutus* alone than when honey agar was added to it.

2.1.11 Adult longevity

Rao and David (1958) indicated that males survived for 52.5 days and reached maximum of 65 days while female survived for 80.2 days with a maximum of 105 days. where as Liotta and Mineo (1965) reported the adult longevity of 60 days for both male and female.

According to Bhat *et al.* (1981), males lived for 61 to 97 days with an average of 75.3 and female lived for 61 to 92 days with an average 67.9 days. when they were reared on grapevine mealy bugs only.

Babu and Azam (1987a) studied effect of temperature on *C. montrouzieri* and concluded that the adult longevity of the predator was to be maximal when maintained at 20°C. The longevity appeared to have been drastically retarded at both the extreme temperatures of 10°C and 40°C. however the higher temperature proved to be more detrimental. Further it was concluded that the longevity of female appeared to be slightly more than that of male irrespective of the temperature.

Shirke and Salunkhe (1996) reported that the longevity of *C. montrouzieri* was greater when reared on *Maconellicoccus hirsutus* alone.

2.1.12 Sex ratio

Mineo (1967), Bhat *et al.* (1981) and Mani (1986) conducted studies on biology of *C. montrouzieri* and reported the sex ratio of male to female as 1:3, 1:1 and 1:0.96, respectively.

2.2 Feeding potential of *Cryptolaemus montrouzieri*

Whitecomb (1940) undertook studies on Biological control of mealybugs with *C. montrouzieri* in green houses. He reported that on an average *C. montrouzieri* grub ate about 1325 eggs of *P. citri*, equivalent of three to four egg masses, during its life cycle.

Mineo (1967) reported that each grub consumed 1450 eggs of 650 first instar nymphs. Each adult consumed 220 eggs.

According to Oncuer and Bayhan (1982), an individual fourth instar grub consumed on an average 3330.6 eggs of *P. citri* in Turki. Murthy (1982) reported that a single fourth instar grub consumed 188.2 eggs of *M. hirsutus* or 157.0 eggs of *P. citri*.

Murthy and Narayana (1986b) studied the feeding behaviour of *C. montrouzieri* and stated that both grubs and adults feed extensively on all stages of mealybugs and also on the eggs and crawlers of some scale insects, however, grubs were found more voracious feeders. They further observed that the mean number of eggs consumed by each instar grubs (first to fourth) was progressively high. According to Mani and Thontadarya (1987) a single grub consumed on an average 881.30 eggs, 239 nymphs or 27.5 adult females of *M. hirsutus*.

The results of the studies made on feeding potential of *C. montrouzieri* revealed that a grub of predatory beetle consumed 100.5

nymphs of *F. virgata* in 17.3 days while the grub ate 3766 eggs of *Chloropulvinaria psidii* during its developmental period of 17.60 days. (Anonymous, 1988).

Babu and Azam (1988) studied predatory potential of *C. montrouzieri* and found that the first, second, third and fourth instar grubs of *C. montrouzieri* consumed daily 18.6, 49.5, 142.0 and 188.6 eggs or 6.9, 42.1, 140.1 and 354.7 nymphs, respectively of *M. hirsutus* at 25°C. The female adult consumed more eggs (305.1) and crawlers (181.7) of *M. hirsutus* daily, than that of the male (258.3 eggs and 165.9 crawlers).

Jayaraman *et al.* (1988) reported that the rate of predation of *C. montrouzieri* on the bio-stages of *M. hirsutus* and *P. citri* was in the order of eggs > nymphs > adult. Further they concluded that the female consumed more bio-stages during their life span than the males.

It was reported that, the number of mealybug eggs consumed by the first, second, third and fourth instar grubs of *C. montrouzieri* averaged 7, 14.80, 138.45 and 190.10, respectively. It was also studied that a single predatory grub consumed 497.75 mealybug nymphs of 10 to 15 days old during the development. The fourth instar grub was found more voracious feeder than the earlier instar grubs. The male predator consumed comparatively less number of mealybug eggs than the female predator (Anonymous, 1994).

2.3 Susceptibility of *C. montrouzieri* to some insecticides

Bartlett (1963) tested 61 pesticides in the laboratory. The results showed that the insecticides viz. aldrin, demeton, heptachlor and

kelthane had low toxicity to the *C. montrouzieri*. BHC and phosphamidon showed medium toxicity, while endosulfan, malathion and carbaryl had high toxicity.

According to Chacko *et al.*, (1979), malathion, quinalphos, fenitrothion and methyl parathion resulted heavy mortality in adult predators. Sekeroglu and Vygun (1980) observed monocrotophos as highly toxic to *C. montrouzieri* and caused cent per cent mortality within 20 hours after application.

Sreedharan and Chacko (1982) reported that the synthetic pyrethroids viz. permethrin (as ambush, corsair and permasect) and fenvalerate had highly toxic residual effect on adult of *C. montrouzieri* and caused mortality within a week.

Residual toxicity of malathion 0.05 per cent, quinalphos 0.015 per cent, fenthion 0.04 per cent and methyl parathion 0.03 per cent was tested by Samuel *et al.*, (1983). They concluded that all compounds were toxic to the larvae. Further Morse and Bellows (1986) recorded the toxicities of insecticides to *C. montrouzieri* in the order of carbaryl > acephate > parathion > methidathion.

Babu and Azam (1987b) found that dichlorvos was the safest insecticide which showed 20 per cent mortality within 24 hours.

Mani and Thontadarya (1988) examined the effect of sixteen selected insecticides on second instar grubs and adult of *C. montrouzieri*. Among them, dichlorvos (0.20 %), chlorpyrifos (0.05 %) and fish oil rosin soap (4 g/ litre) were found to be safe to grubs and adults. While monocrotophos (0.08 %) dimethoate (0.06 %)

oxydemeton methyl, diazinon (0.05 %), methyl parathion (0.10 %) and phosalone (0.07 %) caused 95 to 100 per cent mortality of grubs and 85 to 100 per cent mortality of adults.

Srinivasan and Sundara Babu (1989) observed toxicity of different insecticides to *C. montrozieri* preying on *M. hirsutus*. They found that the order of relative toxicity as per persistent toxicity (PT) value was monocrotophos > methyl parathion > malathion > dimethoate > quinalphos > dichlorvos > bordeaux mixture > fish oil rosin soap.

According to Satyanarayana and Murthy (1991) chlorpyrifos 0.05 per cent and endosulfan 0.07 per cent, were toxic to eggs, grubs and adults of *C. montrozieri* but safe to pupae. Dicofof 0.05 per cent and dichlorvos 0.1 per cent were toxic to eggs, all stages of grubs and adults, where as they were safe to fourth instar grub and pupa. However, monocrotophos 0.05 per cent and quinalphos 0.05 per cent were highly toxic to all the stages of the beetle.

Shirke (1991) reported that chlorpyrifos 0.05 per cent and dichlorvos (0.2 per cent) were much safer to *C. montrozieri*. The LT 50 value of endosulfan 0.07 per cent and methyl parathion 0.08 per cent were less than one week.

Yigit *et al.* (1992) observed that methidathion was harmful to grubs of *C. montrozieri* and methidathion and fluvalinate were harmful to adults.

Yamruktepe and Uygun (1994) found that oxydemeton methyl was highly toxic to grubs and adults of *C. montrozieri* while phosalone was moderately toxic and pirimicarb and savona (fatty acid)

were non toxic. Mani *et al.* (1997) reported that adult longevity of both the sexes and also the progeny production of *C. montrozieri* was not adversely affected when treated with dichlorvos (0.10 per cent), chlorpyrifos (0.05 per cent) and dicofol (0.05 per cent).

Regupathy *et al.* (2000) evaluated new pesticides against *C. montrozieri* and reported that the order of toxicity to the predator was ebuphos > endosulfan > dimethazone > hexaconazole > isoprothiolane > sethoxydim.

MATERIALS AND METHODS

CHAPTER - III

MATERIALS AND METHODS

The studies on biology of *Cryptolaemus montrouzieri* Mulsant and its susceptibility to some insecticides were carried out using grapevine mealybug *Maconellicoccus hirsutus* Green as a host. The nucleus culture of *C. montrouzieri* and *M. hirsutus* was obtained from bio-control Laboratory of Insect Parasitology Scheme. The present investigations were undertaken in the Insect Parasitology Laboratory of Department of Agril. Entomology, College of Agriculture, Parbhani, during year 2000-2001, keeping in view the main objectives like

1. Studies on biology and habits of *C. montrouzieri* Muls.
2. Studies on feeding potential of the predator.
3. To find out its susceptibility to some insecticides.

The different techniques adopted in the maintainance of mass culture of the host and the predator, as well as other techniques tried during course of studies have been described here under.

3.1 Laboratory multiplication of mealybugs, *Maconellicoccus hirsutus* Green.

The grapevine mealybug *M. hirsutus* Green was used as host material throughout the study. The mass production of mealybugs was done on medium size ripened red pumpkins under laboratory conditions at $25 \pm 5^{\circ}\text{C}$ temperature and 75 ± 5 per cent R.H. as suggested by Chacko *et al.* (1978) and Singh (1978).

3.1.1 Rearing of mealybugs on red pumpkins

Just ripened red pumpkins (*Cucurbita maxima* Duch.) with ridges and grooves and bearing a small stalk were selected for easy handling. They were cleared with water to remove dust on them. In order to prevent rotting, the pumpkins were treated with 0.1 per cent carbendazim solution (1 gm per litre of water). Wounds, if any, on the pumpkins were plugged with paraffin wax. The egg sacs of mealybugs from which the eggs have just started hatching, were placed on pumpkins. The inoculation was done at regular intervals to ensure regular supply of all the stages of mealybugs throughout the study period. The inoculated pumpkins were kept in wooden cages (30 x 30 x 33 cm) with sliding glass front and cloths on either sides as suggested by Padmaja *et al.*, (1995). Care was taken to close all cracks and crevices with wax to prevent escape of early instars. Fully matured mealybugs developed within 30 to 40 days (Plate 1).

3.2 Mass rearing of the predator *C. montrouzieri* Muls.

The method adopted by Chacko *et al.*, (1978) and Singh (1978) was followed for rearing the predator after sufficient development of mealybugs on pumpkins. *Cryptolaemus* pairs were released into the cage. The beetles besides feeding on the mealybugs, laid their eggs singly or in groups inside the egg sacs of mealybugs. Fully grown grubs pupated on pumpkins or anywhere inside the breeding cage. The first beetle emerged within 30 days from the date of exposure of mealybugs to the beetles. The emerging adults were



Plate 1. Mass rearing of mealybugs, *Maconellicoccous hirsutus*



Plate 2. Mass rearing of *Cryptolaemus montrouzieri*

collected and used further for multiplication or different laboratory studies (Plate 2).

3.3 Biology of *Cryptolaemus montrouzieri*

The mass culture of *C. montrouzieri* maintained in laboratory was utilized to study the following aspects of its bionomics.

3.3.1 Pre- mating period

A newly emerged male and female pair was confined in to a transparent plastic container (9 to 11 cm) closed with muslin cloth for easy movement of beetles. Ten such containers containing newly emerged pairs of *C. montrouzieri* were kept under observation. The pre-mating period i.e. the period from the emergence of the female upto its first mating was recorded and average of such ten females was worked out. All the pairs were fed with eggs of mealybugs.

3.3.2 Mating period

The same pairs used for observation on pre-mating were further used for observations of mating duration. The duration of mating was counted in minutes for three random matings in each pair. From this an average period of mating was calculated.

3.3.3 Pre-oviposition period

All the ten pairs confined in containers for studying pre-mating and mating periods were used for recording the observations on pre-oviposition period i.e. the period from female adult emergence to first egg laying.

3.3.4 Oviposition period

The period between first egg laying upto the last egg laying i.e. period during which female laid eggs was recorded for the ten females and the average was worked out. The beetles were provided with enough quantity of prey eggs during the studies.

3.3.5 Incubation period and hatching percentage

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.

3.3.6 Grub development

The grubs hatched from each of the petriplate containing ten eggs, kept for earlier observations were transferred separately to ten such petriplates with a moist camel hair brush. The grubs were provided daily with fresh eggs of grapevine mealybugs. These grubs were observed daily for exuviae of the grubs, from this, duration of larval instar was noted in days. Four such instars were noted and duration of each instar was recorded. Average of duration of each instar and total larval period was worked out.

3.3.7 Pre-pupal period

The period during which grub cease feeding till it gets fixed, is considered as pre-pupal period. In this way ten grubs were observed for the pre-pupal period, which were observed for larval development. The data thus obtained was averaged.

3.3.8 Pupal period

The same ten grubs which were about to pupate were kept under observations for calculating duration of pupal period. Each grub was observed till adult emergence and then average was worked out.

3.3.9 Total development period

Total development period from egg laying till adult emergence was computed by combining the data obtained from the observations of incubation period upto the pupal period and is presented.

3.3.10 Fecundity

To study fecundity, ten pairs of the beetles which were previously used for the study i.e. pre-mating, mating, pre-oviposition and oviposition period, were observed and number of eggs laid were recorded daily. The total number of eggs laid by each female in its life time were recorded. During this period, the pairs were supplied with sufficient quantity of mealybug egg sacs. From the data obtained, average fecundity was calculated.

3.3.11 Adult longevity

Ten pairs of newly emerged adults were used for the study. The longevity of male and female adult in each pair was recorded and average of such ten individuals was worked out.

3.3.12 Sex ratio

Adults emerged from the mother culture of *C. montrouzieri* maintained on mealybugs, were sexed and sex ratio was worked out by observing 600 emerged beetles. The sex was judged by

observing the differentiation in first pair of legs i.e. female has black and male has orange coloured legs. (Babu and Azam, 1987a).

3.4 Studies on feeding potential of *C. montrouzieri* to various bio-stages of mealybugs (*M. hirsutus*)

In order to determine the feeding potential of both the stages of the predator, known number of eggs, nymphs and adults of mealybugs were supplied separately as well as in combinations. For this test, newly hatched grubs and emerged adults of *C. montrouzieri* were taken. Petriplates (10 x 2 cm) were used for grubs while the adults were confined to transparent plastic container (9 x 11 cm) with muslin cloth. Male and female 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 mealybug bio-stages left out, from total number of bio-stages 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 was subjected to statistical analysis.

3.5 Susceptibility of *C. montrouzieri* to some insecticides

The susceptibility of both grubs and adults to the insecticides recommended for control of pests in general and mealybugs in particular was tested in insect parasitology laboratory by using method described by Mani and Thontadarya (1988). For this, two

concentrations (below recommended and recommended) of each test insecticides were used. The quantity of test insecticide was worked out by using the formula

$$\text{quantity of insecticidal formulation required} = \frac{\text{Desired strength}}{\text{Percentage of insecticide in formulation}} \times \text{Quantity of spray material required (500 ml)}$$

Exact required quantity of insecticide was dissolved in distilled water. Fresh spray solution was prepared as and when required. Healthy and broad leaves of hibiscus were taken and cleaned with distilled water and shade dried.

Three such leaves of hibiscus were dipped in each concentration of a insecticide for one minute. These leaves were then air dried in shade for removal of excess moisture. To maintain turgidity in treated leaves, their stalks were swabbed with wet cotton. Each leaf was then taken in separate petriplates (10 x 2 cm) and as such three treated leaves from each concentration of insecticide were used for exposure of *C. montrozieri*. Then, ten adults as well as ten second instar grubs were released in each petriplate, with the help of moist camel hair brush. An untreated control was maintained by dipping the leaves in distilled water.

Observations on mortality of adults as well as grubs were recorded 72 hours after treatment. During the entire experiment grubs and adults were provided daily with sufficient quantity of prey material, particularly egg sacs of mealybugs.

The average percentage mortality of grubs and adults were worked out for each treatment and the data were subjected to statistical analysis. by using factorial Randomised Block Design.

The insecticides used, procured from Department of Agril. Entomology, were

	Below recommended	Recommended
1. Malathion (50 EC)	: 0.05 %	0.10 %
2. Quinalphos (25 EC)	: 0.025 %	0.05 %
3. Endosulfan (35 EC)	: 0.03 %	0.06 %
4. Methyl demeton (25 EC)	: 0.015 %	0.03 %
5. Dimethoate (30 EC)	: 0.03 %	0.06 %
6. Spinosad (48 SC)	: 0.0125 %	0.025 %

RESULTS

CHAPTER - IV

RESULTS

The investigations were made on biology, feeding potential and susceptibility of *Cryptolaemus montrouzieri* to some insecticides. The nucleus culture of *C. montrouzieri* and *M. hirsutus*, maintained in laboratory were utilized throughout entire study. The insecticides recommended for control of pests in general and mealybugs in particular were tested. The observations were recorded under laboratory conditions. The outcome of the study is set forth in this chapter.

4.1 **Biology of *Cryptolaemus montrouzieri***

Studies on biology of the predator were conducted in the bio-control laboratory of Insect parasitology scheme of department of Entomology at room temperature. For studying various aspects of biology, the culture of *C. montrouzieri* was procured from nucleus culture maintained in the laboratory (Plate 3).

4.1.1 **Pre-mating period**

The figures presented in Table 1 revealed that the pre-mating period, observed in all the ten pairs confined separately, ranged between 3 to 10 days. The average pre-mating period was 6.0 days.

4.1.2 **Mating period**

The pairs of *C. montrouzieri* used for pre-mating study were further observed for study of mating duration as well as for mating behavior. It was noted that, mating occurred throughout life time of

Table 1. Life history of *C. montrourieri* : Premating, mating, preoviposition and oviposition period

Periof No.	Pre mating period (days)	Mating period (minutes)	Pre ovposition period (days)	Oviposition period (days)
1	6	5. 14. 29	8	57
2	4	9. 17. 20	5	58
3	4	15. 25. 28	6	76
4	4	9. 20. 33.	6	67
5	9	5. 17. 29	10	79
6	3	5. 11. 21	4	84
7	10	17. 25. 30	10	52
8	7	5. 25. 18	8	80
9	8	7. 20. 22	9	66
10	5	8. 5. 30	7	75
Range	3 - 10	5 - 33	4 - 10	52 - 84
Average	6.00	17.8	7.30	69.4

both the sexes. The duration of mating ranged between 5 and 33 minutes (Table 1). On an average mating was lasted for 17.8 minutes. It was also noted that while mating the pair did not respond to any slight disturbance.

4.1.3 Pre-oviposition period

The beetles copulate 3 to 10 days after emergence and oviposition was commenced a day or two later. Thus, the pre-oviposition period ranged between 4 to 10 days with an average of 7.30 days (Table 1).

4.1.4 Oviposition period

The data presented in Table 1 on egg laying period revealed that the total oviposition period, in one case, extended maximum up to 84 days, however, it was averaged for 69.4 days. It was also observed that the female oviposited in the evening hours and continued till early in the morning. Rarely they were found to lay eggs during day time.

The predacious females preferred egg sacs of mealybugs for oviposition. Capsule shaped eggs were found inserted inside the egg sac, either singly or in groups. As many as nine eggs of *Cryptolaemus* were found in a eggsac of mealybug. It was also observed that, in the absence of egg sacs the eggs were found to be laid even on the surface of the container. Very fresh eggs of *Cryptolaemus* were silvery white and gradually turned to pale yellowish orange with shine.

Table 2. Incubation period and hatching percentage

No. of eggs observed	No. of eggs hatched (days after oviposition)												Total eggs hatched	Incubation period	Per cent eggs hatched
	3	4	5	6	7	8	9	10	11	12					
10	0	4	3	1	2	0	0	0	0	0	0	0	10	5.10	100
10	1	2	3	2	1	0	0	0	0	0	0	0	9	5.0	90
10	1	3	0	2	0	1	1	1	1	0	0	0	9	6.0	90
10	0	4	3	0	2	1	1	0	0	0	0	0	10	5.30	100
10	0	0	2	4	2	0	1	1	1	0	0	0	10	6.70	100
10	1	5	2	1	1	0	0	0	0	0	0	0	10	4.6	100
10	0	2	1	2	0	2	1	0	0	0	0	0	8	6.25	80
10	0	0	0	2	2	3	2	0	0	0	0	0	9	7.55	90
10	1	4	3	0	1	0	1	0	0	0	0	0	10	5.00	100
10	0	3	2	2	0	1	0	0	0	0	0	0	8	5.25	80
Range														4.6 - 7.55	80 - 100
Average														5.67	93.00

Table 3. Duration of development of *C. montrouzieri* on *M. hirsutus*

Stage of predator	Development period in days										Range	Average
	1	2	3	4	5	6	7	8	9	10		
Egg	5.1	5	6	5.3	6.7	4.6	6.25	7.55	5	5.25	4.6 - 7.55	5.67
Grub I instar	5	6	7	6	6	5	5	6	6	6	6 - 7	5.8
II instar	4	3	3	5	3	4	3	3	3	4	3 - 5	3.5
III instar	5	6	5	6	7	5	6	4	5	5	4 - 7	5.4
IV instar	6	8	8	6	5	8	6	10	6	5	5 - 10	6.8
Total	20	23	23	23	21	22	20	23	20	20	20-23	21.5
Pre pupa	2	1	2	2	2	1	1	1	1	1	1 - 2	1.4
Pupa	8	6	10	9	7	11	9	9	7	8	7 - 11	8.4
Total development period	35.1	35	41	39.3	36.7	38.6	36.25	40.55	33	34.25	33-40.55	36.97



Egg

Grub

Pupa

Adult

Plate 3. Bio-stages of *Cryptolaemus montrouzieri*

4.1.5 Incubation period and hatchig percentage

Ten fresh eggs laid by each of the ten females were observed daily for grub emergence. At the time of hatching the shining of eggs was disappeared and a longitudinal depression was seen an the egg. The grubs hatched by breaking egg shell at the depression.

Further, it was seen from close scrutiny of the data presented in (Table 2), that incubation period in all the hundred eggs kept under observation was ranged between 4.6 to 7.55 days with an average of 5.67 days. also the hatching percentage was recorded as 80 to 100 per cent with an average of 93.0 per cent (Table 2).

4.1.6 Grub development

The data on grub development presented in Table 3. It was found that the grab moulted three times during its post embryonic development before undergoing pupation, exhibiting four instars. The duration of first instar grub was 6 to 7 days. For the second instar grub, the developmental period varied from 3 to 5 days. The third instar grub took 4 to 5 days for the development, while duration of last, i.e. fourth instar ranged from 5 to 10 days. Thus, the total development of grub was seen to be completed within 21.5 days when reared under laboratory conditions on eggs of *M. hirsutus*, at room temperature.

At the time of emergence the grubs were found devoid of the white waxy strands but were observed to develop within 2-3 hours. With each instar, length of these filaments was seen increasing. When these filaments were removed completely, they were seen again developed within just 2-3 hours.

It was also observed that the grub in third or fourth instar was when disturbed it secreted sticky dark orange fluid from the body.

4.1.7 Pre-pupal period

The data presented in (Table 3) on pre-pupal period showed that it was in the range of 1 to 2 days with an average of 1.4 days.

4.1.8 Pupal period

The grubs confined in the petriplates, seen to pupate mostly at the corners of the petriplates. Pupa was dark brown in colour, hidden beneath the waxy threads. It could be seen from the (Table 3) that the pupal period was found to range from 7 to 11 days with an average of 8.4 days.

4.1.9 Total development period

The perusal of data, on the duration of developmental stages of *C. montrouzieri*. (Table 3) revealed that the duration of egg, grub, pre-pupal and pupal stages were found in the range of 4.6 to 7.55, 20 to 23; 1 to 2 and 7 to 11 days, respectively. The entire life cycle i.e. from egg laying upto adult emergence was thus found to complete between 33 to 40.55 days with an average of 36.97 days.

4.1.10 Fecundity

The ten pairs used for studing pre-mating, mating, pre-oviposition and oviposition period were further kept under observation and the data on the total number of eggs laid by female during its entire life span is presented in (Table 4).

Table 4. Longevity and fecundity of *C. montrouzieri*

Pair No.	Longevity		Fecundity
	Male	Female	
1	64	62	504
2	58	67	435
3	67	83	520
4	62	76	413
5	91	99	682
6	84	88	636
7	63	57	370
8	77	86	605
9	66	69	535
10	71	85	548
Range	58 - 91	57 - 99	370 - 682
Average	70.3	77.2	524.8

The maximum number of eggs laid by a single female were 682 in one case, however on an average, 324.8 eggs were laid by a female during its life span.

4.1.11 Adult longevity

The data on the adult longevity are presented in (Table 4). It was clear from the figures that a female could live longer than male. On an average the longevity of the male was 70.3 days and reached a maximum of 91 days while that of the female was 77.2 days. However, it was observed that a female could live maximum up to 99 days.

4.1.12 Sex Ratio

Among the six hundred beetles observed, there were 311 females and 287 males. Thus the ratio of male to female was found to be 1 : 1.08.

4.2 Feeding potential of *C. montrouzieri*

The feeding potential of different larval instars as well as male and female beetles of *C. montrouzieri* on egg, nymph and adult stages of mealybugs, *M. hirsutus* along with their developmental period are given in (Table 5a to 5g).

The data presented in (Table 5a) indicated that when the grubs of *C. montrouzieri* were provided with eggs of mealybugs, they consumed a total of 1529.40 eggs within 24.2 days of development. The egg consumption of predatory grub in fourth instar was highest i.e. 772.27 among all the four instars; with developmental period of 7.6 days. The first and second instar grubs ingested almost equal number of eggs i.e. 128.93 and 131.40 of *M. hirsutus* within 6.13 and 4.56 days.

Table 5. Feeding potential and development of *C. montrouzieri* on *M. hirsutus*

Table 5a. Feeding on egg stage alone

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	128.93 \pm 4.30	6.13 \pm 0.12
II instar	131.40 \pm 3.82	4.56 \pm 0.34
III instar	496.80 \pm 93.26	5.90 \pm 0.05
IV instar	772.27 \pm 23.48	7.6 \pm 1.04
Total	1529.40 \pm 107.35	24.19 \pm 1.13
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	5049.40 \pm 416.8	66.43 \pm 4.55
Female	6748.03 \pm 193.32	75.10 \pm 3.65

Table 5b. Feeding on nymphal stage alone

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	40.16 \pm 0.31	3.96 \pm 0.12
II instar	48.76 \pm 1.38	3.83 \pm 0.37
III instar	119.43 \pm 8.45	4.43 \pm 1.08
IV instar	185.63 \pm 3.69	4.62 \pm 0.18
Total	393.98 \pm 3.11	16.84 \pm 0.78
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	793.6 \pm 6.47	55.46 \pm 3.96
Female	835.70 \pm 4.75	59.80 \pm 3.04

respectively. The third instar grub consumed 496.80 eggs within 5.9 days. However, the total number of eggs consumed by the adult of *C. montrouzieri* was more when compared with the grub, showing voracious nature than grub. On an average each adult male and female consumed 5049.40 and 6748.03 eggs of mealybugs within 66.43 and 75.10 days, respectively.

From the (Table 5b), it is revealed that the grub of *C. montrouzieri* preyed upon 40.16, 48.76, 119.43 and 185.63 nymphs of *M. hirsutus* in first (3.96 days), second (3.83 days), third (4.43 days) and fourth (4.62 days) instars, respectively with total developmental period of 16.84 days. The male and female adults of *C. montrouzieri* fed on 793.60 and 835.70 nymphs of mealybugs, respectively. The female of the predator lived longer (59.80 days) and consumed more nymphs (835.70) than the male (793.60 nymphs) (55.46 days). The data incorporated in the Table 5c showed that the different larval instars i.e. first to fourth, of *C. montrouzieri* consumed 4.36, 3.2, 4.46 and 8.78 adults of *M. hirsutus* and showed development period almost similar (4.50, 3.30, 4.56, 4.43 days) except in the case of second instar which required less days to complete its development. The male and female adults of *C. montrouzieri* ate 62.16 and 65.83 adults of *M. hirsutus* within 39.13 and 47.20 days, respectively.

The feeding potential of *C. montrouzieri* on egg and nymphal stage of *M. hirsutus* when provided combinely is presented in Table 5d. The data revealed that the grubs completed its total development within 17.15 days with consumption of 635.91 egg and

Table 5c. Feeding on adult stage alone

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	4.36 \pm 0.28	4.50 \pm 0.08
II instar	3.2 \pm 0.43	3.30 \pm 0.57
III instar	4.46 \pm 0.49	4.56 \pm 0.57
IV instar	8.78 \pm 0.04	4.73 \pm 0.21
Total	20.53 \pm 0.04	17.09 \pm 0.48
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	62.16 \pm 0.36	39.13 \pm 3.02
Female	65.83 \pm 3.94	47.20 \pm 1.98

Table 5d. Feeding on egg + nymph stages

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	(85.16 \pm 1.29) + (28.06 \pm 0.83)	4.16 \pm 0.17
II instar	(83.96 \pm 1.29) + (24.80 \pm 2.88)	4.03 \pm 0.26
III instar	(213.86 \pm 8.40) + (29.03 \pm 4.33)	4.16 \pm 0.66
IV instar	(252.93 \pm 2.98) + (29.10 \pm 1.49)	4.8 \pm 0.05
Total	(635.91 \pm 8.94) + (110.99 \pm 6.37)	17.15 \pm 0.49
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	(3240.7 \pm 37.82) + (394.96 \pm 4.66)	60.20 \pm 0.69
Female	(3929.30 \pm 62.35) + (394.1 \pm 10.47)	60.53 \pm 3.00

110.99 nymphs). The first and second instar grubs devoured almost similar number of eggs as well as similar number of nymphs (i.e. 85.16 and 83.96 eggs and 28.06 and 24.80 nymphs), respectively with almost similar development period (4.16, 4.03 days). Third instar grub showed similar development period (4.16 days) like first instar grub which ingested 213.86 eggs along with 29.03 nymphs. Maximum eggs (252.93) and nymphs (29.10) were consumed by fourth instar grub within 4.8 days. The female of *C. montroizieri* consumed 3929.30 eggs along with 394.1 nymphs during its life span of 60.53 days, while male ingested little less i.e. 3240.7 eggs and 394.96 nymphs within 60.20 days.

The data on feeding potential of *C. montroizieri* with simultaneous supply of eggs and adults of *M. hirsutus* are presented in (Table 5e). It was clear from the results that the grub consumed maximum of 366.4 eggs and 4.63 adults of *M. hirsutus* within 6.63 days in its fourth instar, while the least number of egg (64.33) and adults (1.16) were preyed by second instar which required 3.13 days for its development. First and third instar grub, took more or less similar days (5.03 and 5.06 days) to complete development but regarding consumption, third instar grub devoured 284.00 eggs and 3.03 adults which were almost three times more than that of first instar grub. Moreover male lived for 56.56 days by consuming 3164.5 eggs and 29.23 nymphs while female devoured 3774.9 eggs and 34.23 nymphs and lived for 61.46 days.

Table 5c. Feeding on egg + adult stages

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	(102.5 \pm 0.77) + (1.36 \pm 0.04)	5.03 \pm 0.17
II instar	(64.33 \pm 11.68) + (1.16 \pm 0.60)	3.13 \pm 0.38
III instar	(284.00 \pm 19.03) + (3.03 \pm 0.46)	5.06 \pm 0.98
IV instar	(366.4 \pm 17.58) + (4.63 \pm 0.68)	6.63 \pm 0.18
Total	(816.83 \pm 37.05) + (10.18 \pm 1.27)	19.85 \pm 1.24
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	(3164.5 \pm 205.00) + (29.23 \pm 3.23)	56.56 \pm 4.99
Female	(3774.9 \pm 54.04) + (34.23 \pm 1.94)	61.46 \pm 1.83

From the (Table 5f) it is seen that the grub consumed 25.9 nymphs and 1.23 adults 21.43 nymphs and 1.2 adults, 45.20 nymphs and 2.83 adults and 78.03 nymphs and 3.63 adults of *M. hirsutus* in their first, second, third and fourth instar with development period of 3.43, 2.9, 3.83 and 5.66 days respectively. In case of adult, male consumed 456.93 nymphs and 18.6 adults of mealybug and lived for 33.93 days where as female lived little more, 39.60 days than male, which preyed 453.0 nymphs and 26.96 adults of mealy bugs.

Both the predatory stages of *C. montrouzieri* i.e. grubs and adults were fed separately by providing sufficient number of eggs, nymphs and adults of mealy bugs in combination and the results are presented in (Table 5g). The data revealed that the predation of *C. montrouzieri* grub in first to fourth instar was ranged from 62.2 eggs, 18.8 nymphs, 1.06 adults to 299.73 eggs, 56.8 nymphs, 2.26 adults of *M. hirsutus*. Thus the grubs of *C. montrouzieri* devoured a total of 620.99 eggs, 133.46 nymphs and 5.25 adults of mealy bugs within 17.43 days of its development. The developmental period was recorded minimum for second instar (3.93 days) and maximum for first instar (4.70 days). It could also be seen from the table that male predator consumed less prey eggs (2672.46) than the female (2924.46) but consumption on nymphs and adults in case of predatory male (317.16 and 28.70) is slightly more than in female (276.56 and 28.03) with development period of 60.73 and 68.2 days, respectively.

Table 5f. Feeding on nymphs + adult stage

Stage of the predator	No. of eggs consumed (Mean \pm S.D.)	Developmental period (Mean \pm S.D.)
1. Grub		
I instar	(25.9 \pm 1.10) + (1.23 \pm 0.04)	3.43 \pm 0.28
II instar	(21.43 \pm 5.64) + (1.2 \pm 0.43)	2.90 \pm 0.37
III instar	(45.20 \pm 3.84) + (2.83 \pm 0.24)	3.83 \pm 0.37
IV instar	(78.03 \pm 1.32) + (3.63 \pm 0.33)	5.66 \pm 0.12
Total	(170.56 \pm 7.80) + (8.89 \pm 0.92)	15.82 \pm 0.77
2. Adult	No. of eggs consumed (Mean \pm S.D.)	Longevity (Mean \pm S.D.)
Male	(456.93 \pm 4.59) + (18.6 \pm 2.59)	33.93 \pm 3.02
Female	(453.0 \pm 6.23) + (29.96 \pm 1.34)	39.60 \pm 1.98

Table 5g. Feeding on egg + nymph + adult stages

Stage of the predator	No. of eggs consumed (Mean ± S.D.)	Developmental period (Mean ± S.D.)
1. Grub		
I instar	(62.2 ± 2.08) + (18.8 ± 2.16) + (1.06 ± 0.26)	4.70 ± 0.08
II instar	(65.40 ± 4.78) + (22.9 ± 3.15) + (0.6 ± 0.21)	3.93 ± 0.92
III instar	(193.66 ± 1.99) + (34.96 ± 0.69) + (1.33 ± 0.30)	4.5 ± 0.78
IV instar	(299.73 ± 3.41) + (56.8 ± 1.57) + (2.26 ± 0.51)	4.30 ± 0.20
Total	(620.99 ± 10.87) + (133.46 ± 1.31) + (5.25 ± 0.52)	17.43 ± 0.57
2. Adult	No. of eggs consumed (Mean ± S.D.)	Longevity (Mean ± S.D.)
Male	(2672.46 ± 233.73) + (317.16 ± 7.80) + (28.70 ± 4.04)	60.73 ± 4.32
Female	(2924.46 ± 66.99) + (276.56 ± 9.36) + (28.03 ± 2.00)	68.2 ± 2.19



4.3 Susceptibility of *C. montrouzieri* to some insecticides

The predatory beetle *C. montrouzieri* was reared on mealybug infested pumpkin fruits in laboratory. Six insecticides were tested at two concentrations i.e. below recommended and recommended concentrations to determine susceptibility of both predatory stages of *C. montrouzieri*.

4.3.1 Susceptibility of grubs of *C. montrouzieri* to insecticides

The insecticides at two concentrations were tested against second instar grub using leaf dip method. The data on mortality of grub are incorporated in (Table 6) and depicted in (Fig. 1).

After scrutinizing the data it seems that there were significant differences in grub mortality due to various insecticides. Among them, spinosad was found to be totally innocuous to the grubs. In contrast, malathion recorded maximum mortality (78.33 per cent) and proved to be highly toxic to the grubs. Next to this, endosulfan registered 69.99 per cent mean mortality, whereas quinalphos, methyl demeton and dimethoate were equally hazardous to the grubs exhibiting mean mortality of 54.99, 51.66 and 51.66 per cent, respectively.

Moreover, the results showed significant differences in grub mortality among the test concentrations. It was obvious that on an average higher concentration showed maximum of 64.44 per cent mortality followed by below recommended concentration (37.77 per cent).

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Table 6. Susceptibility of grubs of *C. montrouzieri* to some insecticides

Insecticide	Per cent grub mortality at concentration		Mean
	Below recommended	Recommended	
Malathion	66.66 (55.06)	90.00 (71.95)	78.33 (63.51)
Quinalphos	33.33 (35.21)	70.00 (57.77)	51.66 (46.49)
Endosulfan	56.66 (48.92)	83.33 (67.03)	69.99 (57.97)
Methyldemeton	43.33 (41.14)	66.66 (54.98)	54.99 (48.06)
Dimethoate	26.66 (30.99)	76.66 (61.91)	51.66 (46.45)
Spinosad	00.00 (0.81)	00.00 (0.81)	00.00 (0.81)
Average	37.77 (35.35)	64.44 (52.41)	----

	S.E. \pm	C.D. at 5 %
Insecticide (I)	3.13	9.16
Concentration (C)	1.80	5.26
Interaction (I x C)	4.42	12.96

Figures in parenthesis are arc-sin $\sqrt{\text{percentage}}$ transformation

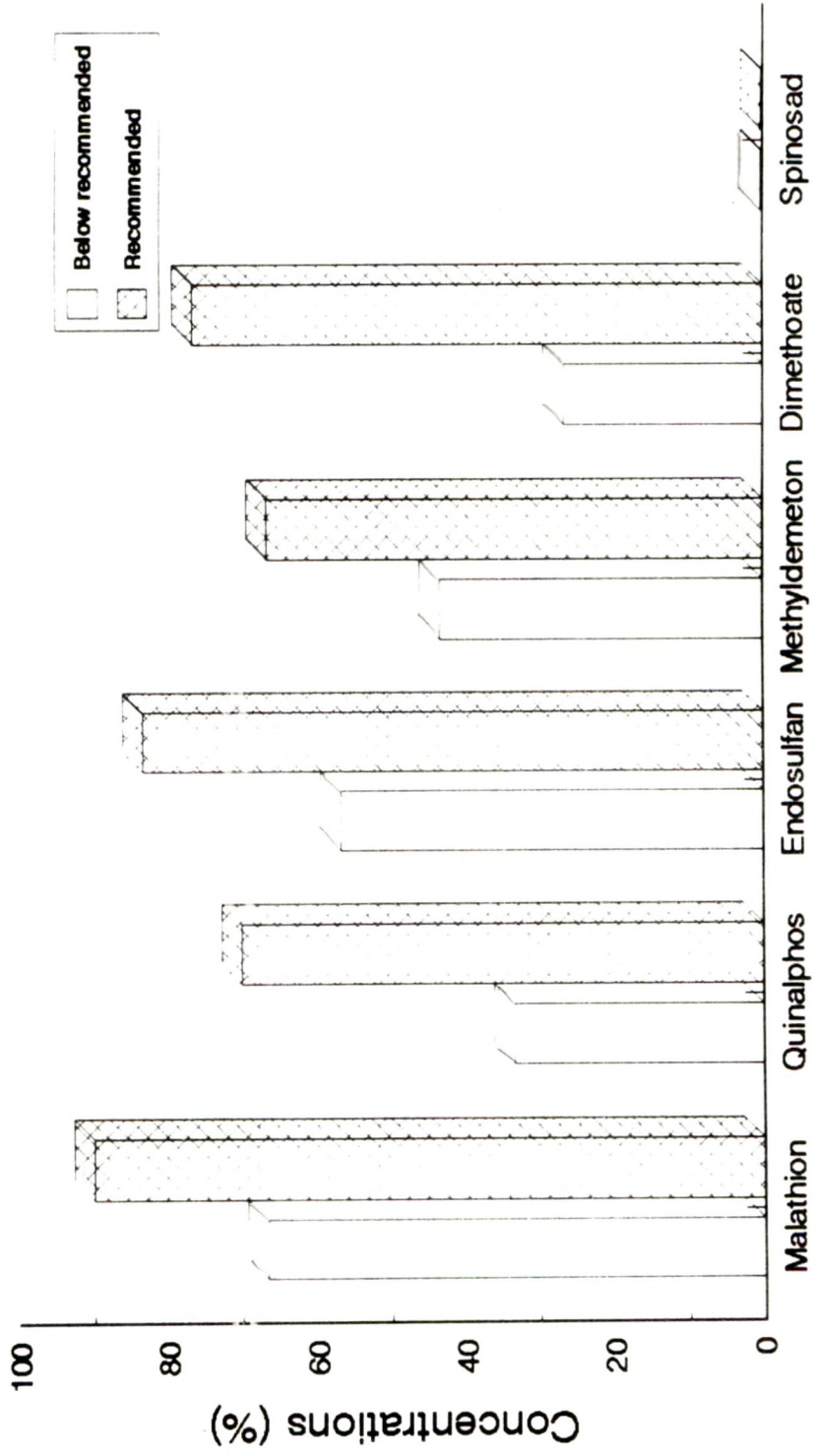


Fig. 1. Susceptibility of grubs of *C. montrouzieri* to some insecticides

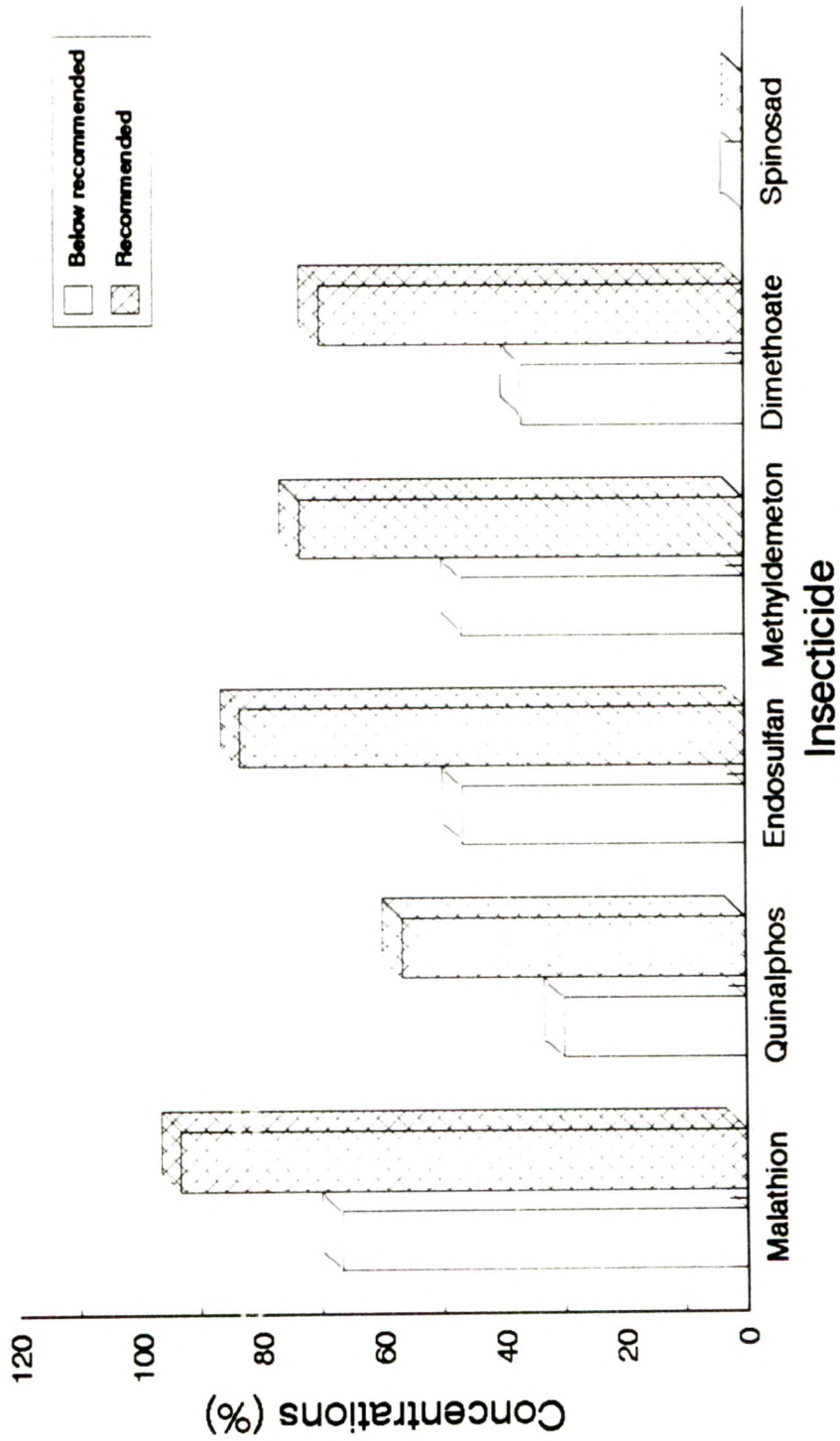


Fig. 2. Susceptibility of adults of *C. montrouzieri* to some insecticides

The interactions among insecticides and their concentrations were found to be non significant in respect of grub mortality.

4.3.2 Susceptibility of adults of *C. montrouzieri* to insecticides

The contact toxicity of six insecticides was tested against newly emerged beetles by leaf dip method. The data incorporated in (Table 7 and depicted in Fig. 2) revealed that malathion was highly toxic to adults of *C. montrouzieri* causing 79.99 per cent mean mortality. Endosulfan (64.99 per cent), methyl demeton (59.99 per cent) and dimethoate (53.33 per cent) were at par with each other, while spinosad was totally harmless to adults showing no mortality of beetles.

The test concentrations of various insecticides showed significant differences in mortality of *C. montrouzieri* adults. The recommended concentrations of all insecticides caused maximum average adult mortality (62.77 per cent) followed by below recommended (48.88 per cent)

The interactions among insecticides and their concentrations were also non-significant in respect of adult mortality.

Table 7. Susceptibility of adults of *C. montrouzieri* to some insecticides

Insecticide	Per cent adult mortality at concentration		Mean
	Below recommended	Recommended	
Malathion	66.66 (54.98)	93.33 (75.07)	79.99 (65.02)
Quinalphos	30.00 (33.20)	56.66 (48.92)	43.33 (41.06)
Endosulfan	46.66 (43.07)	83.33 (67.03)	64.99 (55.05)
Methyldemeton	46.66 (43.07)	73.33 (60.88)	59.99 (51.98)
Dimethoate	36.66 (37.22)	70.00 (57.77)	53.33 (47.49)
Spinosad	00.00 (0.81)	00.00 (0.81)	00.00 (0.81)
Average	48.88 (35.39)	62.77 (51.75)	----

	S.E. ±	C.D. at 5 %
Insecticide (I)	3.27	9.59
Concentration (C)	1.89	5.53
Interaction (I x C)	4.63	13.5

Figures in parenthesis are arc-sin $\sqrt{\text{percentage}}$ transformation

DISCUSSION

CHAPTER - V

DISCUSSION

in Maharashtra, fruit and flower growing has taken considerable stride in the recent past. Such commercial fruit crops and ornamentals suffer heavy losses from number of insect pests. Mealybugs, *Maconellicoccus hirsutus* is one of the important insect pests causing serious damage in orchards. At present, control of mealybugs is mostly depend on available insecticides. Unfortunately, its over use has resulted in undesirable side effects like insecticide resistance, killing of natural organisms and residue deposits of pesticides in or on the harvested produce. To overcome these problems, and to provide a stable ecosystem, the scientists turned their research studies for development of integrated pest management (IPM). IPM seeks to minimize the use of insecticides and resembles the practice of medicine that is concerned with the total well being of the crop and the ecosystem in which it grows. The research institutes have made tremendous progress in areas like biological control in pest management.

Attempts have been made to control the mealybugs by using its natural enemy, *Cryptolaemus montrouzieri*, a coccinellid predator, in some parts of Maharashtra. Hence efforts were made to study biology, feeding potential in order to get information on life history and mass multiplication technique of the beetles and its susceptibility to some insecticides.

The results of the investigations made on biology, feeding potential and susceptibility of bio-stages of the predator to some

insecticides are presented in previous chapter and are discussed in this chapter.

5.1 Biology of *C. montrouzieri*

5.1.1 Pre-mating period

In the present investigations, the pre-mating period in all the ten pairs was found to range from 3 to 10 days with an average of 6.0 days (Table 1). This finding is in agreement with the finding of Bhat *et al.* (1981) who reported it as 6.2 days. Pre-mating period reported by Rao and David (1958) was slightly higher (8 to 11 days) than what was recorded in present studies. The variation, though not much, may be due to the differences in the experimental conditions.

5.1.2 Mating period

During the present investigations, the mating period of beetle was exhibited as 5 to 33 minutes with an average of 17.8 minutes (Table 1). Also copulation was observed up to the age of 70 days of adults i.e. continued just few days earlier to death. This finding is in conformity with the findings of Bhat *et al.* (1981) who reported the mating period as 30 to 40 minutes and also found that copulation continued until shortly before death.

5.1.3 Pre-oviposition period

In the present investigations, the pre-oviposition period of 4 to 10 days with an average of 7.30 days (Table 1) is comparable with the studies conducted by Gokuldaskumar and Vijayalaxmi (1986) who reported it as 6.0 to 7.80 days. However, it is shorter than that reported by Rao and David (1958), as 9 to 13 days at temperature of 24°C to

29.5°C. In contrast, it is slightly greater than what observed by Mineo (1967) i.e. 3 to 4 days at 25°C. The perusal of the study of Babu and Azam (1987a) revealed that the ambient temperature have influence on pre-oviposition period. They reported that pre-oviposition period got extended (9.6 days) when the predator was maintained at constant temperature of 20°C, compared with the maintenance at ambient temperature (2.4 days) whereas at 30°C it was 3.6 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 temperatures while conducting the experiment.

5.1.4 Oviposition period

In the present study (Table 1) oviposition period was found to range between 52 to 84 days with an average of 69.4 days which is comparable with 75 days as reported by Rao and David (1958). It was also observed that the female of *Cryptolaemus* preferred egg sacs of mealy bugs for egg laying. Merlin *et al.* (1996) stated that female delay ovipositior and with held mature eggs in absence of wax filament produced by the prey.

5.1.5 Incubation period and hatching percentage

The incubation period found to range between 4.6 to 7.55 days with an average of 5.67 days (Table 2). These findings deviates slightly from those of Hall (1926), Rao and David (1958) and Mani (1986) who reported it in the range of 3 to 4, 2 to 4 and 4 to 5 days, respectively. The reason for slightly longer incubation period possibly lies in the climatic variations during period of experiment. Babu and

Azam (1987a) concluded that higher temperature shortened the incubation period and vice versa.

Viability of eggs of 93 per cent noted in present study closely agrees with that of conducted by Mineo (1967) and Bhat *et al.* (1981) who showed it as 97 and 100 per cent. respectively.

5.1.6 Grub development

The results regarding rearing of grubs on eggs of *M. hirsutus* revealed that the grub moulted three times thus had four instars and completed its development within 21.5 days (Table 3). This finding in the present study is supported by the researches of Van der Goot (1920) and Bhat *et al.* (1981) who reported the duration of grub development as 20 and 19.5 days. respectively. The present findings differ from the observations of Liotta and Mineo (1965) and Murthy and Narayana (1986a) who reported it as 14 to 17 and 31.6 days. respectively. The variation in the developmental period may be due to quality and quantity of prey available and variation in the environment of rearing room

5.1.7 Pre-pupal period

The duration of pre-pupal period was found to be 1 to 2 days during present studies (Table 3). This finding is in agreement with the study conducted by Murthy and Narayana (1986a). who reported it as 1 to 2 days.

5.1.8 Pupal period

The fully matured grubs undergo pupation, preferring mostly the dark and shady places. Pupa was dark brown in colour

covered with white waxy filament. Pupal stage lasted for 7 to 11 days with an average of 8.4 days. (Table 3). However Rao and David (1958), Liotta and Mineo (1965) and Mani (1986) reported that the pupal period lasted for 7 to 8, 6 to 13 and 7 to 9 days, respectively which are in corroboration with the present results.

5.1.9 Total development period

According to results of present investigations the life cycle (from egg to adult emergence) was completed in 33 to 40.55 days with an average of 36.97 days (Table 3). This finding is in agreement with that of Bishop (1931) and Bhat *et al.* (1981) who reported the total life cycle in the range of 32 to 36 and 33 to 39 days, respectively.

5.1.10 Fecundity

The egg laying capacity of female beetle was recorded in the range of 370 to 682 with an average of 524.8 when fed with mealybug eggs only (Table 4). This result obtained is quite deviating from the earlier record of Rao and David (1958) who reported it as 207. However Fisher (1963) reported it in the range of 194 to 729. Gokuldas Kumar and Vaijayalaxmi (1986) found the fecundity of female as 1062.5 eggs when reared on *Planococcus citri*. Further they stated that fecundity of the predator depend upon specificity of the host supplied. Merlin *et al.* (1996) reported that oviposition was enhanced due to presence of waxy filaments produced by the prey. In the present study as whole egg sacs of mealybugs were provided, there might be increase in fecundity. The other causes of variation in fecundity may be the

differences in environmental conditions and quality and quantity of the prey provided

5.1.11 Adult longevity

The male and female beetles lived for 58 to 91 days (with an average of 70.3 days) and 57 to 99 days (with an average of 77.2 days), respectively (Table 4). These results of present investigations show more or less similarity with the observations made by Rao and David (1958) who reported it as 52.2 days for male and 80.2 days for females.

5.1.12 Sex ratio

The male to female ratio observed during the present study was 1 : 1.08. The same is in close agreement with the reports of Bhat, *et al.*, (1981) and Babu and Azam (1987a) who reported it as 1 : 1 and 1 : 1.3 respectively.

5.2 Feeding potential of *C. montrouzieri*

The studies were made on the feeding potential of different larval instars as well as male and female beetles of *C. montrouzieri*, under laboratory conditions. For these investigations, eggs, nymphs and adults of mealybug species *M. hirsutus* were supplied separately and in combination as prey to the both predatory stages. Along with feeding potential, the developmental period of grub and longevity of adults was worked out.

In the current studies, there was increasing trend of consumption for prey eggs with successive instars (Table 5a). The number of eggs consumed by first, second, third and fourth instar grubs

were 128.93, 131.40, 496.80 and 772.27, respectively. Thus the total consumption was 1529.40 eggs within development period of 24.19 days. Babu and Azam (1988) recorded that grubs of *C. montrouzieri* consumed total 98.0 to 1103.2 eggs of *M. hirsutus* at 30°C temperature. Murthy and Narayana (1986b) observed that, the mean number of eggs consumed by each instar grub was progressively high when they were feed on eggs of grape mealybugs. Similar observations were recorded by Mani and Krishnamoorthy (1990). They found that, the predatory grub consumed a total 2181.27 eggs of *M. hirsutus* within 30.20 days of development. Thus these observations are in conformity with the present findings. However, there is slight variation between present findings and the results obtained by Oncuer and Bayhan (1982), Murthy (1982) and Mani and Thontadarya (1987). The differences might be due to method of application, host species employed and environment in rearing laboratory.

The female beetle of *C. montrouzieri* ingested more eggs of mealy bugs (6748.03) than that of the male (5049.40). This finding is supported by finding of Murthy and Narayana (1986b), Babu and Azam (1988). However overall consumption of the prey eggs by male and female was found higher than the earlier reports. This increase in prey number is may be due to quality of prey supplied and the rearing conditions like temperature.

The results showed that when mealybug nymphs were supplied as a prey to the grubs of *C. montrouzieri* they consumed in all 393.98 nymphs and took 16.84 days for completing its development

(Table 5b). Consumption of nymphs by first instar grubs was found least and it was progressively increased. When the beetles of *C. montrouzieri* were provided mealybug nymphs, as prey, the female devoured maximum of 835.70 nymphs within life span of 59.80 days and the male ingested minimum of 793.60 nymphs within 55.46 days of its longevity. Murthy and Narayana (1986b) provided different nymphal instars of mealy bugs to first to fourth instar grub of *C. montrouzieri* separately and found that daily consumption rate was increased. Mani and Thonadarya (1987) observed that Single grub devoured on an average 259 nymphs of *M. hirsutus* within its developmental period of 13.85 days. Thus these observations supports the findings of present studies in respect of consumption and development of the predatory grub. Regarding adult consumption, Murthy and Narayana (1986b) noticed higher consumption rate of female beetles than the males. Further Jayaraman *et al.* (1988) recorded that female and male beetle consumed 618.0 and 482.2 nymphs of *M. hirsutus*, respectively. Thus these observations are in corroboration with present results. However, variation to certain extent may be due to rearing conditions, quality of host species and stages of mealybug provided.

When only adult stage of *M. hirsutus* was provided to the grubs and adults of *C. montrouzieri* their predatoin rate was found to be reduced greatly (Table 5c). The development period of grub and longevity of adults was also reduced. The grubs during its development period of 17.09 days devoured 20.33 adults of mealy bugs.

These findings in present investigations are comparable with results of Murthy and Narayana (1986b) who reported that grubs consumed 25.84 adults of mealybug within 19.47 days.

The male and female adults of *C. montrouzieri* consumed as many as 62.16 and 65.83 adults of *M. hirsutus* respectively. Moreover prolonged longevity of female was observed than male. Similar results were recorded by Jayaraman *et al.* (1988). They found that the female of *C. montrouzieri* preyed upon more number of adults of *M. hirsutus* (65.01) than the male beetle.

Thus, it is evident from the present investigations that higher consumption was noticed for the eggs of mealybugs, by both the predatory stages of *C. montrouzieri*, followed by nymphs and adults. Also their life span was found prolonged when reared on eggs and went on reducing when fed with nymphs and adults. It can be further opined that female beetle was found to be voracious feeder exhibiting longer longevity as compared to male beetles and grubs. These observations are in agreement with findings of Murthy and Narayana (1986b), Mani and Thontadarya (1987), Jayaraman *et al.* (1988).

Moreover, the investigations were carried out on the feeding potential along with development and life span of both predatory stages of *C. montrouzieri*. In the study, they were supplied with egg, nymph and adult stages of mealy bugs in different combinations like eggs + nymphs, eggs + adults, nymphs + adults and eggs + nymphs + adults.

In the treatment of eggs + nymphs, the grub of *C. montrouzieri* ingested 635.91 eggs and 110.99 nymphs of *M. hirsutus*.

within 17.17 days of its development (Table 5d). The consumption of eggs and nymphs was found to increase with successive instars. The adult beetles lived for 60 days. However, regarding consumption the female ranked first. Thus it is obvious from the results that both grubs and adults of *C. montrouzieri* preferred eggs of mealybugs than the nymphs when provided in combination. The information in this context of combined feeding is scanty in the literature surveyed. However similar trend of feeding was noted by Murthy and Narayana (1986b), Jayaraman *et al.* (1988). Also Mani and Krishnamoorthy (1990) indicated that *C. montrouzieri* preferred to feed on ovi sacs rather than nymphs and adults of *C. psidii*. Thus, these reports are comparable with present findings.

In the another set of treatment (Table 5e), *C. montrouzieri* was supplied with eggs and adults of mealy bugs, simultaneously. In this case also, similar habit of feeding was observed. The consumption rate was observed increasing in grubs, males and females, successively. Development period of grubs was found to be 19.83 days. Male lived shorter (56.56 days) than female (61.45 days). Thus, it seems that, grubs and adults of *C. montrouzieri* fed voraciously and preferred eggs of mealy bugs rather than adults. The consumption rate was found to be directly proportionate to development period. As in the literature, the information in this regard is lacking, the present results could not be compared, however higher predation on eggs of mealy bugs as against adults was noted by Murthy and Narayana (1986b), Mani and

Thontadary (1987) and Mani and Krishnamoorthy (1989) closely agrees with present findings.

When nymph and adult stages of mealybug were provided in combination to *C. montrouzieri*, the feeding potential was found to be considerably reduced (Table 5f). The second instar grub devoured minimum nymphs and adults, whereas fourth instar grub are maximum. Male showed poor feeding potential than females. In literature, information in this context of combined feeding is meagre. It can be noted considering the results that, feeding potential of *C. montrouzieri* was in declining order as female < male < grubs.

In another treatment feeding potential of *C. montrouzieri* was judged by providing them with all the bio stages of mealybug combinely viz., eggs, nymphs and adults, as they would occur naturally in the field. All the larval instars of *C. montrouzieri* showed higher feeding on eggs of mealybugs followed by nymphs and adults (Table 5g). Further it was observed that their feeding potential goes on increasing with successive instars. Similar trend was observed in case of adults as female ingested more bio-stages than male, with longer life span. Considering lack of information on this aspect, the present results could not be compared. However, higher feeding of *C. montrouzieri* on eggs of mealybugs was observed followed by nymphs and adults, is in the line of findings of Murthy and Narayana (1986b), Babu and Azam (1988) and Jayaraman *et al.* (1988). Further, Oncuer and Bayham (1982) gave opinion that eggs as well as other stages of mealy bugs are essential in the diet for successful development of *C. montrouzieri*.

5.3 Susceptibility of *C. montrouzieri* to some insecticides

Susceptibility of the active stages (i.e. grub and adult) of *C. montrouzieri* was tested against commonly used insecticides by following leaf dip method.

5.3.1 Susceptibility of grubs of *C. montrouzieri* to insecticides

During the present study, malathion was recorded to have maximum mean mortality of 78.33 per cent of grubs. Samuel *et al.* (1983) tested the residual toxicity of malathion 0.05 per cent to the grubs and found it to be highly toxic. As such, the present findings are in agreement with the results obtained by Samuel *et al.* (1983).

Endosulfan ranked next with mean mortality of 69.99 per cent. The results are in corroboration with findings of Bartlett (1963) who recorded that endosulfan and malathion were highly toxic to grubs. In the present study, spinosad was found to be safest insecticide to the grubs at both the concentrations i.e. below recommended and recommended. It is obvious that mortality at below recommended concentration was less compared to recommended concentrations.

5.3.2 Susceptibility of adults of *C. montrouzieri* to insecticides

The effect of different insecticides on mortality of adults of *C. montrouzieri* showed that malathion was highly toxic among test insecticides with mortality of 93.33 per cent at recommended concentration. This finding is supported by results of Chacko *et al.* (1979) and Srinivasan and Sundara Babu (1989). The order of toxicity to adults of *C. montrouzieri* was malathion > endosulfan > methyl demeton > dimethoate > quinalphos. Almost similar trend was

noticed by Srinivasan and Sundara Babu (1989), Satyanarayana and Murthy (1991) and Shirke (1991) for different pesticides tested by them. However, the slight differences may be due to method of application of insecticides, concentrations employed and stage of predator used.

Thus it can be said from the present findings that malathion was highly toxic to *C. montouzieri* while spinosad was totally safe. Moreover quinalphos was comparatively less toxic among the tested insecticides except spinosad to grubs and adults of *C. montouzieri*.

SUMMARY

CHAPTER - VI

SUMMARY

The grapevine mealybug *M. hirsutus* Green has been serious threat to orchards in India. Control of mealybug by releasing the natural predator is preferable rather than the use of insecticides. *Cryptolaemus montrouzieri* M. is a general predator of a wide range of mealybugs at all stages of the development. Hence, exploitation of this exotic coccinellid, as bio-control agent is worthwhile. Therefore, certain biological aspects of this coccinellid are contemplated to generate information which will be useful in the mass multiplication and augmentation programme.

The beetles were reared successfully in laboratory and were found to breed all through the year. The life cycle varied from 33 to 39 days. The egg stage being 4.5 to 7.55 days, larval 20 to 23 days, pre-pupal 1 to 2 days and pupal 7 to 11 days at room temperature rearing of the beetle.

The beetle copulated 3 to 10 days after emergence and commence oviposition a day or two latter. The total period of oviposition extended up to 84 days in one case, with an average of 69.4 days and it was continued till few days before death of adults. The total number of eggs laid during the entire life period of a beetle came up to 524.8. The longevity of the male was on an average 70.3 days and reached a maximum of 91 days while that of the female was 77.2 days. The male to female ratio was found to be 1 : 1.08.

Feeding potential of grubs and adults of *C. montrouzieri* was recorded along with their developmental period and longevity, by providing them egg, nymph and adult stages of *M. hirsutus* separately and in combinations, as a prey. The results of the study indicated that females dominate in their predatory rate compared to male and grubs due to its long life span in all cases. The consumption rate of different larval instars was in the order of IV > III > I > II. The developmental period of these stages of *C. montrouzieri* was directly proportionate to the number of mealybug stages consumed by them. It was also found that both the predatory stages of *C. montrouzieri* devoured more number of eggs of mealybugs followed by nymphs and adults when provided separately or in combinations.

Application of insecticides in orchards is very common to control insect pests. A study was undertaken to determine susceptibility of *C. montrouzieri* to different insecticides. Among the six insecticides tested, it was found that malathion was highly toxic to *C. montrouzieri* while spinosad was totally innocuous, at both the concentrations tried i.e. below recommended and recommended. The significant differences were recorded in grub and adult mortality due to treatment with various insecticides and their test concentrations and interactions among them were non significant.

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* Original not seen