The increasing mealy bug problem in mulberry is mainly due to the indiscriminate use of insecticides to control other pests in and around mulberry garden, suppression of natural enemies and the higher chemical fertilization in mulberry garden.

The mealy bugs habitat and the mealy coating protect themselves from the pesticides. The mechanical control of clipping the affected area cause qualitative and quantitative damage in leaf production. On the other hand mealy bugs being sessile, they are more amenable to biological control in which parasitoids and predators can effectively reduce the mealy bug population. Mealy bug is prone to attack by several parasitoids and predators.

The predators C. montrouzieri, S. coccivora and parasitoid A. kanali were selected for the study as they are widely recommended to control mealy bug.

C. montrouzieri feeds on eggs, nymphs and adult of M. hirsutus. C. montrouzieri is a small dark brown lady beetle with a tan to orange head and posterior. The grubs grow up to 1.3 cm. Both grub and adult are predacious. C. montrouzieri pupates in sheltered places and emerges after 7 to 10 days. The C. montrouzieri are adversely affected by low temperature. Dichlor vas and chlorpyrifos are relatively nontoxic (Mani, 1988; Mani, 1989; Ramkishore et al., 1993; Jalai et al., 1999; Muralibaskaran et al., 2002; and Masilamani et al., 2003).

S. coccivora adults are light yellowish with dark brown markings along the mid dorsal regions. Eggs are laid singly in mealy bug colonies. Grubs and
adults are predators. The *S. coccivora* feed on wide range of coccids and aphids but prefer *M. hirsutus* (Mani and Thontadarya, 1987; Katiyar and Sen, 1998; and Muralibaskaran *et al.*, 2006).

*A. kamali* also parasitizes 60–100 per cent of *M. hirsutus* population and complete its lifecycle within. (Mani, 1989; Noyes and Hayat 1988, and Katiyar and Sen, 1998). The third instar and pre-oviposition adult stages were shown to be the preferred hosts of *A. kamali*. Most eggs per host were laid in adult females, but 60 per cent of parasitoid eggs were encapsulated in this stage, and more progeny emerged successfully from younger rather than older parasitized mealy bugs (Sagarra and Vincent, 1999).

In the present study, the biology of the mealy bug, the incubation period, nymphal period, total developmental period, adult longevity, and fecundity were studied on mulberry. The morphological characters of egg, nymph, adult, and ovisac were studied under scanning electron microscope to understand mealy bugs adaptability to ecosystem. The biology, predatory potential of *C. montrouzieri, S. coccivora* and parasitization potential of *A. kamali* were also studied on *M. hirsutus* to find their efficiency.

1.2 MATERIALS AND METHODS

The experiments were done at the laboratory and screen house of Scott Christian College, Nagercoil at the room temperature of 28±2°C and 65±5 per cent of relative humidity.
1.2.1. Massculturing of *M. hirsutus*

The *M. hirsutus* was mass cultured on sprouted potato tubers (Fig.1.1). Medium sized potatoes were washed with 40 per cent formaldehyde and shade dried to avoid microbial infections. They were inoculated with 2 - 3 ovisacs of *M. hirsutus* per potato placed in plastic jars of two litre capacities. The jar containing 15 - 20 tubers were placed at the room temperature of 28 ± 2°C and 60 ± 5 per cent relative humidity for further development. The jars were covered with black cloth to restrict the movement of crawlers. *M. hirsutus* developed colonies on potatoes. The tubers were used for only one generation (Gautam, 1994).

1.2.2. Massculturing of entomophages

1.2.2.1. Massculturing of *C. montrouzieri* and *S. coccivora*

The adult coccinellids were allowed to lay egg on the *M. hirsutus* colonies on potatoes at the rate of 25 beetles per plastic jar (Fig.1.2&1.3). The beetles during their period of exposure fed on mealy bugs and laid eggs. The grubs were seen within a week of exposure. As they grew they feed voraciously on all stages of mealy bugs. For facilitating pupation pieces of paper were kept at the base of the cage. The beetles started emerging after 30 days of confinement. Beetles were collected and kept in separate cages for mating and to complete pre oviposition period. After that they were exposed to lay egg on mealy bug colonies (Joshi *et al.*, 2003).
Fig. 1.1 Mass culturing of M. hirsutus on potatoes

Fig. 1.2. Mass culturing of C. montrouzierie

Fig. 1.3. Mass culturing of S. coccivora

ig. 1.4. Mass culturing of A. kamali

Fig. 1.5. Feeding potential experimental setup
1.2.2.1 Massculturing of A. kamali

Potatoes with *M. hirsutus* colonies were placed in half litre capacity plastic bottles and covered with black cloth (Fig.14). The *A. kamali* parasitized mealybug mummies were placed inside for adult emergence. The adults were fed through sponge dipped in semi solid food consisting of equal quantities of honey and water. They were allowed to lay egg on mealy bug colonies and multiply.

1.2.3 Biology studies of *M. hirsutus*

The biological studies of *M. hirsutus* were conducted on 35 days old mulberry plants of V1 variety. All the experiments were replicated five times.

1.2.3.1 Nympal period

The gravid females were allowed to lay egg on potted mulberry plants. The nymphs emerged were allowed to settle and feed on mulberry. Plants were covered with mylar film cages and replicated five times. The mean developmental period for each instar were counted. Observations were recorded separately for male and female.

1.2.3.2 Adult longevity

The experimental setup was similar to that of the above. A newly emerged male and a female were introduced in mulberry plant. The insects were observed daily until death. Days to mortality were recorded.
1.2.3.3 Fecundity

The gravid females collected from mulberry plants were allowed to lay egg in potted mulberry plants. The ovisacs were carefully opened under dissection microscope and number of eggs per sac was counted and average worked out.

1.2.3.4. Incubation period

Gravid females were allowed to lay egg on potted plants which were covered with mylar film cages. Later the plants were observed for the eggs to hatch to arrive at the incubation period of eggs. Experiments were replicated five times.

1.2.4. Morphological studies under electron microscopes

The eggs, nymphs, and adults of *M. hirsutus* were fixed in 2.5% glutaraldehyde prepared in 0.2M CaCo dilate buffer at pH 7.2 for one hour at room temperature. Washed in the cacodylate buffer and then washed again with double distilled water, dehydrated in graded series of ethanol. Critically dried in the critical point dryer, mounted on to the copper stubs and coated by gold in the sputter coater. The stubs were scanned from different angles under the scanning electron microscope (JEOL 100 C x 11-ASID4D) at 20 KV (Tewari *et al.*, 1994).
1.2.5. Biological studies of C. montrouzieri and S. coccivora

The biological studies of C. montrouzieri and S. coccivora were conducted separately on 35 days old mulberry plants of V1 variety with M. hirsutus infestation. All the experiments were replicated five times.

1.2.5.1 Total developmental period

The freshly hatched grubs were allowed to feed on mealy bug. The numbers of days taken to complete each instar, pre pupal and pupal period were recorded.

1.2.5.2 Ovipositional period and Fecundity

A pair of freshly emerged beetles was confined to cage with mealy bugs on potted mulberry plants. The numbers of days taken to lay eggs were recorded. The numbers of eggs laid were counted and recorded and taken average.

1.2.5.3 Incubation period

The freshly laid eggs were carefully observed for its hatching to find out the incubation period.

1.2.5.4 Adult longevity

Freshly emerged male and female were confined to mealy bug cages and insects were observed until death to calculate adult longevity.
1.2.5.5. Feeding potential of the predator

Freshly laid eggs of the predators were kept individually in small plastic jars and closed with cotton cloth (Fig.1.5). After hatching predator grubs in 20 jars were fed daily with fresh *M. hirsutus* eggs alone to find out number of eggs consumed in its grubal period. Predator grubs in other 20 jars were fed daily with *M. hirsutus* nymphs and predator in another 20 jars was fed with *M. hirsutus* adults daily. The similar feeding was continued until pupation. The number of eggs consumed, number of nymphs consumed and number of adults eaten, were counted separately and tabulated.

1.2.6. Biological studies of the parasitoid *A. kamali*

1.2.6.1. Developmental period

Third instar *M. hirsutus* nymphs were allowed to settle on mulberry sprouts and covered with mylar film cages. The freshly emerged adults of *A. kamali* were allowed into the cage for egg laying. After egg laying, the incubation period, larval period, pupal period were calculated by carefully examining under microscope.

1.2.6.2. Adult longevity:

A pair of freshly emerged *A. kamali* was allowed into test tubes covered with cotton wool. Honey syrup soaked cotton was placed for feeding. Adult longevity was recorded.
1.2.6.3. Fecundity and incubation period:

A pair of freshly emerged *A. kamali* male and female adults was allowed to lay egg on mealy bug (100 no.s) in mulberry sprouts. The number of eggs laid was counted under microscope. The eggs were daily examined until hatching to record incubation period.

1.2.6.4. Parasitization potential of *A. kamali*

A pair of freshly emerged *A. kamali* male and female adults was allowed to lay egg on mealy bug (100 no.s) in mulberry sprouts. The percentage of mealy bugs parasitized were recorded.

1.3. EXPERIMENTAL RESULTS

Results of the experiment on biological studies are detailed below:

1.3.1. Biology of *M. hirsutus*.

*M. hirsutus* is a hemimetabolous insects, had three stages egg, nymph and adult (Table 1.1).

1.3.1.1. Eggs

Eggs were found in loose white cottony ovisac(Fig.1.6). Eggs were orange in colour (Fig.1.7) and became pink before hatching. The incubation period of the eggs was $7 \pm 1.2$ days.
Table 1.1. Biology of mealy bugs *Maconellicoccus hirsutus* on the host mulberry.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Stage of the Mealy bug</th>
<th>Duration in days (Mean ± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>1</td>
<td>Incubation period of egg.</td>
<td>7 ± 1.2</td>
</tr>
<tr>
<td>2</td>
<td>Total nymphal period</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I instar</td>
<td>6.7 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>II instar</td>
<td>6.5 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>III instar</td>
<td>1.5 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>IV instar</td>
<td>6.2 ± 0.4</td>
</tr>
<tr>
<td>3</td>
<td>Total developmental period</td>
<td>27.9 ± 0.4</td>
</tr>
<tr>
<td>4</td>
<td>Adult longevity</td>
<td>3 ± 0.5</td>
</tr>
<tr>
<td>5</td>
<td>Fecundity</td>
<td>--</td>
</tr>
</tbody>
</table>

S.D – Standard deviation.
1.3.1.2 Nymphs

First instar nymphs called crawlers were light yellowish colour and gregarious (Fig. 1.8). They moved towards apical portion and started feeding with needle like mouth parts (Fig. 1.9). After feeding the nymphs become pink in colour. The first instar nymphal duration was $6.7 \pm 0.2$ days in male and $6.9 \pm 0.2$ days in females. The second instar nymphs were pinkish in colour settled in a place and started sucking the plant sap (Fig. 1.10). The second instar lasted for $6.5 \pm 0.3$ days for male and $6.7 \pm 0.31$ days for female. The third instar nymphs were broader and oval (Fig.1.11). The female nymphal duration was $8.0 \pm 0.7$ days and male was $1.5 \pm 0.2$ days. The males had four nymphal instar and females had only three nymphal instar. IV instar of male lasted for $6.2 \pm 0.4$ days. The total development period of male nymphs was $27.9 \pm 0.4$ days and of female nymphs were $28.6 \pm 0.8$ days (Chart.1.1).

1.3.1.3 Adults

Sexual dimorphism existed. Adult males were slender, elongate and possessed a pair of wings and caudal filament(Fig. 1.15). The male longevity was $3 \pm 0.5$ days. The females were oval, flat and devoid of wings (Fig.1.12) and caudal filament. Females longevity was $11 \pm 1$ days, died shortly after depositing eggs (Fig.1.14). Each female deposited $432 \pm 21$ eggs in ovisac. The males were moving but female remained sluggish. The nymphs and female adult were covered with white waxy filamentsand live in colony(Fig.1.13).
EARLIER STAGES OF *M. HIRSUTUS*

- fig. 1.6 Eggs inside cottony ovisac
- fig. 1.7 Egg mass
- fig. 1.8 I instar nymphs
- fig. 1.9 I instar nymphs in a tukra cluster
- fig. 1.10 II Instar nymphs
LATER STAGES OF *M. HIRSUTUS*

Fig. 1.11. III instar nymphs

Fig. 1.12. Adult Female

Fig. 1.13. Mealy bugs colony in tukra cluster

Fig. 1.14. Adult female with ovisac

Fig. 1.15. Adult Male
1.3.2. Morphological studies in electron microscope

1.3.2.1 Eggs

The eggs were elongate with thin membranous egg shell (Fig.1.16).

1.3.2.2 Nymphs

First instar nymphs were elongate, oval, and possessed a pair of anal lobes (Fig.1.17). Pair of triocular pores and several setae was observed on the antero ventral part of the nymph. Several trilocular pores scattered all over the nymphal body (Fig.1.18). The eyes were prominent. Two pairs of ostioles which exudates honeydew were seen on the dorsal surface.

Second instar nymph was broad anterior and rounded. The anal ring bears several setae. The antennae consist of six segments.

Sexual dimorphism was well marked from third instar nymph, female was oval with slightly broader anterior part (Fig.1.19). The male was elongate with two small wing pads at mesothorax. Trilocular, multilocular pores and ostioles were prominent (Fig.1.22). Fourth instar male nymphs had well developed antennae and wing pads (Fig.1.20).

1.3.2.3 Adult

Anterior end of the female body was round with prominent anal lobes. The vulva was placed postero ventrally enriched by a large number of tubular ducts (Fig.1.23). The adult male had well developed head, thorax, and abdomen,
SEM PHOTOGRAPHS OF M. HIRSUTUS

Fig. 1.16. Egg

Fig. 1.17. Dorsal view of a I instar nymph

Fig. 1.18. Ventral view of I instar nymph

Fig. 1.19. Postero ventral view of last instar female nymph
SEM PHOTOGRAPHS OF *M. HIRSUTUS* continued

Fig. 1.20. Male pupae covered with wax filaments

Fig. 1.21. Anterior view of male

Fig. 1.22. A wax pore

Fig. 1.23. Ventral view of female adult
with a pair of wings (Fig.1.21) and sickle shaped penal sheath at the posterior end.

1.3.3. Biological studies on predators.

Predators *C. montrouzieri* and *S. coccivora* were holometabolous insects and their biology are tabulated in table.1.2.

1.3.3.1 Biology of *C. montrouzieri*

The adult female laid eggs on the mealy bug colonies, the eggs were pale yellowish white, oval and shiny. Incubation period of eggs was 4.5 ± 0.5 days. The tiny first instar grub was grey in colour with white line across the body and fed on eggs and small insects in the colony. First instar lasted for 3.7 ± 0.2 days. Later the white line became white wax line. The duration of second, third and fourth instar nymphs were 2.3 ± 0.5, 4.5 ± 0.3, and 5.0 ± 0.1 days. The grubs were in prepupal period for 2.5 ± 0.5 days and pupal period for 9.0 ± 0.5 days. The grown up grubs were entirely covered with white waxy filaments (Fig.1.24) which was difficult to identify in a mealy bug colony. The total developmental period lasted for 31.5 ± 0.7 days. The grubs pupate inside the waxy strands. Adult longevity was 57 ± 3 for male and 60 ± 1 for female. The fecundity was 232 ± 10 in 45 ± 3 days of ovipositional period. The adults were dark brown beetle with dark orange head and posterior (Fig.1.25). The male can be differentiated from female by the brown colour of the first pair of legs where in female all the three pairs of legs were black.
Table 1.2. Biology of the predators and parasitoid of mealy bug

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Stages</th>
<th>Duration in days (mean ± S.D)</th>
<th>Cryptolaemus montrouzieri</th>
<th>Scymnus coccivora</th>
<th>Anagyrus kamali</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Incubation period</td>
<td></td>
<td>4.5 ± 0.5</td>
<td>4.5 ± 0.5</td>
<td>2.5 ± 0.5</td>
</tr>
<tr>
<td>2</td>
<td>Grub (larval period)</td>
<td></td>
<td>15.5 ± 0.9</td>
<td>11.5 ± 1</td>
<td>9 ± 0.5</td>
</tr>
<tr>
<td></td>
<td>I instar</td>
<td></td>
<td>3.7 ± 0.2</td>
<td>3.5 ± 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II instar</td>
<td></td>
<td>2.3 ± 0.5</td>
<td>2.0 ± 0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III instar</td>
<td></td>
<td>4.5 ± 0.3</td>
<td>2.5 ± 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV instar</td>
<td></td>
<td>5.0 ± 0.1</td>
<td>3.5 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Prepupal period</td>
<td></td>
<td>2.5 ± 0.5</td>
<td>2 ± 0.5</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>Pupal period</td>
<td></td>
<td>9.0 ± 0.5</td>
<td>6 ± 0.5</td>
<td>7 ± 1</td>
</tr>
<tr>
<td>5</td>
<td>Total developmental period</td>
<td></td>
<td>31.5 ± 0.7</td>
<td>24 ± 1.2</td>
<td>18.5 ± 1</td>
</tr>
<tr>
<td>6</td>
<td>Adult longevity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td></td>
<td>57 ± 3.0</td>
<td>59 ± 1.5</td>
<td>25 ± 6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td></td>
<td>60 ± 1.0</td>
<td>65 ± 2.5</td>
<td>30 ± 8</td>
</tr>
<tr>
<td>7</td>
<td>Ovipositional period</td>
<td></td>
<td>45 ± 3.0</td>
<td>35 ± 3.0</td>
<td>13 ± 4</td>
</tr>
<tr>
<td>8</td>
<td>Fecundity</td>
<td></td>
<td>232 ± 10</td>
<td>52 ± 6.2</td>
<td>60 ± 5</td>
</tr>
</tbody>
</table>

S.D - Standard deviation.
1.3.3.2 Biology of *S. coccivora*

Pale yellow coloured eggs were laid on the mealy bug colonies. The incubation period was $4.5 \pm 0.5$ days. The grub had four instars lasted for $11.5 \pm 1$ days. Long waxy threads were seen on grown up grubs (Fig.1.26). The prepupal and pupal periods were $2 \pm 0.5$ and $6 \pm 0.5$ days. The pupa was oval, light reddish brown seen beneath the waxy threads shed at the last moulting. The total developmental period of *S. coccivora* was $24 \pm 1.2$ days. The female longevity was $65 \pm 2.5$ days in which $35 \pm 3.0$ day were ovipositional period. Adult laid $52 \pm 6.2$ eggs during its life time (Charts 1.2). The adults were light yellowish brown with dark brown markings along the mid dorsal line (Fig.1.27).

1.3.4. Biology of parasitoids.

The biology of *A. kamali* was studied on *M. hirsutus*. The incubation period of egg was $2.5 \pm 0.5$ days. The larva with three instar lasted for $9 \pm 0.5$ days. The pupa seen inside the mealy bug mummies (Fig.1.28) lasted for $7 \pm 1$ days. The total developmental period was $18.5 \pm 1$ days. The adult is a hymenopteran fly (Fig.1.29) The male longevity was $25 \pm 6$ days and female longevity was for $30 \pm 8$. The ovipositional period was $13 \pm 4$ days. A single female laid $60 \pm 5$ eggs.
ENTOMOPHAGES OF *M.hirsutus*

Fig. 1.24. Larvae of C. montrouzieri

Fig. 1.25. Adult of C. montrouzieri

Fig. 1.26. Larva of S. coccivora

Fig. 1.27. Adult of S. coccivora

Fig. 1.28. Parasitized M. hirsutus mummy

Fig. 1.29. Adult of A. kamali
1.3.5. Feeding potential of the predators.

1.3.5.1 *C. montrouzieri*.

Both grubs and adults were found feeding on all the stages of mealy bug. The fourth instar grub was the voracious feeder. A single grub consumed 880 ± 15 eggs, or 250 ± 15 mealy bug nymphs or 25 ± 3 adults. An adult beetle consumed 1251 ± 25 eggs or 300 ± 11 nymphs or 127 ± 5 adults of mealy bug (Table 1.3).

1.3.5.2 *S. coccivora*

*S. coccivora* grubs and adult were predacious on all stages of mealy bug. The grub consumed 200 ± 25 eggs or 60 ± 5 nymphs or 7 ± 2 adults during their life period. The beetle consumed 950 ± 50 mealy bug eggs or 125 ± 10 nymphs or 45 ± 5 adults.

1.3.6 Parasitization potential of *A. kamali*

This is a solitary endoparasitoid of the mealy bug. The larvae developed inside the mealy bug. At the end pupa was formed inside the mealy bug which looked like mummies. A single adult parasitized 50 ± 2 bugs. Overall 60 ± 5 per cent of bugs were parasitized by *A. kamali* the in a mealybug colony.
Table 1.3. Feeding potential of coccinellid predators on *M. hirsutus*

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Coccinellid</th>
<th>Stage of the coccinellid</th>
<th>Stage of the <em>M. hirsutus</em> consumed in numbers (mean + S. D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Egg</td>
</tr>
<tr>
<td>1</td>
<td><em>C. montrouzieri</em></td>
<td>Adult</td>
<td>1251 ± 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grub</td>
<td>880 ± 15</td>
</tr>
<tr>
<td>2</td>
<td><em>S. coccivora</em></td>
<td>Beetle</td>
<td>950 ± 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grub</td>
<td>200 ± 25</td>
</tr>
</tbody>
</table>

S.D - Standard deviation.
1.4. DISCUSSION

Studies on the biology of the insects of different trophic level is very essential to correctly study the tritrophic relation and fit them in integrated pest management programmes (Manjunath, 2003). Hence the biological studies were conducted on pest, predator and parasitoids and the results are discussed below.

1.4.1. Biology of *M. hirsutus*

The oval shaped orange coloured eggs deposited in the ovisac were protected by white cottony wax secreted by the adult female. Cox and Pearce (1983) reported that prior to oviposition the female begin to secrete wax from different pores and tubular ducts located around the vulva which form a whitish waxy ovisac. This white cottony wax protected the eggs. The total development period of adult male was 27.9 ± 0.4 days and a female was 28.6 ± 0.8 days. The male had four nymphal instars and female had three instars. These are in confirmity with the reports of Mani (1987), Gautam (1994) and Manjunath et al. (1996).

The adult male was winged, slender, elongate, and possessed a pair of caudal filament and it quickly moved in the colony but did not feed. This is in confirmity with the studies of Tewari *et al.*, (1994). They also reported that the mouth parts were absent in adult male.

Female longevity was 11 ± 1 days, they were neotenic, apterous, immobile, oviparous and attain largest size in the colony. The fecundity was 432 ± 21. The
CHART 1.1. LIFECYCLE OF MEALYBUG, *MACONELLICOCCUS HIRSUTUS* ON THE HOST MULBERRY

<table>
<thead>
<tr>
<th></th>
<th>Incubation period</th>
<th>I instar</th>
<th>II instar</th>
<th>III instar</th>
<th>IV instar</th>
<th>Adult longevity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
anterior end of female body was round with prominent anal lobes. The vulva placed postero - ventrally enriched by a large number of tubular ducts. Same observations were also reported by Ghose (1971), Sriharan et al., (1979) and Cox and Pearce (1983).

1.4.2. Biology of *C. montrouzieri*

The *C. montrouzieri* completed its development in $31.5 \pm 0.7$ days and the adult female longevity was $60 \pm 1$ days with ovipositional period of $45 \pm 3.0$ days. Female laid $232 \pm 10$ eggs with $4.5 \pm 0.5$ days of incubation. The grub had four instars and the fourth instar grub was the voracious feeder. The grown up grubs were entirely covered with white waxy filaments (Mani, 1989). Jalali et al., (1999) and Muralibaskaran et al., (2002) also reported the similar observations.

1.4.3. Biology of *S. coccivora*

This common indigenous predator of *M. hirsutus* laid $52 \pm 6.2$ eggs in their life time, which hatched in $4.5 \pm 0.5$ days. The larval period was completed in $11.5 \pm 1$ days. The total developmental period was $24 \pm 1.2$ days and it was seven days lesser than *C. montrouzieri*. But the adult longevity was $59 \pm 1.5$ days for males and $65 \pm 2.5$ for females with the total ovipositional period of $35 \pm 3.0$ days. The similar observations were done by Mani and Thontadarya (1987) and Muralibaskaran et al., (2006).
CHART 1.2 LIFE CYCLE OF THE PREDATORS OF MEALYBUG

Developmental period and adult longevity

- Incubation period
- I instar
- II instar
- III instar
- IV instar
- Prepupal period
- Pupal period
- Female longevity
- Male longevity

Days

Scymnus coccivora
Cryptolaemus montrouzierie
CHART 1.3 LIFE STAGES OF THE PREDATOR AND PARASITOIDS OF MACONELLICOCCUS HIRSUTUS

Number in days

Cryptolaemus montrouzieri Scymnus coccivora Anagyrus kamali

Incubation period Larval period Prepupal period Pupal period Female longevity Male longevity Ovipositional period
1.4.4. Biology of A. kamali.

The total developmental period of A. kamali was 18.5 ± 1 days. The larvae developed inside the mealy bug and become pupa inside the mealy bug which looked like mummies. This is in agreement with the finding of Noyes and Hayat (1988) and Sagara et al., (2000). The male longevity was 25 ± 6 days and that of female was 30 ± 8 days in which 13 ± 4 days was ovipositional period with 60 ± 5 fecundity (Chart 1.3).

1.4.5. Feeding potential of the predator.

1.4.5.1 C. montrouzieri.

This Australian lady bird beetle, called mealy bug destroyer is a potential predator of M. hirsutus (Goolsby et al., 2002). The grubs and adults were the predator. Among the four stages of grub the last instar was the voracious feeder. A single grub consumed 880 ± 15 eggs, or 250 ± 15 nymphs or 25 ± 3 adults through out the immature stage. This is in accordance with reports of Mani (1988).

The adult also consumed 1251 ± 25 mealy bug eggs or 300 ± 11 nymphs or 127 ± 5 mealy bug adults. These are in confirmity with the reports of Mani, (1988), Muralibaskaran et al., (2002) and Masilamani et al., (2003).
CHART 1.4 FEEDING POTENTIAL OF CICCINELLID PREDATORS ON *M. HIRSUTUS*

![Bar chart showing feeding potential of Ciccinellid predators on *M. Hirsutus*.](chart)

- **Cryptolaemus montrouzieri**
  - Adult
  - Grub

- **Scymnus coccivora**
  - Adult
  - Grub

Legend:
- ☐ Egg of *M. hirsutus* consumed
- ☐ Nymph of *M. hirsutus* consumed
- ☐ Adult of *M. hirsutus* consumed

The chart indicates the feeding potential of *Cryptolaemus montrouzieri* and *Scymnus coccivora* in terms of numbers consumed (Egg, Nymph, Adult) of the prey *M. hirsutus*. The consumption levels are quantified on the y-axis, with bars showing the frequency or quantity of each type of prey consumed by each predator species.
1.4.5.2. *S. coccivora*

The grubs were active predators on all the stages of mealy bug. The fourth instar grubs were voracious feeder. A grub during its life period consumed $200 \pm 25$ mealy bug eggs for its development. A grub consumed $60 \pm 5$ mealy bugs to complete its development or $7 \pm 2$ *M. hirsutus* adults. These are in accordance with the earlier reports of Mani and Thontadarya(1987) and Mani (1988).

The adult coccinellid was also a predator. It consumed $950 \pm 50$ mealy bug eggs when fed with eggs alone. When fed with mealy bug nymphs the coccinellid consumed $125 \pm 10$ nymphs and when fed with adult mealy bugs the coccinellid consumed $45 \pm 5$ adults. This is in confirmation with the reports of Katiyar and Sen, (1998) and Muralibhaskaran *et al.*, (2006) (Charts 1.4).

1.5. Parazitation potential of *A. kamali*

*A. kamali* was an endoparasitoid on mealy bug nymph. A single adult parasitized $50 \pm 2$ mealy bugs. Katiyar *et al.*, (1997) reported one female parasitized 67 mealy bugs. Overall $60 \pm 5$ per cent *M. hirsutus* nymphs were parasitized by *A. kamali* in a colony. Mani, (1989) reported that *A. kamali* parasitized 66 - 100 per cent of *M. hirsutus* mealy bugs in a colony. Sagara, *et al.*, (2001) reported that $4.5 \pm 2.04$ numbers of *M. hirsutus* host were parasitized by a single female in 30 minutes. Katiyar and Sen (1998) reported that the *A. kamali* adults released in field was found to parasitize 69.1 per cent of mealy bug colony.