LIFE CYCLE OF LADYBIRD BEETLE (*Rodolia sp*.) AND ITS PREDATION EFFICIENCY ON MANGO MEALYBUG (*Drosicha mangiferae*)

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CERTIFICATE

This is to certify that thesis entitled **"LIFE CYCLE OF LADYBIRD BEETLE (*Rodolia sp.*) AND ITS PREDATION EFFEICIENCY ON MANGO MEALYBUG *(Drosicha mangiferae)*"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **MST. AFRIN AKTER BHUIYAN, Registration No. 14-06354** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY BELOVED PARENTS

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LIFE CYCLE OF LADYBIRD BEETLE (*Rodolia sp.*)AND ITS PREDATION EFFICIENCY ON MANGO MEALYBUG (*Drosichamangiferae*)

ABSTRACT

The life cycle and predation efficiency of ladybird beetle(*Rodolia sp.*) on mango mealybug (*Drosicamangiferae*) were studied under the central laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, during December, 2015 to March 2016. Initially the eggs were deep yellow to pale red in color. The average length and breadth of the eggs were 1.21±0.07 mm and 0.67±0.09 mm, respectively. The eggs hatched within 12 to 14 days with an average of 12.90±0.57 days. The larvae were soft bodied, reddish in color, elongate and passed through four larval instars in three moults. The duration of larval period was 64.00±19.80 days. The 1st, 2nd, 3rd and 4th larval instars lasted for 8, 17, 22 and 31 days, respectively. The final instar larvae attained a greater size and become more strong and stout. Their body sizes was9.55±0.39 mm in length and 3.02±0.05 mm in breadth. The duration of the 4th instar larvae varied from 17 days to 31 days. The duration of pre-pupal and pupal stage varied from 2 to 5 days and 3 to 8 days respectively. The total duration from egg to adult was completed within 67 to 105 days. The adult beetle was initially orange in color but finally it gained red color. The size ranged from 7.00 mm to 8.40 mm in length and 5.00 mm to 5.50 mm in breadth. Ladybird beetle fed on mango mealybug. But their rate of feeding varied. They feed in both day and night but mainly in day time. The feeding rates increased gradually from the 1st instar to 2nd instar but decreased sharply in the 3rd instar and in the adult stage as well. One 1st instar larva of ladybird beetle consumed 0.63±0.13 1st instar nymph per day. Second instar larva of ladybird beetle fed 0.92±0.27 nymph of 2nd instar per day. The average consumption of 3rd instar ladybird beetle larva was 0.52±0.05 nymph of 3rd instar per day and an adult ladybird beetle fed 0.13±0.08 adult mango mealybug per day.

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CHAPTER I

INTRODUCTION

The ladybird beetle has been known worldwide as predator of a number of insects. The species is distributed in many countries of Asia namely, India, Bangladesh, Taiwan and Malaysia. Both the larvae and adults are used in pest control, where they are applied primarily as feeder of plant lice. The beetles have already established themselves as one of the major predators of mealybugs. Mealybug feeder coccinellid beetles reduce the incidence of mealybug infestations. Three types of feeding regimes are present within the Coccinellidae predation (zoophagy), plant feeding (phytophagy) and fungus feeding (mycophagy). Most Coccinellidae (90%) are predators, feeding on the suborder Sternorrhyncha(Seago *et al.* 2011, Iperti 1999, Giorgi *et al.* 2009). The predator status of most ladybirds justifies its importance as regulators of many potential insect pests of agricultural and forest ecosystems (Iperti 1999).Biological control with *Coccinellids* has contributed greatly and suppressed the pests below economic damage level (Hoy and Nguyen2000).

The family Coccinellidae comprises 5,200 described species worldwide. These are medium size beetles with an oval, oblong or hemispherical body shape (Majerus 1994). Most of them are of brightly shining colours with a pattern of spots or patches against a contrasting background. Many appear to be distasteful to birds and their conspicuous appearance is likely to be an example of warning coloration (Moreton1969). Numerous species of ladybirds are major biological control agents of pests such as aphids, mealybugs, scale insects, thrips and mites in all parts of the globe (Moreton 1969). Some are specific in their choice of food, while many are polyphagous. Ladybird beetles undergo complete metamorphosis with distinct egg, larval, pupal and adult stages (Shah 1985). Their life cycle is completed in three months depending upon location and

temperature; two or three generations are generally produced in a year. Adults overwinter in sheltered locations such as tree holes and other natural hiding places (Majerus and Kearns 1989).Debraj Singh (1990) investigated the total period from egg to adult of *Micraspis sexmaculatus* in the laboratory. They found that the total period from egg to adult was completed within 40 to 45 days. The incubation period was 8-10 days. The mean duration of the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} larval instars and pre pupal and pupal periods were 4.69, 3.92, 5.0, 7.6, 2.6 and 8.6 day, respectively. The total larval period ranged from 20 to 23 days.

Mango, *Mangifera indica*, is an evergreen tree in the family Anacardiaceae grown for its edible fruit. Mangoes play an integral part in rural household lives not only by being rich nutrient source but also serving as a common food that is consumed casually. Particularly in rural areas mango serves principally as a complementary food to populations during the dry-season when staple crops are not produced and food reserves have dwindled. This crop provided the most freely available fruit energy and vitamin A and C sources, especially valuable for children in a part of the world where up to 20% of infants die before the age of five (Moore 2004).It is the national fruit of India, Pakistan and Phillipines and national tree of Bangladesh.

Many insect pests attack mango tree. Among them mango Mealybug, *Drosicha mangiferae* (Homoptera: Monophlebidae) is a serious one.Mango Mealybugs are soft bodied, sap feeding insects with mouthparts adapted to piercing and sucking. They secrete a powdery, white wax covering over the body. Williams (2004) described that Mealybugs are of ever increasing importance in economic entomology. Some species are notorious crop pests and several have caused immense economic damage.Moore (2004) reported that mango mealybug became a serious pest of mango and citrus in West Africa which reduced mango fruit 50-90% andcaused social and cultural problems. *D. mangiferae*

made the growers decrepitude through setting of no fruits at all (Sen 1955). Farmers in Pakistan uprooted their orchards to cascade pest invasion. Karar *et al*. (2010) found 18 to 81% yield loss in different varieties of mango due to this pest attack.

The occurrence of mango mealybug in Bangladesh was first reported by Karim (1989). The mango mealybug, suck the sap from different parts of the plant and weaken it. The leaves become crinkled, yellowish and withered. Other parts also become withered and dropped down from the plant. The honey dew excreted by the mealybug and the associated black sooty mould formation impairs photosynthetic efficiency of the affected plants.

The control of mango mealybug in Bangladesh is principally achieved by the conventional use of the insecticides. Their indiscriminate use has created several problems in agro-ecosystem, such as direct toxicity to beneficial organisms, fishes and man, increased insecticide resistance, increased environmental and social costs, health hazards and environmental pollution. Franco (2009) reported that apart from health and environmental hazards caused by chemical pesticides, pesticide applications do not generally provide adequate control for mealybugs in the long term owing to their cryptic behavior, their typical waxy body cover and clumped spatial distribution pattern. The biological control is one of the most effective means of achieving insect control (Pedigo 2004). Now a days, integrated pest management (IPM) is well known to entomologists, where all suitable pest control techniques are being used to find ecologically sound and environmentally safe ways of pest control. Biological control should be regarded as the backbone of any IPM program and about 90% of all potential pests are already under biological control (Debach and Rosen 1991).The predaceous coccinellid beetles are considered to be of great economic importance in agro-ecosystem. They have been successfully employed in the biological control of many injurious insects. Therefore, it is

very important to study the life cycle of lady bird beetle. Though the mango mealybug is a serious pests and control through non-chemical tactics by the researcher throughout the world is limited. To minimize the use of synthetic insecticides and problems arising out of their frequent use, it is very essential to develop alternate control option. Therefore, the present study was under taken to find out the synchronization of its life cycle with mango mealybug. In view of this requirement studies were undertaken to study the life cycle of ladybird beetle and its predaceous effect on mango mealybug with the following objectives:

- to study and determine different stages and duration of life cycle of ladybird beetle (*Rodolia sp*.)
- to study the predation efficiency of various active stages of ladybird beetle (*Rodolia sp.)*

CHAPTER II

REVIEW OF LITERATURE

Research works on life cycle of ladybird beetle and its predation efficiency on mango mealybug are scanty in home and abroad literature have been found on the predation efficiency of ladybird beetle on other mealybug and other insects. Review of literatures on the relevant field were searched and presented under the following sub headings.

2.1 Distribution of ladybird beetle

Coccinellidae are extremely diverse in their habits, they live in all terrestrial ecosystems (Skaife 1979). They are distributed in many countries of Asia, including Bangladesh. These beetles often called ladybug or coccinellids. They are the most commonly known beneficial insects. In Europe these beetles are called Ladybirds (Williams 2004). Lady bird beetle are more or less worldwide in distribution. About 6000 species of Coccinellidae are known worldwide (Vandenberg 2000) with over 300 species known from the Indo-Pakistan sub-continent (Rahatullah *et al.* 2010). Rahatullah *et al*. (2010) documented 4,000 predatory species of this family of which more than 300 species from Indo-Pak subcontinent. While 71 species are found only in Pakistan (Irshad 2001).

2.2Biology of ladybird beetle

Biology of ladybird beetle was studied by a number of researcher in Bangladesh, India, Thailand and the Philippines (Hannan 1997, Prodhan *et al*. 1995, Pathan and Khan 1994, Agarwala *et al.* 1988, Ngammuang 1987, Samal and Misra 1985, Islam and Nasiruddin 1978). Predaceous ladybird beetles (Coleoptera: Coccinellidae) occur within the subfamilies Chilocorinae, Coccinellinae, Coccidulinae, Scymninae, Sticholotidinae (Hodek and Honek 1996, Latreille 1807). Islam and Nasiruddin, (1978) described that,

the ladybird beetles have been known worldwide as a predator of a number of insects. Shah (1985) described that, ladybird beetles undergo complete metamorphosis with distinct egg, larval, pupal and adult stages. Majerus and Kearns (1989) reported that ladybird beetles lay their eggs on the leaves, stems and sometimes on the bark of trees often near pray. The eggs of most species are long, usually oval and vary from a light yellow to a deep orange color. Larvae are usually brightly colored with various protuberances on the body segments. They go through four instars and then pupate on a leaf or branch by attaching the body to leaf surface. Although the pupae are generally thought to be inactive, they are not completely immobile.

Majerus and Kearns (1989) also observed that their life cycle is completed in one month depending upon location and temperature; two or three generations are generally produced in a year. Adults overwinter in sheltered locations such as tree holes and other natural hiding places. They are of great economic importance as predaceous both at larval and adult stages on various important crop pests such as aphids, mealybug and other soft bodied insects (Kring *et al*. 1985, Hippa *et al*. 1978).

Frazer and Mc Gregor (1992) recorded the temperature dependent survival and hatching rate of eggs of seven species of coccinellids. At 12^0C egg hatched within 14 to 21 days at 20^0C it was within 4 to 5 days depending on species. The survival rate of eggs masses differed significantly between species and temperature.

Agarwala and Dixon (1993) stated that clusters of coccinellids eggs were less viable than single one. They also found single larva developing faster than in groups when food supplies were abundant. Patro and Sontakke (1994) studied the biology of *Coccinella transversalies* (F.) in the laboratory at 28^0C±^{0}1 with 57.9%±10.4 R.H on *Aphis craccivora*Koch a pest of *Dolichos lablab* (L.). They found that the duration of egg, larva,

pre-pupal and pupal stages of this coccinellids were 2.03± 0.22, 8.23± 0.13, 0.61± 0.13 and 2.48± 0.21 days, respectively.

The total life cycle of *Coccinella eryngii* was recorded to be 24 to 34 days using *Metopolophium dirhodum* as prey (Aguilera 1995). In the same years, Obrycki (1990) recorded the pre-oviposition and oviposition period of *Coccinella septempunctata* L. to be 6 and 12 days respectively at 26^0C when reared on *Acyrthosi phonpisum*.

Miller and Lamana (1995) stated that the oviposition period of *Coccinella trifasciata* decrease from 44.2 to 11.1 days when temperature was increased from 18^0C to 34^0C. Jagadish *et al*. (1996) studied the biology of *C. septempuctata* L. and *C. transversalis* (F.) using aphid (*Hysteroneura seteriae*) as prey. They found that the incubation periods of *C. septempuctata* L. *C. transversalis* (F.) was 4.5 to 5.0 and 4.0 days, respectively. The larval duration of *C. septempuctata* was 8.9days, and for *C. transversalis* (F.) it was 8.9 days, whereas for *C. transversalis* (F.) it was 7.1 days. Adult females of *C. septempuctata* L. *C. transversalis* (F.) lived for 42 and 37 days producing 518 and 407 eggs respectively. Biology of *C. septempuctata* L.was studied under laboratory condition in cabbage aphid (Nirmal *etal*. 1996). The durations of the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instar larvae were 2.0± 0.35, 1.67± 0.31, 1.33± 0.18 and 2.33V 0.25 days, respectively. The fecundity of the predator was recorded as 466.00± 1.96 eggs.

Samal and Misra (1985) studied the seasonal effects on the biology of *Micraspis discolor*. They found that total life cycle lasted about 18 to 24 days in August- December, 18 to 34 days in November to January and 18- 26 days in February to May and the adults lives for 25- 40 days in September to November. Islam (1978) reported that incubation period of *Micraspis discolor* (F.) was 2 days and hatching percentage of eggs was almost 100%. Ngammuang (1987) found that *Micraspis discolor* produced of 181.07±66.37 eggs on

Aphis craccavivora as food. The incubation period was 2.45± 0.5 days, while the pupal duration was 3.43± 0.57 days. Adult longevities of male and female were 37.80± 15.24 and 59.53± 23.47 days, respectively.

Hannan (1997) reported that the larvae passed through four larval instar with three moults. The first instar larva measured on an average of 1.52 mm in length and 0.49 in breadth. The average duration of first to fourth instar larva was 1.53, 1.40, 1.64 and 2.48 days, respectively when these were supplied with maize aphid, wheat aphid, bean aphid and rice pollen, respectively. The mean length and breadth of second instar larva averaged 2.88 mm and 0.6 mm. The average duration was 2.33, 2.35, 2.05 and 2.89 days on maize aphid, wheat aphid, bean aphid and rice pollen, respectively. The third instar larvae were more active. The length and breadth was found 4.06 mm and 1.02 mm, respectively. The highest duration (3.89 days) was found on rice pollen followed by 3.31, 3.10 and 3.05 days when maize, wheat and bean aphids were used as host, respectively. The 4^{th} instar larva measured with an average of 5.09 mm in length and 1.20 mm in breadth. The average duration of fourth instar larva was 3.23, 3.25, 3.65 and 4.499 days when fed on maize aphid, wheat aphid, bean aphid and rice pollen, respectively. Total larval duration was 10.22, 10.40, 10.33 and 13.75 when reared on maize, wheat, bean and rice pollen, respectively.

Prodhan *et al*. (1995) reported a short pre-pupal stage of *M. discolor*. At the beginning of this stage the full grown larva stopped feeding and became stout and thick. The pre-pupal stage lasted for 1.2 days. The pupa was reddish in colour. The female pupa was larger than the male. The mean length and breadth of the male pupa were 2.98 mm and 2.06 mm and those of the female pupa were 3.23 mm and 2.43 mm, respectively. The mean pupal period was 3 days. Samal and Misra (1985) observed the pupal period to be 4.8 days during February to May. Hannan (1997) found that in pupal stage all the larval characters

were lost became raddish in color. The female pupa is larger than male. The average length and breadth of a male pupa was 2.98 mm and 2.01 mm, respectively whereas those for females were 3.23 mm and 2.42 mm, respectively.

Samal and Misra (1985) reported that *M. discolor*lived for 25- 40 days in September to November. Ngammuang (1987) found that the longevities of male and female were 37.8± 15.24 and 59.53± 23.53 days, respectively when fed on *Aphis craccavora*. Hannan (1997) reported that the longevity of female and male were 43.10 and 34.29 days, respectively when fed on maize aphid. When the beetle was fed on wheat aphid the longevities of male and female were 27.7 and 37.0 days respectively. Longevities on bean aphid and rice pollen were 48.47 and 54.57 days, respectively. Male lived for 39.14 days on bean aphid 42.00 days on rice pollen.

Solangi *et al*. (2005) studied the biology of zigzag ladybird beetle (*M. sexmaculatus*) on mustard aphid, *Lipaphis erysimi* Kalt. The results indicated that the mean duration of different larval instars in days of *M. sexmaculatus* were 1st instar 2.7±0.48, 2nd instar 2.6±0.52, 3rd instar 3.2±0.63 and 4th instar 3.8±0.78 days. The mean larval period of all larval instars was 12.3±2.41 days and the mean pupal duration was 6.5±0.28 days. The mean fecundity was recorded 18.0±9.32 eggs. The mean incubation period was 3.6±12.03 days and the percent hatching was 54.12±12.03 days. The results also suggested that mean emergence (%) of male and female were 42.40% and 42.49%, respectively.

Mari *et al*. (2004) studied the bilogy of *M. sexmaculatus* on alfalfa aphid, *Therioaphis trifolii* Monell Duration of copulation in *M. sexmaculatus* was 4.5±6.1 minutes. The oviposition and post-oviposition periods were 27.4±4.1 and 4.5±0.3 days, respectively. The mean egg period was 8.6±1.2 days, larval duration of first, second, third and fourth

instars were 7.3±0.6, 4.3±0.2, 3.8±0.3 and 6.7±1.1 days, respectively. The adult periods of female and male under this study were 34.9±1.8 and 29.7±1.2 days, respectively.

Jagadish and Jayaramaiah (2004) reported that *Chilominus sexmaculatus* is a key predator of the tobacco aphid, *Myzus nicotianae*. The development of the predaceous beetle was studied at five temperatures (15, 20, 25, 30 and 35^0C) and five relative humidity regimes from 32.5 to 96.5% and their interactions. Temperatures at 25^0C and 30^0C were highly congenial, whereas 15^0, 20^0 and 35^0C were lethal. A decrease in the RH resulted in the increase in the grub and adults period. The study demonstrates that extreme temperatures of 15^0, 20^0, 30^0C were not favorable for the development of the predator, while 25^0C and 30^0C and their relative humidity combinations were optimum.

Hameed *et al.* (2013) reported that, eleven spotted ladybird beetle, *C. undecimpunctata* L. laid clusters of yellowish orange eggs that turned into dark yellow before hatching. Each cluster had an average of 10-15 eggs. Incubation period was about 2-3 days, average duration of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} larval instars were 3-4, 2-3, 3-4 and 3-4 days, respectively and they are black in color with an appearance of small alligator. The pupa was dark brown in color and pupal period was 4-5 days.

Solangi *et al.* (2007) reported that the mean incubation period of ten eleven spotted ladybird beetle in the laboratory was 3.7±0.94 days within the range of 2-3 days, while 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instar larval period was 3.1±1.19, 3.1±0.87, 3.5±1.26 and 3.3±0.94 days within the range of 2-5, 2-4, 2-6 and 2-5 days, respectively and pupal period was 5.6±0.96 days within the range of 4-6 days.

In another study it was reported that egg production per female averaged 142.33, incubation period of eggs 2-9 days, four larval instars and last larval stage duration were 7.0, 7.5, 12.0, 16.0 and 23.0 days, pupal development average 2.5 days at 30C and 7.5

days at 14C and egg to adult life cycle duration 12, 14, 21, 27.5 and 38.5 days at 30^0, 26^0, 22^0, 18^0 and 14^0C, respectively was reported by Eraky and Nasser (1995).

Siddhapara (2012) studied *Cryptolaemus montrouzeiri* on cotton mealybug, *Phenococcus solenopsis* (Tinsley) and reported that it did not lay eggs in the mealybug colonies under the laboratory conditions when reared on *P. solenopsis.* The average incubation period and hatching percentage were 5.12±0.87 days and 92.61±3.93 percents, respectively. The average developmental period of first, second, third, and fourth instar larva were 3.04±0.28, 2.34±0.48, 3.06±0.24 and 4.18±0.48 days, respectively. The average total larval period was 12.62±1.67 days, while prepupal and pupal period were 1.88±0.39 and 6.98±0.58 days, respectively. The average pre-oviposition, oviposition and post oviposition period were 5.68±1.10, 41.04±2.26 and 5.26±1.21 days, respectively. The average longevity of male and female was 42.3±2.03 and 51.98±2.68 days, respectively. Total life cycle occupied on an average of 68.92±2.37 days by male and 78.58±2.98 days by female.

2.3 Damage caused by mango mealybug (*Drosicha mangiferae*)

William 2004 reported that mealybugs are soft bodied, sap feeding insects with mouthparts adapted for piercing and sucking, secrete a powdery, white wax covering over the body. Mealybugs are of ever increasing importance in economic entomology. Some species are notorious crop pests and several have caused immense economic damage. In the last thirty years, four major outbreaks of mealybugs have occurred globally due to species being accidentally introduced to countries outside their area of origin, without the natural enemies that normally keep them in check.

Mealybugs are sap feeding insect pests inflict losses to their host plants in several ways. They suck sap from the host plant phloem tissue, removing biomass and water. Exud

sugary honeydew that cover plant surfaces, blocking stomata, so impeding gas exchange, respiration and photosynthesis and hence yield (Abbas *et al*. 2005,Watson and Kubiriba 2005, Williams 2004, Gullan and Kosztarab 1997). Worldwide, mealybugs constitute one of the major threats to horticultural production, causing heavy pre-harvest and post-harvest losses and curtailing expansion of both domestic and international trade of fruits (Osman and Chettanachitara 1989). Several mealybug species are vectors of viral diseases of various crops: banana (Watson and Kubiriba 2005, Kubiriba *et al*. 2001, Thomson *et al*. 1996) black pepper (Bhatt *et al.* 2003), grapevine (Cid *et al*. 2007; Sforza *etal*. 2003), rice (Abo and Sy 1998), sugarcane (Lockhart *et al*. 1992) etc. Many mealybug species have been reported attacking vegetables, fruit trees, citrus, curry leaf plant, cotton, mango, banana, coffee etc (Daane *et al*. 2007, Rao *et al*. 2006, Cox 1989). Among mealybug, the giant mango mealybug, *Drosicha mangiferae* Green (Monophlebidae: Homoptera) is a serious pests of the fruit tree in India (Stebbing 1902), China (Pradhan 1969) and Pakistan (Rahman and Latif 1944).

Ashfaq *et al*. (2005) reported that mango was severely damaged by the giant mango mealybug (*Drosicha stebbingi*). Karar *et al.* (2010) also reported that *D. mangiferae* was the serious, dilapidating, polyphagus, dimorphic and notorious pest of mango orchards in Pakistan. Their feeding process steadily weakened the branches, which leads to falling of flowers and the immature fruits. The honeydew exuded by developing mealybugs induced appearance of sooty mould near the affected region and caused necrosis of the affected parts (Khan 1989, Atwal 1976). Mohan *et al*. (2004) described that mango mealybug *D. mangiferae* was a serious pest in fruit orchards. The nymphs and females of this bug suck sap from inflorescence, tender leaves, shoots and fruit peduncles. Affected panicles shrivel and died. Infested plants were affected by the sooty mould (Tandon and Lal 1978). Similarly Pruthi and Batra (1960) reported the growth of sooty mould on the leaves

affected photosynthetic activity. Sooty mould fungus growth on the honeydew (Smith *et al*. 1997) rendered the fruit unmarketable, reduced the photosynthetic efficiency of leaves and caused leaf drop (CAB International 2005). Severe infestation affected the fruit set and caused fruit drop. It caused immense damage and deprived the trees from its nutrients, ultimately quality and quantity of the fruit were severely reduced (Herren 1981). Moore (2004) reported that mango mealybug became a serious pest of mango and citrus in West Africa which reduced mango fruit 50-90% and pest caused social and cultural problems. *D. mangiferae* made the growers decrepitude through setting of no fruits at all (Sen 1955). Farmers in Pakistan uprooted their orchards to cascade pest invasion. Karar *et al*. (2010) found 18 to 81% yield loss in different varieties.

2.4 Predaceous effect of Ladybird beetle

Franco (2009) reported that apart from health and environmental hazards caused by chemical pesticides, pesticide applications do not generally provide adequate control for mealybugs in the long term owing to their cryptic behavior, their typical waxy body cover and clumped spatial distribution pattern.

About 90% of coccinellid species are considered beneficial because of their predatory activity, mainly against homopteran insects and phytophagous mites injurious to various agricultural and forest plants.

Since prey is the main limiting factor for ladybird beetle reproduction (Dixon 2000, Hodek and Honek 1996) adults tend to synchronize their life cycle with that of their prey (Dixon 2000, Sloggett & Majerus 2000 and Evans and Dixon 1986). Life cycle synchronization may be achieved through dormancy, migration or reproductive diapause (Hodek and Honek 1996).

In many studies it is known that *Coccinella septempunctata* L. commonly called lady bird beetle is a capable predator and can be used for the biological control of *T. tabaci* and *T.vaporariorum* in a greenhouse (Soloman 1949). Victor 1997 reported that *Coccinellaseptempunctata* is considered to be an important bio control agent for soft bodied insects such as aphids, white flies, jassids and lepidopterous larvae which are among the first to be used in this fashion.

Mani and Thontadarya (1987) observed that *Cryptolaemus montrouzieri* Muls (Coleoptera: Coccinellidae) is a mealybug predator, both larvae and adults attack all stages of mealybug, *Planococcus citri* (Risso). This predator is most effective in high infestations, but with the scarcity of food, it feeds on soft scale insects and aphids.

Mani (1988) reported that *C. montrouzieri* succeeded to suppress the population of the grape vine mealybug, *Maconellicocushirsutus*; the release of 1000-1500 adults predator/acre gave an effective control within two months.

Srinivasan and Babo (1989) in India found that maximum effect of this predator against the mealybug, *Macunillicocus hirsutuson*Grapes was observed at six weeks after the initial release, with 64.3% reduction when 10 predators were per vine.

In India, Mani *et al*. (1990) reported that the population of the mealybug *Ferrisia virginata* in guava orchards was controlled within 50 days after releasing *Cryptolaemus montrouzieri.*

Hafiz *et al*. (2012) studied that both predators *Chrysoperla carnea* and *Cryptolaemus montrouzieri* larvae had high consumption rates in cotton field, *C. montrouzeiri* being the most voracious feeder. In the no choice feeding tests, third instar larvae of *C. montrouzeiri* devoured the highest mean number of first instar *P.solenopsis* (439.38). In the choice feeding tests, a similar number of first instar nymphs (410) were consumed. In

both feeding tests, *C. carnea* devoured relatively fewer number of *P. solenopsis* than *C. montrouzeiri.*

Hameed *et al*. (2013) found that, eleven spotted ladybird beetle (*Coccinela undecimpunctata Linnaeus*) proved to be the best predator against cotton mealy bug. 1st instar larvae of eleven spotted beetle is an effective bio control agent which consumed on an average 91.99 1st instar cotton mealybug whereas 2nd, 3rd instar and adult consumed 45.00, 44.00, 5.44 cotton mealybug, respectively. The *C. undecimpunctata* L. at 2ndinstar devoured 97 1st instar, 35.66 2nd instar and 45.00 3rd instar cotton mealybug and 7.11 adult stage cotton mealybug. Whereas 3rd instar beetle took in 121.66 1st instar, 51.66 2nd instar and 54.33 3rd instar cotton mealybug and 8.21 adult stage cotton mealybug respectively. The larvae of 4th instar *C. undecimpunctata* preyed 93.00 1st instar, 35.00 2nd instar and 33 3rd instar cotton mealybug. and 7.33 adult stage cotton mealybug respectively. Adult female of this beetle consumed higher number of mealybugs than adult male during its whole life.

Samal and Misra (1985) observed that the grubs of *M. discolor* fed on nymph and adults of brown plant hopper (BPH). During the total larval period of the predator it consumed on an average of 57 third instar BPH nymph. Ngammuang (1987) observed that the average number of bean aphids consumed by the larval and adult stage of the predator were 252.10 ± 43.40 and 1547.80 ± 552.55 aphids respectively. He reported that the feeding capacities of four larval and the adult stages M. discolor were 21 ± 3.29, 41.90 ± 7.78, 66.25 ± 20.13, 125 ± 25.20 and 1295.7 ± 605.69 aphid per individual, respectively. Rahman (1990) observed that the feeding rate of *Micraspis discolor* during the first day after hatching ranged between 2 and 7 cotton aphids (average 5.2 ± 0.58) from the 2nd day, the consumption rate gradually increased and reached an average of 26.8 ± 2,59 aphids on the 9th day after which feeding rate dropped sharply. Each larva consumed on

an average of 131.6 ± 13.25 aphids in total larval period. The adult consumed 21 aphids during their first day and the rate gradually increased up to 9th day on an average of 86.4 aphids. From the 10th day the rate declined to an average of 82.0 aphids.

Nathapol and Pensook (1991) found that the average predation capacities of *M. sexmaculatus* (F.) in 1st, 2nd, 3rd and 4th larval instars and adult stage of male were 8.35, 20.60, 36.05, 44.65 and 1012.7 aphids (*A. glycines*), respectively. The average predation capacity in the larval instars and adult stage of female were 9.3, 22.25, 36.15, 48.25 and 1106.9 aphids respectively. Das (1994) found that the feeding rate of larvae of *M. sexmaculatus* (F.) during the 1st day after hatching ranged between 9.0 to 13 adults of *A. craccivora* from the 2nd day the rate of consumption gradually increased and reached an average of 53.05 ± 0.93 aphids on the 8th day after which feeding rate fall down sharply. It was also reported that a single larva consumed 270.0 to 367.0 aphids prior to pupation.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted in Central laboratory in Sher-e-Bangla Agricultural University, Dhaka, during December, 2015 to March, 2016 for the purpose of life history and predation efficiency studies. The room temperature and relative humidity during the research period were 23^0 C±2 and 75%±5%, respectively. Photographs of each instar and predation were taken through Digital camera.

3.1 Collection of Mango Mealybug (*Drosicha mangiferae*) and the coccinellid predator (*Rodolia sp*.)

Mango mealybugs were collected from infested mango orchards of Entomology research field, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka. Mango mealybugs were collected regularly from the infested mango leaves, stems, twigs and inflorescences. Ladybird beetle adults were also collected from the same mango orchards of entomology research field. The ladybird beetles were collected not only in mango trees but also from other trees of the same orchard.

3.2 Mass culture of ladybird beetle (*Rodolia sp*.)

Adult ladybird beetles were collected from the mango mealybug infested orchard of department of Entomology. These beetles were kept in Petri dishes (9.0 cm x1.0 cm). The Petri dishes were examined regularly. The beetles were provided with soil and leaves in the Petri disesh to make a favorable environment for them. The female ladybird beetles were left undisturbed for egg laying and the eggs laid by the female were also kept undisturbed for hatching. After hatching the predator larvae were transferred into similar Petri dishes and reared till adult emergence.

3.3 Biology of Ladybird beetle (*Rodolia sp*.)

From the laboratory culture adult ladybird beetles were confined for egg laying in Petri dishes (9.0cm x 1.ocm). Ten Petri dishes were maintained (Plate 1.). The beetles were observed to record incubation period. Eggs laid by each female during 24 hour were counted and kept in separate Petri dishes to determine the total number of eggs laid per female. The color, length and breadth, and shape of the egg were also obsereved. After hatching of eggs young larvae were transferred individually to ten Petri dishes. The mango leaves infested with mango mealybugs were provided as food for the predator larvae every morning. The larvae were observed twice daily until pupation to record the number of instars, the length and breadth of 1^{st}instar, 2^{nd} instar, 3^{rd} instar and 4^{th} instar larvae and duration of each instar. Pupae were kept undisturbed in the respective Petri dishes until the emergence of adult to record the duration of pre-pupae, pupae and the adult.

Plate 1.Petri dishes to study the biology of ladybird beetle (*Rodolia sp*.)

3.4 Predatory efficiency of ladybird beetle (*Rodolia sp*.)

3.4.1 Collection of mango mealybug (*Drosicha mangiferae*) and the coccinellid predator (*Rodolia sp*.)

Mango mealybugs of different instars were collected from infested mango orchards of Entomology research field, Sher-e-Bangla Agricultural University (Plate 2 and 3). Bugs were collected from the infested mango leaves, stems, twigs and inflorescences. Eggs of mango mealybug were collected from the soil under the tree infested mango orchards. Ladybird beetle larvae of different instars were also collected from the same mango orchard. The ladybird beetles were collected not only from mango trees but also from other trees of the orchard.

Plate 2. Collection of 1st instar nymph of mango mealybug

Plate 3. Mealybug infested twig of mango

Plate 4.Collection of different instars of ladybird beetle(*Rodolia sp*.)

3.4.2 Predation efficiency of 1st instar ladybird beetle (*Rodolia sp*.) larvae on 1st instar mango mealybug (*Drosicha mangiferae*) nymph

Just after hatching two young larvae of ladybird beetle were released on 10 1st instar mango mealybug nymphs in each Petri dishes. Fresh tender mango leaves were supplied as food for the mango mealybug nymph. The base of the mango leaves were covered by water soaked cotton for protecting it from wilting. The food was changed within 24 hours. The number of mango mealybug nymphs consumed by ladybird beetles larvae within 24 hours were recorded. Finally the predation efficiency of one ladybird beetle larvae was calculated per day.

3.4.3 Predation efficiency of 2nd instar ladybird beetle (*Rodolia sp*.) larvae on 2nd instar mango mealybug (*Drosicha mangiferae*) nymph

Ten 2nd instar mango mealybug nymph were collected from the infested orchard and kept in a Petri dish which were evaluated by two 2nd instar ladybird beetle larvae. Fresh tender mango leaves were supplied as food for the mango mealybug nymph. The base of the mango leaves were covered by water soaked cotton for protecting it from wilting. The food was changed within 24 hours. The number of mango mealybug nymphs consumed by ladybird beetles larvae within 24 hours were recorded. Finally the predation efficiency of one ladybird beetle larvae was calculated per day.

3.4.4 Predation efficiency of 3rd instar ladybird beetle (*Rodolia sp.*) larvae on 3rd instar mango mealybug (*Drosicha mangiferae*) nymph

Two ladybird beetle of 3rdinstar were released on 3rdinstar 10 nymph of mango mealybug which were kept in a Petri dish. Fresh tender mango leaves were supplied as food for the mango mealybug nymph. The base of the mango leaves were covered by water soaked cotton for protecting it from wilting. The food was changed within 24 hours. The number of mango mealybug nymphs consumed by ladybird beetles larvae within 24 hours were recorded. Finally the predation efficiency of one ladybird beetle larvae was calculated per day.

3.4.5 Predation efficiency of adult ladybird beetle (*Rodolia sp.*) on adult mango mealybug (*Drosicha mangiferae*)

For determining the predaceous efficiency of adult ladybird beetle the newly emerged adult beetles were transferred to Petri dishes from the laboratory culture against mango mealybug adults. Two adult ladybird beetles were released against five adult mango mealybugs. Fresh mango leaves were supplied as food. The base of the mango leaf was covered with water soaked cotton to prevent the leaf from wilting. The number of adult mealybugs consumed by the adult ladybird beetle was recorded every 24 hours. Lastly, the predation efficiency of one adult ladybird beetle was calculated in one day.

3.4.6 Predation efficiency of adult ladybird beetle (*Rodolia sp.*) on the egg of mango mealybug (*Drosicha mangiferae*)

To determine the predaceous efficiency of adult ladybird beetle on the egg of mango mealybug, the newly emerged adult beetles were transferred to Petri dishes from the laboratory culture against mango mealybug eggs. Two adult were released against ten mealybugs eggs. Soil was provided in the Petri dishes to create favourable condition. The number of eggs of mango mealybug consumed by the adult ladybird beetle was recorded every 24 hours.

3.5 Data analysis

Data obtained from the biology of ladybird beetles were analyzed statistically using Excel. The data obtained from different studies of predatious efficiency of ladybird beetle on mango mealybug *Drosicha mangiferae* were analyzed statistically using excel as well.

CHAPTER IV
RESULTS AND DISCUSSION

The present studies included investigations of life cycle and predation efficiency of the ladybird beetle on mango mealybug. The results are presented below:

4.1 Biology of ladybird beetle (*Rodolia sp*.)

4.1.1 Egg

The number of eggs laid per female ladybird beetle ranged from 18-25 with a mean of 20.50±1.84 (Table 1). A typical egg was small with smooth and shiny surface. The eggs were elongate, oval and round but slightly pointed at both ends. Initially the eggs (Plate 5) were deep yellow to pale red in color. The eggs were more transparent prior to hatching. These were so transparent that the movement of the 1st instar larva can be seen from outside through the transparent egg membrane. The average length of the egg was 1.21±0.07 mm with minimum size of 1.10 mm and maximum size of 1.30 mm; the breadth of the egg averaged 0.67±0.09 mm with a minimum and maximum size of 0.50 mm and 0.75 mm, respectively (Table 2). Pathak and Khan (1994) described egg to be small with smooth and shiny but gradually change to dark before hatching. They were oval shaped with slightly pointed ends. It has been reported that the egg was 1.02±0.03 mm long and 0.42±0.03 mm broad Samal and Misra 1985.

Plate 5. Eggs of ladybird beetle (*Rodolia sp*.)

4.1.2 Incubation period

Incubation period is the duration between the dates of egg laying and egg hatching. The incubation period varied from12 to 14 days with an average of 12.90±0.57 days (Table 3). The results differ with the findings of several authors. Eraky and Nasser (1995) reported that the incubation period of *M. discolor* was 2 to 9 days. Solangi *et al.* (2005) recorded that the mean incubation period of *M. sexmaculatus* was 3.6±1.03 days when they feed on mustard aphid, *L. erysimi*. Nathapol and Pensook (1991) found that the incubation period of *Menochilus sexmaculatus* was 2 to 3 days on cotton aphid. Prodhan *et al*. (1995) observed the incubation period of *M. sexmaculatus* and *M. discolor*were 2 and 3 days, respectivelywhen fed on bean aphid as host.

Table 1. Number of egg laid per female ladybird beetle (*Rodolia sp.)*

Observation No.	No. of eggs/female ladybird beetle	Mean±SD
1	21	
2	20	
3	20	
4	25	
5	20	20.50±1.84
6	20	
7	19	
8	21	
9	18	
10	21	

Table 2. Length and breadth of eggs of ladybird beetle (*Rodolia sp.)*

Obseravation No.	Length (mm)	Mean ± SD	Breadth (mm)	Mean ± SD
1	1.30	1.21±0.07	0.75	0.67±0.09
2	1.15		0.60	
3	1.25		0.70	
4	1.20		0.50	
5	1.25		0.75	
6	1.10		0.75	
7	1.25		0.70	
8	1.10		0.65	
9	1.25		0.75	
10	1.20		0.55	

Table 3. Incubation period of egg of ladybird beetle (*Rodolia sp.)*

Observation No.	Date of egg laying	Date of egg hatching	Incubation period (days)	Mean±SD
1	9.12.15	22.12.15	13	
2	9.12.15	22.12.15	13	
3	10.12.15	22.12.15	12	
4	10.12.15	23.12.15	13	
5	10.12.15	23.12.15	13	12.90±0.57
6	9.12.15	22.12.15	13	
7	9.12.15	23.12.15	14	
8	11.12.15	24.12.15	13	
9	11.12.15	24.12.15	13	
10	12.12.15	24.12.15	12	

4.1.3 Larva

The larva came out of the egg by making an irregular hole through the upper end of egg shell during hatching. Single and batch of egg hatched simultaneously and the larvae remained together for almost a day. Larvae were soft bodied, reddish, elongate, somewhat flattened and covered with minute spiny structures. Three pairs of legs were long and slender. The larvae were very active while preying. The larvae passed through four larval instars with three moults. The duration of different instar was different as confirmed from observations of exuvae and shell in the Petri dish. Just before moulting the larvae shrunk and exhibited very slow movement and attached themselves to the surface of the Petri dish or leaves with posterior end. The larvae then created pressure on the outer skin of the

head region and shedding of cuticle took place by gentle jerking and twist in movement of the larvae. Islam and Nasiruddin (1978) reported that larva of *M. discolor* passed through four larval instars. The total larval period averaged 64±19.80 days with minimum of 50 days and maximum of 78 days (Table 4).

Table 4. Maximum and minimum duration of different stages of ladybird beetle (*Rodolia sp.)*including total development period from egg to adult.

Different stage	**Duration in days**		**Mean ± SD**
	Minimum	**Maximum**	
Incubation period	12	14	13.00±1.41
Larval instar 1	6	8	7±1.41
Larval instar 2	10	17	13.50±4.95
Larval instar 3	17	22	19.50±3.54
Larval instar 4	17	31	24±9.90
Total larval period	50	78	64±19.80
Pre-pupal period	2	5	3.50±2.12
Pupal period	3	8	5.50±3.54
Total development period from egg to adult	67	105	86±26.87

First instar larvae

The general coloration of the first instar larva was light red immediately after hatching. After 4-6 hours of hatching they began to move for searching food. Initially their movement was very frequent. The body of the 1st instar larva (plate 6) was slightly tapering at the posterior region. At this instar, their head, thorax, and abdominal segments were not visible clearly. The newly emerged larva measured from 2.70 to 3.00 mm with

an average of 2.88±0.11 mm in length and the breadth varied from 0.97 mm to 1.20 mm with an average of 1.07±0.08 mm (Table 5). The duration of this stage varied from 6 to 8 (Table 6) days with an average of 7.20±0.79 days (Table 6). Prodhan *et al.* (1995) studied that the mean length and breadth of the first instar larva were 1.52±0.3 mm and .09±0.003 mm, respectively. The second and third instar larvae were more or less similar to those of the first instar. The mean length and breadth of the second instar larva was 2.88±0.03 mm and 0.602±0.03 mm respectively and those of third instar larva was 4.06±0.03 and 1.02±0.02 mm. The fourth instar larva measured 5.09±0.02 mm in length and 1.20±0.03 mm in breadth.

In 1990, Debraj and Singh found that the duration of 1st instar larvae of *C. transversalis* (F.) was 4.69 days on *Aphis craccivora* Koch at 18^{0}C.

Plate 6. Newly hatched 1st instar larva of ladybird beetle *(Rodolia sp.)*

Second instar larvae

The second instar larvae (Plate 7) came out soon by leaving their exuviae. After moulting the body of the 2nd instar larvae was clear. Except increased size, all other part as well as habits and general appearance of larvae of this instar were same as previous instar. The body segments are somewhat prominent than the first instar larvae. The second instar larvae was 4.00 mm to 4.50 mm with an average of 4.18±0.19 mm in length and in breadth 1.05 mm to 1.50 mm with an average of 1.22±0.17 mm (Table 5)

Table 5. Length and breadth of 1st and 2nd instar larvae of ladybird beetle (*Rodolia sp.*)

Observation No.	**1st instar**		**2nd instar**	
	Length (mm)	**Breadth (mm)**	**Length (mm)**	**Breadth (mm)**
1	2.75	1.15	4.50	1.20
2	2.85	1.00	4.00	1.10
3	3.00	1.05	4.10	1.15
4	2.90	0.97	4.30	1.50
5	2.75	1.00	4.00	1.10
6	2.90	1.15	4.15	1.05
7	3.00	1.20	4.50	1.30
8	3.00	1.10	4.00	1.50
9	2.90	1.00	4.10	1.05
10	2.70	1.05	4.15	1.20
Mean ± SD	2.88±0.11	1.07±0.08	4.18±0.19	1.22±0.17

Plate 7. Second instar larvae of ladybird beetle (*Rodolia sp.*)

Table 6. Duration of 1st and 2nd instar larvae of ladybird beetle (*Rodolia sp*.)

Observation No.	1st instar			2nd instar		
	Date of hatching	Date of transferred into 2nd instar	Duration (Days)	Date of transferred into 2nd instar	Date of transferred into 3rd instar	Duration (Days)
1	22.12.15	30.12.15	8	30.12.15	13.01.16	14
2	22.12.15	29.12.15	7	29.12.15	11.01.16	13
3	22.12.15	30.12.15	8	30.12.15	10.01.16	11
4	23.12.15	31.12.15	8	31.12.15	10.01.16	10
5	23.12.15	31.12.15	8	31.12.15	12.01.16	12
6	22.12.15	29.12.15	7	29.12.15	15.01.16	17
7	23.12.15	29.12.15	6	29.12.15	12.01.16	14
8	24.12.15	31.12.15	7	31.12.15	10.01.16	10
9	24.12.15	31.12.15	7	31.12.15	11.01.16	11
10	24.12.15	30.12.15	6	30.12.15	14.01.16	15
Mean±Sd			7.20±0.79			12.70±2.31

Third instar larvae

By leaving their exuviae the third instar larvae came out by second moulting. The third instar larvae were similar to the second instar larva, but morphologically different only in size and shape of the body. Third instar larvae were elongated and more active than previous instars (Plate 8). The third instar larvae measured 6.00 mm to 7.00 mm with an average of 6.38±0.36 mm in length and 2.00 mm to 2.80 mm with an average of 2.31±0.29 mm in breadth (Table 7). The average duration of the 3rdand 4th instar larvae were 19.80±1.90 days and 22.50±5.0 respectively (Table no.8). In 1990, Debraj and Singh reported that duration of 3rd instar for *C. septempunctata* L. was 5.0 days on *Aphis craccivora* Koch.

Fourth instar larvae

The 4th instar larvae were deep red colored and bigger in size than the previous stages. The body is elongated, cylindrical and somewhat flattened in size and shape (Plate 9). Their body segments were quite distinct. They are stronger and their voracity and mobility were more than 3rd instar. The larvae were 9.00 mm to 10.00 mm with an average of 9.55±0.39 mm in length and 2.95 mm to 3.10 mm with an average of 3.02±0.05 mm in breadth (Table 7). The duration of the 4th instar larvae averaged 22.50±5.0 days (Table 6) with minimum of 17 days and maximum of 31 days. Eraky and Nasser (1995) reported that four larval instars duration of eleven spotted beetle 7.0, 7.5, 12.0 and 16.0 days.

Plate 8. Third instar larva of ladybird beetle (*Rodolia sp.*)

Plate 9. Fourth instar larva of ladybird beetle (*Rodolia sp.*)

Table 7. Length and breadth of 3rd and 4thinstar larvae of ladybird beetle (*Rodolia sp.*)

Observation No.	**3rd instar**		**4th instar**	
	Length (mm)	**Breadth (mm)**	**Length (mm)**	**Breadth (mm)**
1	7.00	2.75	9.00	3.00
2	6.45	2.40	9.40	3.05
3	6.00	2.10	9.90	2.95
4	6.35	2.20	9.20	3.00
5	6.20	2.10	10.00	3.00
6	7.00	2.50	9.00	2.95
7	6.10	2.00	9.65	3.00
8	6.25	2.20	10.00	3.05
9	6.00	2.05	9.80	3.10
10	6.45	2.80	9.50	3.05
Mean ± SD	6.38±0.36	2.31±0.29	9.55±0.39	3.02±0.05

Table 8. Duration of 3rd and 4th instar larvae of ladybird beetle (*Rodolia sp.*)

Observation No.	3rd instar			4th instar		
	Date of transferred into 3rd instar	Date of transferred into 4th instar	Duration (Days)	Date of transferred into 4th instar	Date of pupation	Duration (Days)
1	13.01.16	01.02.16	19	01.02.16	27.02.16	19
2	11.01.16	30.01.16	19	30.01.16	27.02.16	28
3	10.01.16	29.01.16	19	29.01.16	26.02.16	24
4	10.01.16	01.02.16	22	01.02.16	26.02.16	25
5	12.01.16	30.01.16	18	30.01.16	26.02.16	18
6	15.01.16	01.02.16	17	01.02.16	26.02.16	17
7	12.01.16	30.01.16	18	30.01.16	27.02.16	18
8	10.01.16	01.02.16	22	01.02.16	28.02.16	27
9	11.01.16	29.01.16	18	29.01.16	29.02.16	31
10	14.01.16	01.02.16	18	01.02.16	29.02.16	18
Mean±Sd			19.80±1.9			22.50±5.10

4.1.4 Pre-pupal stage

The duration between the date when larvae stops feeding and the date of pupation was considered as pre-pupation period. At the starting of the pre-pupal period the larvae stopped feeding, became less active and did not move fast and selected a hiding place such as surface of the land or Petri dishes for pupation (Plate 10). The duration of pre-pupal stage varied from 2 to 5 days with an average of 3.30±1.06 days (Table 9).

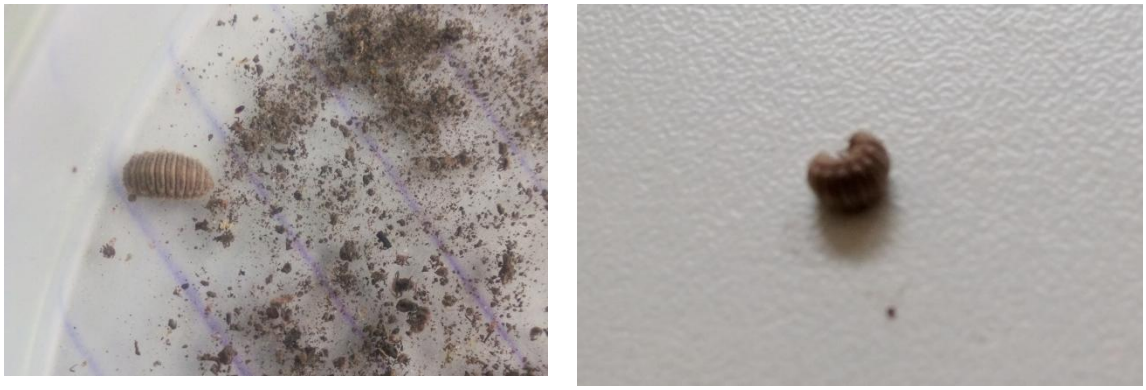

Plate 10. Pre-pupal stage of ladybird beetle(*Rodolia sp*.)

4.1.5 Pupal stage

The pre-pupa finally transformed into pupa. At this stage, all the larval characters including size and shape are lost. At the very first stage, the pupa were yellowish in color but after 1or 2 days some red stripes were visible on the upper portion of the pupae (Plate 11). The pupal period ranged from 3 to 8 days with an average of 6.10±1.37days (Table 9).The average body length of the pupa was 7.77±0.50 mm having 5.13±0.17 mm in breadth (Table 10).

Different findings revealed that the pupal period of coccinellid beetles varied with variation of foods and was correlated with the temperature (Sakurai *et al.* 1991). Siddhapara *et al*. found that the average prepupal and pupal period of *Cryptolaemus montrouzieri* on cotton mealybug were 1.88±0.39 and 6.98±0.58 days respectively which was closely related to this findings. Eraky and Nasser (1995) observed the mean pupal duration of eleven spotted beetle was 2.5 days at 30^0C and 7.5 days at 14^0C. Solangi *et al.* (2005) found that the mean pupal duration of *Menochilus sexmaculatus* in days was 6.50±0.28 on mustard aphid, *L. erysimi*.

Plate 11. Pupae of ladybird beetle (*Rodolia sp*.)

4.1.6 Adult beetle

The adult emerged out from the pupal skin by means of convulsive movement of their legs and body. At the time of emergence, the head came first followed by the thorax. Later the abdomen was released from the pupal skin. The newly emerged adult beetle was orange in color and after 2 or 3 days it finally turned red and black spots appeared on the skin of the adult. The adult ladybird beetle was reddish in color (Plate 12). They were oval, flat beneath and convex above. Elytra closely enclosed the abdomen. Their heads are small and partly concealed by the brown pronotum. The antenna was eleven segmented, short and clavate. The adult beetles generally possessed chewing type of mouth parts. The adult ranged from 7.00 mm to 8.40 mm with an average of 7.76±0.48 mm in length and the breadth varied from 5.00 mm to 5.50 mm with an average of 5.23±0.20 mm (Table 10).

Plate 12. Adult of ladybird beetle (*Rodolia sp.*)

Table 9. Duration of pre-pupa and pupa of ladybird beetle (*Rodolia sp.*)

Observation No.	Pre-pupa			Pupa		
	Date of stopped feeding	Pupation date	Pre-pupal period (days)	Pupation date	Date of adult emergence	Pupal duration (days)
1	24.02.16	27.02.16	3	27.02.16	6.03.16	8
2	22.02.16	27.02.16	5	27.02.16	4.03.16	6
3	22.02.16	26.02.16	4	26.02.16	29.02.16	3
4	24.02.16	26.02.16	2	26.02.16	4.03.16	7
5	23.02.16	26.02.16	3	26.02.16	3.03.16	6
6	24.02.16	26.02.16	2	26.02.16	3.03.16	6
7	24.02.16	27.02.16	3	27.02.16	3.03.16	5
8	23.02.16	28.02.16	5	28.02.16	5.03.16	6
9	26.02.16	29.02.16	3	29.02.16	7.03.16	7
10	26.02.16	29.02.16	3	29.02.16	7.03.16	7
Mean±Sd			3.30±1.06			6.10±1.37

Table 10. Length and breadth of pupa and adult of ladybird beetle (*Rodolia sp.*)

Observation No.	Pupa		Adult	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
1	7.00	5.00	8.40	5.50
2	8.50	5.50	7.80	5.30
3	7.10	5.10	7.00	5.00
4	7.45	5.20	7.50	5.30
5	7.80	5.25	8.00	5.20
6	8.00	5.10	8.20	5.50
7	8.20	5.00	7.60	5.00
8	7.60	4.90	8.30	5.40
9	8.30	5.20	7.70	5.10
10	7.70	5.00	7.10	5.00
Mean ± SD	7.77±0.50	5.13±0.17	7.76±0.48	5.23±0.20

4.1.7 Life cycle (Egg to Adult)

The total duration from egg to adult of ladybird beetle varied from 67 to 105 days (Table 4). Eraky and Nasser found that the total development period i.e. egg to adult of eleven spotted beetle was 12, 14, 21, 27.5 and 38.5 days at 30, 26. 22, 18, and 14^{0}C, respectively.

4.2 Predation efficiency of ladybird beetle (*Rodolia sp*.)

Predaceous efficiency depended on the searching behavior, size of the prey as well as on the surrounding nature of the predator and availability of the prey. Larvae of ladybird beetle fed on mango mealybug (Plate 13). But their rate of feeding varied. They did not feed continuously rather they fed intermittently both day and night, but mainly in day time. Usually the larvae did not move during feeding and fed mango mealy bug one after another. Replication wise predation of 1st, 2nd, 3rd, 4th instar and adult ladybird beetle were presented in Appendix I, II, III, IV and V respectively.

The predation efficiency of larvae was determined by counting the total number of mango mealybug consumed during each larval instar within 24 hours. One 1st instar larva of ladybird beetle consumed 0.63±0.13 1st instar mango mealybugs nymph. In the 2ndinstar the ladybird beetle consumed an average of 0.98±0.27 mango mealybug nymph . The average consumption of 3rd instar nymph of mango mealybug by the 3rdinstar ladybird beetle larvae and adult mango mealybug by the adult ladybird beetle were 0.52±0.05 and 0.13±0.08, respectively (Table 11). There was no feeding of eggs of mango mealybug occurred by the adut ladybird beetle. The results pointed out that the feeding rates increased gradually from the 1st instar to 2nd instar but decreased sharply in the 3rd instar and in the adult stage as well. Moreover it is noticeable that in the study of predation efficiency of adult ladybird beetle on mango mealybug egg, there was no feeding.So statistically 2nd instar larvae is more efficient than the any other instars and adult.Hameed *et al*. (2013) found that, eleven spotted lady bird beetle (*Coccinela undecimpunctata* Linnaeus) proved the best predator against cotton mealybug. 1st instar larvae of eleven spotted beetle is an effective bio-control agent which consumed an average no. of 91.99 cotton mealybug of 1st instar whereas 2nd, 3rd instar and adult consumed 45.00, 44.00, 5.44 cotton mealybug, respectively. *C. undecimpunctata* L. 2nd instar larvae devoured 97

1st instar, 35.66 2nd instar and 45.00 3rd instar cotton mealybug and 7.11 adult stage cotton mealybug, respectively, whereas 3rd instar beetle consumed 121.66 1st instar, 51.66 2nd instar and 54.33 3rd instar cotton mealybug and 8.21 adult stage cotton mealybug. Adult female of this beetle consumed higher number of mealybugs than adult male during its whole life.

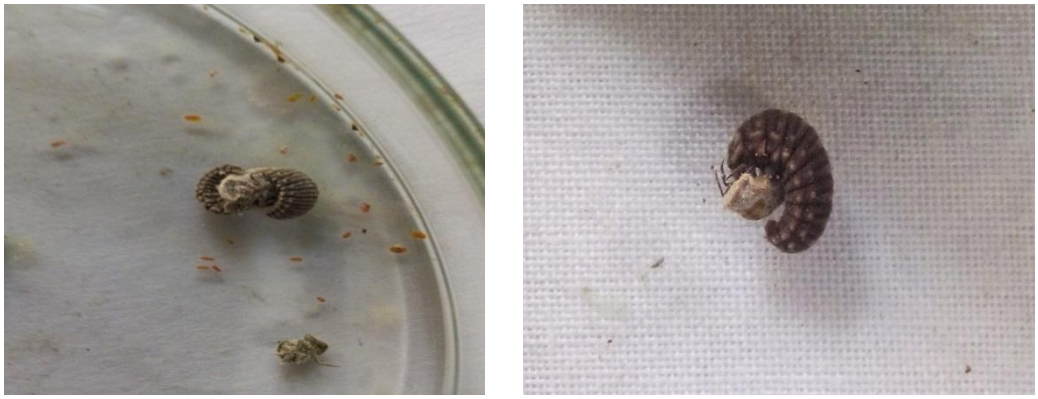

Plate 13. Ladybird beetle (*Rodolia sp*.) predate mango mealybug.

Table 11. Predation efficiency of ladybird beetle (*Rodolia sp*.) on mango mealybug (*Drosicha mangiferae*)

Instars of ladybird beetle	**Stage of mango mealybug**	**No of nymphs consumed per ladybird beetle in a day**
		Mean±SD
First instar	First instar	0.63±0.13 b
Second instar	Second instar	0.98±0.27 a
Third instar	Third instar	0.52±0.05 b
Adult	Adult	0.13±0.08 c
Adult	Egg	0

CHAPTER V

SUMMARY AND CONCLUSION

Ladybird beetle, member of the family Coccinellidae is the most familiar insect and one of the most beneficial insects of various agricultural crops. A research work was carried out in the central laboratory of the Department of Entomology, SAU, Dhaka, to study its life cycle and predation efficiency on mango mealybug, *Drosicha mangiferae* during December, 2015 to March 2016.

The ladybird beetle (*Rodolia sp*.) laid eggs in clusters with an average of 20.50 eggs. The eggs were elongate, oval and round, slightly pointed at both ends. Initially the eggs were deep yellow to pale red in color. The average length and breadth of the eggs were 1.21±0.07 mm and 0.67±0.09 mm, respectively. The eggs hatched within 12 to 14 days with an average of 12.90±0.57 days. The larvae were soft bodied, reddish in color, elongate, somewhat flattened and covered with minute spines. They passed through four larval instars with three moults. The larvae were very active while preying. The total larval period averaged 64±19.80 days. The 1^{st}, 2^{nd}, 3^{rd} and 4^{th} larval instars lasted for 8, 17, 22 and 31 days, respectively. The first instar larvae measured from 2.70 to 3.00 mm in length and 0.97 to 1.20 mm in breadth. The body of the first instar larva was tapering at the posterior region. Except size, all other structures and general appearance of the second instar larva remained same as previous instar. The average length and breadth of the second instar larvae were 4.18±0.19 mm and 1.22±0.17 mm, respectively. The duration of this stage varied from 10 to 17 days. In the third instar they become more elongated and more active suddenly than the previous instars and their body sizes were 6.00 mm to 7.00 mm in length and 2.00 to 2.80 mm in breadth. The fourth instar larvae attained a greater size and shape. Their body segments were quite distinct. They become more stout and strong than the previous instars. Their body sizes are averaged 9.55±0.39 mm in length

and 3.02±0.05 mm in breadth. The duration of the 4th instar larvae varied from 17 days to 31 days.

In the pre-pupal period, the larvae stopped feeding and became C shaped. The duration of pre-pupal stage varied from 2 to 5 days with an average of 3.30±1.06 days. In the pupal stage all the larval characters including size and shape are lost. Initially the pupae were yellow in color. The average body length of the pupa was 7.77±0.50 mm and the breadth was 5.13±0.17 mm. The total duration from egg to adult was completed within 67 to 105 days.

The adult beetle was initially orange in color but finally it gained red color. They were oval, flat ventrally and convex dorsally. The adult ranged from 7.00 mm to 8.40 mm in length and 5.00 mm to 5.50 mm in breadth.

Larvae of ladybird beetle (*Rodolia sp.*)fed on mango mealybug both day and night but mainly in day time. The feeding rates increased gradually from the 1st instar to 2nd instar but decreased sharply in the 3rd instar and in the adult stage. One 1st instar larva of ladybird beetle consumed 0.63±0.13 1st instar mango mealybugs nymph. In the second instar the ladybird beetle consumed on an average 0.98±0.27 mango mealybugs nymph . The average consumption by the third instar ladybird beetle larvae of third instar nymph of mango mealybug and by the adult ladybird beetle adult of mango mealybug were 0.52±0.05 and 0.13±0.08, respectively. There was no feeding of eggs of mango mealybug occurred by the adut ladybird beetle.

Conclusion

Based on above findings it can be concluded that the ladybird beetle (*Rodolia sp*.) laid eggs in clusters. The eggs hatched within 12 to 14 days. They passed through four larval instars with three moults. The larvae were very active while preying. The total larval period averaged 64±19.80 days. The 1st, 2nd, 3rd and 4th larval instars lasted for 8, 17, 22 and 31 days, respectively. The total duration from egg to adult was completed within 67 to 105 days. The adult beetle was initially orange in color but finally it gained red color. They were oval, flat ventrally and convex dorsally. The adult ranged from 7.00 mm to 8.40 mm in length and 5.00 mm to 5.50 mm in breadth. The feeding rates increased gradually from the 1st instar to 2nd instar but decreased sharply in the 3rd instar and in the adult stage. Statistically second instar larvae of ladybird beetle (*Rodolia sp*.) was more efficient in predating mango mealybug nymph than the other instars.

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I: Predation efficiency of 1st instar ladybird beetle (*Rodolia sp*.) larvae on 1stinstar mango mealybug (*Drosicha mangiferae*) nymph

Date	Petridish Number				
	R1	R2	R3	R4	R5
26.12.15	8	7	9	9	9
27.12.15	6	7	8	7	9
28.12.15	5	5	6	7	7
29.12.15	3	4	5	6	6
30.12.15	1	4	5	4	6
31.12.15	0	2	3	3	4
1.01.16	0	0	0	1	1
02.01.16	0	0	0	0	0

Appendix II: Predation efficiency of 2nd instar ladybird beetle (*Rodolia sp*.)larvae on 2ndinstar mango mealybug (*Drosicha mangiferae)* nymph

Date	Petridish Number				
	R1	R2	R3	R4	R5
2.01.16	9	6	8	10	6
3.01.16	8	2	6	8	3
4.01.16	5	1	4	7	1
5.01.16	3	0	3	5	0
6.01.16	3	0	2	5	0
7.01.16	2	0	1	3	0
8.01.16	2	0	1	3	0
9.01.16	0	0	0	1	0
10.01.16	0	0	0	0	0

Appendix III: Predation efficiency of 3rd instar ladybird beetle (*Rodolia sp.*) larvae on 3rd instar mango mealybug (*Drosicha mangiferae*) nymph

Date	Petridish Number				
	R1	R2	R3	R4	R5
13.01.16	9	8	9	8	8
14.01.16	6	7	7	6	7
15.01.16	5	6	5	6	5
17.01.16	4	6	3	5	4
18.01.16	3	4	2	5	4
19.01.16	3	4	2	3	3
20.01.16	2	3	1	2	2
21.01.16	2	3	1	1	2
22.01.16	0	2	0	1	0
23.01.16	0	0	0	0	0

Appendix IV: Predation efficiency of adult ladybird beetle (*Rodolia sp.*) on adult mango mealybug (*Drosicha mangiferae*)

Date	Petridish Number				
	R1	R2	R3	R4	R5
04.03.16	4	5	5	5	4
05.03.16	4	4	5	4	4
06.03.16	4	4	5	4	4
07.03.16	4	4	5	4	3
08.03.16	3	4	5	4	3
09.03.16	3	4	4	4	3
10.03.16	3	3	4	3	2
11.03.16	2	3	4	3	2
12.03.16	2	3	4	3	1
13.03.16	1	3	4	3	1
14.03.16	0	3	4	3	0

Appendix V: Predation efficiency of adult ladybird beetle (*Rodolia sp*.) on egg of mango mealybug (*Drosicha mangiferae*)

Date	Petridish Number				
	R1	R2	R3	R4	R5
10.12.15	0	0	0	0	0
11.12.15	0	0	0	0	0
12.12.15	0	0	0	0	0
13.12.15	0	0	0	0	0
14.12.15	0	0	0	0	0