BIOLOGY AND PREDATION EFFICIENCY OF LADYBIRD BEETLE ON MUSTARD APHID

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CERTIFICATE

This is to certify that thesis entitled, "*BIOLOGY AND PREDATION EFFICIENCY OF LADYBIRD BEETLE ON MUSTARD APHID*" submitted to the *Faculty of Agriculture*, Sher-e-Bangla Agricultural University, 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 *MD. ABUBAKAR SIDDIQUE, Registration No. 10-4136* 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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ABSTRACT

A laboratory experiment was conducted in the central laboratory of Sher-e-Bangla Agricultural University to find out the biology and predation efficiency of ladybird beetle on mustard aphid. Zigzag ladybird beetle (*Cheilomenes sexmaculata*), black ladybird beetle (*Cheilomenes sexmaculata*) and transverse ladybird beetle (*Coccinella transversalis*) were taken as treatment to find out their biology and predation efficiency on mustard aphid. Incubation period, 1^{st}, 2^{nd}, 3^{rd}, 4^{th} instar grub period, pupal period, adult male and female longevity and ovipositional period of female for zigzag ladybird beetle were 2-3, 1-2, 1-3, 2-3, 2-3, 3-5, 17-22, 19-25 and 19-27 days, respectively; for black ladybird beetle 2-3, 1-2, 1-3, 2-3, 2-3, 3-5, 17-23, 20-25 and 18-27 days, respectively and 5-7, 2-3, 2-4, 3-5, 3-5, 6-10, 27-33, 31-36 and 30-41 days, respectivelyfor transverse ladybird beetle. The length of egg, 1^{st}, 2^{nd}, 3^{rd}, 4^{th} instar grub, pupa and adult male and female were 0.92-1.12, 1.45-2.50, 2.6-3.8, 3.17-5.52, 5.6-7.5, 3.8-5.2, 3.8-4.4 and 4.1-5.4 mm, respectively for zigzag ladybird beetle; 0.96-1.15, 1.50-2.35, 2.35-4.15, 4.07-5.85, 5.5-6.84, 3.9-5.3, 3.8-4.6 and 4.16-5.5 mm, respectivelyfor black ladybird beetle; and 1.15-1.36, 1.66-2.23, 3.2-3.98, 4.81-6.07, 5.77-7.9, 5.0-6.6, 5.0-5.4 and 5.35-6.7 mm, respectivelyfor transverse ladybird beetle. The breadth of egg, 1^{st}, 2^{nd}, 3^{rd}, 4^{th} instar grub, pupa and adult male and female were 0.45-0.50, 0.45-0.6, 0.57-0.98, 1.4-2.25, 1.4-2.25, 3.0-4.1, 3.0-3.6 and 3.4-4.1 mm, respectivelyfor zigzag ladybird beetle; 0.47-0.50, 0.45-0.65, 0.59-1.1, 1.51-2.27, 1.51-2.27, 3.0-4.2, 3.0-3.9 and 3.25-4.8 mm, respectivelyfor black ladybird beetle and 0.46-0.54, 0.51-0.7, 0.9-1.2, 1.63-2.6, 1.63-2.6, 3.7-4.9, 3.8-4.2 and 3.9-5.0 mm, respectivelyfor transverse ladybird beetle. The predation efficiency of male and female of zigzag, black and transvers ladybird beetle were 847-899 and 972-1010; 835-915 and 958-1020; and 2073-2394 and 2403-2825 aphids, respectively. In case of predation efficiency, transvers ladybird beetle showed the best performance and zigzag and black ladybird beetle showed more or less similar. But the host range or diversity capacity of zigzag and black ladybird beetle were same and highest than transvers ladybird beetle.

LIST OF ABBREVIATIONS AND ACRONYMS

ABBREVIATION	FULL MEANING
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And othiss
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support Program
J.	Journal
Kg	Kilogram
LLB	Ladybird Beetle
LSD	Least Significant Difference
Mg	Milli gram
Ml	Milli liter
MP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
SAU	Shis-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

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CHAPTER I

INTRODUCTION

Mustard (*Brassica* spp) is a noteworthy oilseed crop on the planet which is cultivated in 53 nations including Bangladesh. Mustard has a place with the sort Brassica of the family Cruciferae symbolized by rapeseed and is one of the main oilseed crops in Bangladesh. It is the most prevailing oilseed crop in Bangladesh and covers alone 80% of the all out territory under oilseed crops. It is utilized as a topping, plate of mixed greens, green compost and grub crop, and as a leaf and stem vegetable in the different mustard developing nations of the World (FAO, 2004). In Bangladesh, more than 363 thousand metric ton mustard produced from of 831 thousand acres of land in the year 2016-2017 (BBS, 2017).

Worldwide aphids are serious notorious pest of agriculture (Minks and Harrewijn, 1987). Aphids are likewise called as plant lice since they are significant sucking irritations of natural products, vegetables and other distinctive field crops. Among 4400 known species, around 250 species are regarded as pest for plants (Saleem *et al.*, 2014) Mustard aphid, is a soft bodied small greenish insect which can reproduce parthenogenetically. Nymph and adult cause damage to stems, flowers, leaves, and pods of the plant by sucking sap from which cause reduction of mustard seed quality and quantity. They extend their proboscis in the phloem arrangement of plants for sucking the cell sap (Ali and Rizvi, 2011). If there should be an occurrence of serious infestation, failure of flowering of the plants and about 20-40% yield loss in Asia (Chowdhury *et al.*, 2008). Depending upon the agro-climatic conditions the mean yield reduction from aphid invasion shifts from 35.4% to 73.3% and midpoints 56.2% over all of India and in mustard, the oil yield loss is evaluated to be 32% (Kanrar *et al.*, 2002). There is

diminished photosynthetic proficiency of the plant as it secrets honey dew which improves the development of shooty mold. (Rizkalla *et al.*, 1994).

Aphids such as bean aphid, brinjal aphid, safflower aphid, wheat aphid and mustard aphid are notorious insect pests of different vegetables in Bangladesh. They are clustered on flower buds, under leaves, stems, reduce plant vigor, produce molting or leaf curl, gall formation, yellowing or speckling and shooty mold which reduce photosynthesis.

Aphids are always be a threat to agriculture productivity in Bangladesh. So farmers of our country frequently use chemical insecticides to control insect pest including aphid for increasing the production of crops (Katsarou, 2005). These chemical insecticides are hazardous for the environment and human health (Habeck, 1990). But indiscriminate use of chemical insecticides causes pest resistance, pest outbreak, phytotoxicity and destruction of beneficial pests like predators, parasitiods, microorganisms and pollinators (Luckman and Metcalf, 1978). In the contest of ecofriendly sound and environmentally safe insect control method should be chosen. Integrated Pest Management has been opted in which biological control as one of strong components (Debach and Rosen, 1991). Ladybird beetle is one of the most effective biological control agent.

The ladybird beetle, has been referred to worldwide as predator of various pest. This predatory cocciinellid are common in all countries of Asia (Nasiruddin and Islam, 1979). It is exceptionally regular in the field. There are more than 6000 species of *Coccinellis* on the planet and of which more than 400 happen in the Indian sub-region (Vandenburg, 2000). About 36 species of aphidophagous coccinellids are reported from Indian subcontinent (Baskaran and Subramanyan, 1992). Both the larvae and adults of the species are used as aphid control. The beetles have effectively settled themselves as

one of the effective predators of aphids. Aphidophagous coccinellid insects decrease the frequency of aphid invasion because of their high population density throughout the year.

In Bangladesh, numerous number of coccinellid beetles predate upon different aphids species. The major important coccinellid beetles occurring in Bangladesh include *Micraspis discolor*, *Coccinella septempunctata*, *Coccinella transversalis*, Black ladybird beetle, *M. sexmaculatus*. They are quite common and mostly abundant in winter season.

Generally adult ladybirds aggregate in areas of high aphid population (Mills, 1982; Sakuratani *et al., 1983,* Kareiva, 1986; Obata and Johki, 1990; Evans and Youssef, 1992; Ives *et al.*, 1993). Ladybird beetle have a close synchronization aphids. In field conditions their population may increase or decrease according to the frequency of aphid species (Kenneth and Hagen, 1970). It has high reproductive potential and long oviposition period which is the major characteristics of biological control agent. As a result it receives great attention by the policy maker and entomologists (Pedigo, 2004). Since a biological control agent to control aphid it can be used by augmentation by translocation and release and mass rearing (Saharia, 1982). Predaceous ladybird beetle feeds on a wide range of soft bodied insects such as aphids, mealy bugs, scale insects, leaf hoppers and mites (Omkar, 1996; Joshi, 2008). Through biological control with coccinellids economic damage by the pests could be suppressed. It is known to prey on 39 arthropod species (Gautam, 1989). Coccinellids provide better ecosystem and keeping the pest frequency low and thereby reducing the farmer's dependence on chemical pesticides by maintaining ecological balance. They are bio-indicators and provide the typical information about the health of the ecosystem in which they occur (Agarwala and Bardhanroy, 1999). These predators are tolerant to many insecticides

which is an advantage over other predators (William, 2002; Zala, 1995). Many species of Coccinellids with polymorphs of the species are used as bio control agents on aphids in all over the world.

Ladybird beetle, are very popular cosmopolitan insects assumes a significant role as a natural control operator as a result of its degree to control numerous soft bodied insect basically the aphids on which larvae as well as adults feed vigorously (Gautam, 1989; Omkar, and Pervez, 2000).

By the cautious determination of coccinellid species that are very much adjusted to the climatic conditions the capability of coccinellid insect as predators of aphids could be improved. Natural control of aphids is alternate option of exceptionally risky and harmful insecticide that are as often as possible connected to ensure the plants (Bellows, 2001). The biological control with coccinellids has contributed greatly and suppressed the pest economic damage. Keeping in view the present study was conducted to determine the feeding potential of *C. transversalis, M. sexmaculatus* and Black ladybird beetle on mustard aphid.

Research objective:

1. To study the biology of ladybird beetle found on mustard field.
2. To study predation efficiency of ladybird beetle on mustard aphid collected from the field.

CHAPTER II

REVIEW OF LITERATURE

Ladybird beetles are more or less distributed worldwide and can be found from seacoast to alpine pastures. About 6000 species under 490 genera of Coccinellidae are known worldwide. They are mostly considered beneficial because of their predatory activity and help in regulating pest populations of soft bodied insects like aphids, coccids, mites, jassids, etc. The literatures on the biology of ladybird beetles and their predatory behavior are very sporadic. For the purpose of the study, the most relevant information's are given bellow under the following sub-headings:

2.1 *Coccinella transversalis*

2.1.1 Population dynamics

Agarwal and Bardhanroy, (1999) reported that the number of eggs and adults of *Coccinella transversalis* (Fabricius) increased in response to increase in the population of *Aphis craccivora* in the field. The peak population of *C. transversalis* was recorded during the third week of January on safflower plants, which coincide with aphid, *Uroleucon composite* (Iheobald) peak.

2.1.2 Morphometric

Santosh (2011) reported that in *C. transversalis*, mean body length was 4.46 mm and width 3.49 mm, head 1.23 mm and width 1.43 mm, antennal length 0.73 mm, thorax length 3.62 mm and width 2.61 mm, fore leg length 4.32 mm, middle leg 3.53 mm, hind leg length 438 mm, elytra length 4.40 mm and width 2.40 mm, hind wing length 6.66 mm and width 2.39 mm and abdomen length 2.28 mm and width 2.70 mm.

2.1.3 Biology

Ali and Rizvi, (2007) studied the age specific life-table of *C. transversalis* at various reveals that it took maximum period of 60 days to complete a generation at 20 ± 1°C followed by 56 days at 24 ± 1°C and days at 28 ± 1°C. The survivorship showed a stair step pattern, whereas mortality curve exhibited an irregular pattern with sharp high peaks and negative low However, the life expectancy exhibited a continuous decline with advancement of age. The developmental stages (egg, larva, pre-pupa and pupa) of *C. transversalis* showed highest survivor fraction and lowest apparent mortality, mortality/ survival ratio, indispensable mortality, and k-values at lowest as compared to high. On the other hand, minimum total generation mortality (K) was recorded of 0.1612 at 24 ± 1°C followed by 0.2076 at 20 ± 1°C, and 0.2596 at 28±1°C study

revealed that three different constant temperature, 24 ± 1°C has been proved as a most suitable development of *C. transversalis.*

2.1.4 Fecundity

Santosh (2011) studied the comparative biology of *C. transversalis.* It showed that when it was reared on *A. craccivon* the mean egg period ranged from 2 to 5 days with an average of 2.70 ± 0.76 days, and while on *M. persicae* these periods ranged from 2 to 5 days with an average of 2.70 ± 0.76 days. Fecundity of *C. transversalis* on *A. craccivora, Lipaphis erysimi* and *M. persicae* ranged from 234 to 467, 319 to 423 and 325 to 433 eggs with an average 376.46 ± 47.32, 364.88 ± 27.44 and 377.36 ± 28.96 eggs per female, respectively.

2.1.5 Incubation period

Roy (1976) reported that the larvae of *C. transversalis* hatched after 7 to10 days when feed on mustard aphid, *L. erysimi* laboratory at about 20°C and 70% relative humidity. Debaraj and Singh (1990) reported that the incubation period of *C. transversalis* was 8 to 10 days when reared on *A. craccivora*. Jagadish *et al*. (1996) recorded that the incubation period of *C. transversalis* 4.5-5 days.

2.1.6 Larva (grub)

Santosh (2011) studied the comparative biology of *C. transversalis* and reported that when it was reared on *A. craccivora* mean total larval period ranged from 10 to 15 days with an average of 12.90 ± 1.44 days whereas on *L. erysimi* these periods ranged from 10 to 17 with an average of 12.68 ± 1.63 days. Debaraj and Singh, (1990) showed that the mean developmental period of first. 1st, 2nd, 3rd and 4$^{t'}$ instar larva of *C. transversalis* was 4.69, 3.92, 5.0 and 7.69 days, respectively and the total larval period ranged from 19 to 23 days when reared on *A. craccivora.* Whereas, the developmental period of 1st, 2nd, 3rd and 4th instar larvae of *C. coeruleus* varied from 2.5 to 4.6, 3.0 to 4.5, 3.4 to 4.9 and 7.0 to 8.4 days, respectively when feed on *H. cubana* (Diraviam and Viraktamath, 1991). Roy (1976) studied that the total larval stage of *C. transversalis* lasted for 21 to 22 days when reared on mustard aphid, *L. erysimi* in the laboratory at Kalyani, West Bengal at about 20°C and 70 percent relative humidity.

2.1.7 Pupa

Santosh (2011) studied the comparative biology of *C. transversalis* and reported that when it was reared on *A. craccivora* the mean total pupal periods ranged from 2 to 4 days with an average of 2.62 ± 0.63 days whereas on *L. erysimi* these periods ranged from 2 to 4 days with an average of 2.62 ± 0.69 days. Debaraj and Singh, (1990) found

that the pre-pupal and pupal stage of *C transversalis* was 2.62 and 8.60 days, respectively when fed on *A. craccivora*. However, the length of pupa of *C. coeruleus* ranged from 4.2 to 4.5 mm, whereas the breadth varied from 3.1 to 3.4 mm. Moreover, the pupal period lasted for 6.9 to 7.7 days on *H. cubana* (Diraviam and Viraktamath, 1991). Patro and Sontakke, (1994) observed that the pre-pupal and pupal stages of the *C. transversalis* lasted for 0.61 to 0.13 and 2.48 to 0.21 days, when reared on *A. craccivora.*

2.1.8 Adult

Debaraj and Singh (1990) reported that freshly emerged *C. transversalis* adult was yellowish in colour and its permanent colour appeared after 3 to 4 hours. Body was oval, convex and measured 5.43 to 6.80 mm in length. Roy (1976) reported that *C. transversalis* preyed on mustard aphid, *L. erysimi* in the laboratory at Kalyani, West Bengal at about 20°C and 70 per cent relative humidity. A pre-ovipositon period upto 5 days was observed. Most of this time being in mating and the eggs were laid 24 hours later on the lower surface of the mustard leaves, at the rate of 100 to 200 per female.

2.1.9 Longevity

Santosh (2011) studied the comparative biology of *C. transversalis* and observed that when it was reared on *A. craccivora* mean total adult male and female adult periods ranged from 26 to 38 and 42 to 59 days with an average of 31.58 ± 3.22 and 39.10 ± 3.37 days, whereas on *L. erysimi* these periods ranged from 21 to 40 and 29 to 40 days with an average of 29.08 ± 4.25 and 37.12 ± 2.27 days, respectively. Jagadish *et al.* (1996) reported that the female of *C. transversalis* lived for 37 days and lay 407 eggs when feed on *H. setaria.*

2.1.10 Total life cycle

Santosh (2011) reported the total life cycle of male and female *C. transversalis* on *A. craccivora, L. erysimi* and *M. persicae* ranged from 42 to 59 and 40 to 64, 37 to 58 and 41 to58 days and to 50 67, 46 to 63 and 49 to 63 days with an average 50.80 ± 3.92, 49.12 ± 4.87 and 48.28 ± 5.38 days and 58.32 ± 392, 52.88 ± 3.48 and 56.32 ± 3.07 days, respectively. The percent adult emergence was 80.36 ± 10.830. Debaraj and Singh (1990) made a study on the biology of *C. transversalis* in the laboratory at 18.23 ± 1.60°C and 55.54 ± 2.38 percent relative humidity. The predator was reared on *A. craccivora* (Koch) infesting *Dolichos lablab*. They found that the life cycle from egg to adult was completed in 38 to 45 days.

2.1.11 Feeding potential

Santosh (2011) studied the feeding potential of predator on the different aphid species viz., *A. craccivora, L. erysimi* and *M. persicae*. The *C. transtersalis* larvae consumed a total of 120.24 ± 9.427, 265.86 ± 43.706, and 250.18 ± 26.439 aphids during its developmental period when reared on *A. craccivora, L. erysimi* and *M. persicae,* respectively. The adult devoured on an average 3229.5 ± 675.716, 2529.8 ± 494.682 and 2299.4 ± 562.18 aphids of *A. craccivora, L. erysimi* and *M. persiae,* respectively. The total aphid consumed by predator were 3349.78 ± 675.246, 2795.68 ± 508.780 and 2549.54 ± 565.608, *A. craccivora, L. erysimi* and *M. persiae*, respectively in its entire life span. Borah and Dutta (2010) studied that first, second, third, fourth instar larva and adult male and female of *C. tranversalis* and they consumed 19.95 ± 3.23, 34.25 ± 4.36, 58.30 ± 7.54, 65.67 ± 8.23, 58.32 ± 5.23, 62.17 ± 5.76 apterous adults *L. erysimi* in 24 hours. Prabhakar and Roy (2010) studied that the consumption rate of coccinellid predators on aphid *A. craccioora, A. gossiypii. M. persiae and L. erysimi*. The result observed on male and female *C. septempunctata, C. transversalis, C. sexmaculata, M. discolor* and *Pulus pyrochilus* have high consumption rate on *A. craccivora* (65.6 ± 3.01, 52 ± 4.2), followed by *L. erysimi* (57 ± 4.4, 41.25 ± 1.7), *A. craccivora* (57±2.26, 39.5 ± 0.55), *M. persicae* (43.4 ± 0.51, 30.66 ± 0.62) and *L. erysimi* (34.75±1.4, 25.2 ± 0.65). Patro and Sontakke (1994) reported that *C. transversalis* preyed on bean aphid. *A. craccivora* (Koch) as the larvae and adults captured the aphids by their legs and puncture them on the abdominal region with powerful jaws and finally sucked out body content. George (1999) studied on the feeding preference of *C. transversalis* for three aphid species, higher number of *A. gossypii* were consumed within 1 hour (41.42) followed by *A. nerri* (38.48) and *Pentalonia sp*. (30.42). Consumption of all three species decreased in later hours. Omkar and Srivastava (2003) reported the comparative prey consumption and searching efficiency of fourth instar grubs of *C. septempunctata and C. transversalis* against three species, viz., *Rhopalosiphum maidis, M. persicae* and *Macrosiphum rosae* were evaluated to assess the efficiency of these predators in aphid bio-control. The larvae of *C. septempunctata* consumed maximum number 245.60 ±1.92 of *M. prsicae* at prey density of 800 and minimum 18.80± 0.88 of *R. maidis* at prey density of 25 in 24 hours. Fourth instar of *C. transversalis* consumed maximum of *M. persicae* 24.80± 1.93 at the prey density of 800 and minimum i.e. 17.40 0.58 of *M. rosae* at the prey density of 25 in 24 hours.

The functional response in terms of prey consumption and numerical response in terms of number of eggs oviposited by individual adult females of *Coccinella transversalis*

and *Cheilomenes sexmaculatus* (*C. sexmaculata*) was studied at varying prey (*Aphis gossypii*) densities under laboratory conditions. The feeding rate by individual predators increased as prey density increased, with both coccinellids showing a Type II functional response. One hundred percent prey consumption was observed up to an initial prey density of 50 and 20 for *Coccinella transversalis* and *Cheilomenes sexmaculata*, respectively. The fecundity of *Coccinella transversalis* increased at higher prey densities, but that of *Cheilomenes sexmaculatus* remained unchanged (Veeravel and Baskaran, 1997).

2.2 *Menochilus sexmaculatus*

2.2.1 Population dynamics

Dngale (2008) reported that the activity of ladybird beetle, *M. sexmaculatus* on lucern crop started in 1st meteorological week (1st week of January) to the time of 2.64 per plants which closely followed the aphid incidence with its peak level in 3rd meteorological week (3rd week of January) with 3.94 per plant. The higher average population of *M. sexmaculatus* (9.00/dplant) was recorded on brinjal crop in last week of March (Ghcsh *et al*., 2007). Initially its population was low during winter season and the population increased from March onwards to October except during rainy season where population become very low.

2.2.2 Morphometric

Santosh (2011) reported that the mean body length of *M. sexmaculatus* was measured as 3.79 mm and width 2.97 mm, head length 0.84 mm and width 1.14 mm, antennal length 0.54 mm, thorax length 1.64 mm and width 1.58 mm, fore leg length 3.34 mm, middle leg 2.63 mm, hind leg length 3.92 mm, elytra length 3.90 mm and width 2.52 mm, hind wing length 5.64 mm and width 2.11 mm and abdomen length 1.37 mm and width 2.09 mm.

2.2.3 Biology

Ali (2015) observed the age specific survival, death and life expectancy of *Menochilus sexmaculatus* on different aphid species revealed that it took maximum period of 56 days to complete generation on *Aphis craccivora* and shortest of 50 days on *Lipaphis erysimi*, respectively. The survivorship and the mortality exhibited an irregular pattern with high and low peaks. The high peaks reflecting maximum mortality and low peaks denote the negligible mortality on respective days. As far as the life expectancy was concerned, it declined gradually till the culmination of generation on all aphid species. In nature, the pupae of *M. sexmaculatus* were also found parasitized by *Oomyzus*

scaposus, and *Dinocampus coccinellae*. Abiotic factors viz., temperature, relative humidity, rainfall, wind velocity and evaporation also play an additional role in the mortality of *M. sexmaculatus* in natural environment. Moreover, variation in the rate of mortality of *M. sexmaculatus* could also be influenced by the quality of foods or change in aphid.

2.2.4 Egg

Patel (2006) studied the biology of *M. sexmaculataus* on *U. compositae* (Theobald) under the laboratory conditions. The freshly laid eggs were cigar shaped, yellow in colour with smooth chorion but without any reticulation. Moreover, the length varied from 0.81 to 1.29 mm with an average of 1.13 ± 0.14 mm whereas the breadth ranged from 0.36 to 0.43 mm with an average of 0.39 ± 0.02 mm. Rao *et al*. (1997) studied the biology of *M. sexmaculatus* (Fabricius) and *Verania vincta* (Gorham) on aphid, *A. craccivora* under laboratory conditions and reported that the length and breadth of eggs of *M. sexmaculatus* were 1.13 and 0.47 mm, respectively. More over the eggs of *V. vincta* were 1.15 mm and 0.49 mm in length and breadth, respectively. Campbell *et al*. (1980) reared *Menochilus sexmaculntus* (F.) upon the green bug, *Schizaphis graminum* (Rondani) in which females laid an average of 11.4 eggs/day with a mean fertility of 70%; mean fecundity 779.8 eggs. The mean of days from egg to adult was 12.25 while average longevity for adults were 63.68 days.

2.2.5 Incubation period

Bhadauria *et al.* (2001) studied the biology of *M. sexmaculata* on *L. erysimi*, *A. craaccivora*, *Hydaphis coriandari* and *A. nerri* under the laboratory conditions and reported that incubation period was 2.5, 3.5, 3.0 and 4.0 days, respectively. Patel and Vyas, (1984) showed that incubation of *M. sexmaculatus* lasted for 2 days when feed on *A. craccivora*.

2.2.6 Larvae (Grub)

Rao *et al.* (1997) reported that the larval duration of *M. sexmaculata* on *A. craccivora*, *L. erysimi* and *A. gossypii* ranged from 6.23 to 6.83, 7.84 to 8.17 and 7.20 days, respectively. However, larva of *V. vincta* ranged 13.46 to 14.29, 13.02 to 16.24 and 13.60 days when fed on *A. craccivora*, *L. erysimi* and *A. gossypii*. Patel and Vyas (1984) showed that the total larval period of *M. sexmaculataus* lasted for 6 days when reared on *A. craccivora*. Bhadauria *et al*. (2001) studied the influence of different aphid hosts on the larval development of *M. sexmaculatus*. The study revealed that the *U. compositae* hindered the larval development of *M. sexmaculatus* as it 18.8 days to

transform into pupae as against 10.3 days on *A. craccivora* 10.5 days on *A. nerri* and 1.8 days on *L. erysimi*. Patel (2006) reported that the total larval period of *M. sexmaculatus* varied from 9 to 12 days with an average of 10.00 ± 0.88 days when reared on *U. compositae*. Bhatt (2005) revealed that the duration of first, second, third and fourth instar larvae of *M. sexmaculatus* varied from 1 to 2 (1.02 ± 0.15), 1 to 2 (1.07 ± 0.26), 1 to 2 (1.02 ± 0.15) and 3 to 4 (3.05 ± 0.22) days, respectively when reared on *A. craccivora* whereas, in case *of L. erysimi* it was 1.0 (1.0 ± 0.0), 2.0 (2.0 ± 0.0), 2 to 3 (2.95 ± 0.22) and 3 to 4 (3.05 ± 0.22) days for first, second, third and fourth instar larvae, respectively. Moreover the total larval period varied from 6.0 to 10.0 (6.17 ± 0.44) and 8 to 10 (9.11 ± 0.33) days when feed on *A. craccivora* and *L. erysimi*, respectively. According to Omkar and James (2004) the larval developmental period of *C. transversalis* was shortest on *A. gossypii* (13.01± 0.80 days) and longest on *A. nerii* (20.54 ± 0.25 days). Lyla *et al*. (2008) studied that the instar wise mean durations of *C. transversalis* were 1, 1.8 ±0.13, 2.7±0.15 and 4.8±0.13 days, respectively when reared on *A. craccivora*.

2.2.7 Pupa

Rao *et al*. (1997) reported that the pupal development of *M. sexmaculatus* and *V. vincta* was completed in 3.03 and 3.83 days, respectively when reared on brinjal aphid *A. gossypii*, while it was longer when reared on bean aphid, *A. craccivora*. Bhadauria *et al*. (2001) reported that the mean pupal period of *M. sexmaculatus* was 5.3 ± 0.7 days when reared on different aphid species viz., *L. erysimi*, *A. craccivora*, *H. coriandari*, *A. nerri* and *U. compositae* under the laboratory conditions. Bhatt (2005) opined that pupal period of *M. sexmaculatus* varied from 3 to 4 days with an average of 3.95± 0.74 days when reared on *A. craccivora*, while 3 to 4 days with an average of 3.05± 0.22 days on *L. erysimi*. Patel and Vyas (1984) showed that pupal period of *M. sexmaculatus* lasted for 2 days when reared on *A. craccivora.*

2.2.8 Adult

Bhatt (2005) reported the pre-oviposition, oviposition and post oviposition period of *M. sexmaculatus* were 2.50 ± 1.040, 16.83 ± 2.630 and 2.33 ± 0.81 days, respectively when female on actual feeding level. While in case of 50% feeding level, the pre-oviposition, oviposition and post-oviposition period were 3.83 ± 0.980, 11.66 ± 17.50 and 3.16 ± 0.750 days, respectively. Mari *et al*. (2004) recorded that average adult period of *M. sexmaculatus*, (female and male) recorded as 34.9 ± 4.8 and 29.7 ± 1.2 days, respectively.

2.2.9 Fecundity

Rao *et al*. (1997) reported that highest fecundity of 281 and 115.4 eggs per female was observed in *M. sexmaculatus* and *V. vincta*, respectively when reared *on A. craccivora*, whereas it was very low when reared *on L. erysimi* collected from mustard and cabbage fields. Bhadauria *et al*. (2001) studied the influence of different aphid hosts on the development of *M. sexmaculatus*. The fecundity per female was markedly higher when reared on aphid adults in comparison to nymphs. The variation was 1.4 fold in *A. craccivora* to 3.1 fold in *H. coriandari*. Similarly, there was a great variaüon in the fecundity of *M. sexmaculatus* when reared on different aphid species. The maximum fecundity was recorded when reared on *A. craccivora* (337 on nymphs and 470 on adults). Whereas, it was only 30 and 62 when reared on the nymphs and adults of *A. nerri*, respectively. Moreover, no laid egg was observed when reared on *U. compositae*.

2.2.10 Longevity

Bhatt (2005) reported male and female of *M. sexmaculatus* survived for 9 to 18 and 9 to 20 days with an average of 16.712.39 and 16.79 2.22 days, respectively on *A. craccivora*. Moreover in case of *L. erysimi*, male and female survived for 13 to 17 and 16 to 18 days with an average of 14.5 1.08 and 17.05 0.8 days, respectively. Patel (2006) reported the duration of male and female of *M. sexmaculatus* varied from 22 to 28 days (Av. 25.0±2.19 days) and 21 to 28 days (Av. 25.62 ±2.13 days), respectively when reared on *U. composite*.

2.2.11 Total life cycle

Mari *et al*., (2004) recorded the mean total life cycle of *M. sexmaculatus* (female and male) were 34.9 ± 4.8, 29.7 ± 1.2 respectively, when reared on alfalfa aphid, *Therioaphis. trifolii*. Bhatt (2005) reported that the entire lifecycle of *M. sexmaculatus* ranged from 18 to 30 days with an average of 26.33 ± 3.76 days when reared on *A. craccivora*, while it was 24 to 31 days with an average of 29.52 ± 2.48 days when feed on *L. erysimi*. Patel and Vyas (1984) found that the developmental period of *M. sexmaculatus* adult was 6 to 39 days when reared on *A. craccivora*.

2.2.12 Feeding potential

Shani *et al*. (2016) studied the development biology of *M. sexmaculatus* and to assess its suitability as a biocontrol agent from January to June, 2015 at 27°C and 80 % RH. Ll, L2, L3 and L4 larvae consumed aphid nymphs at the rate of 10.3 ± 1.9, 7.5 ± 1.3, 38.1 ± 3.5 and 69.1 ± 3.1 per day, respectively. Ll, L2, L3 and L4 consumed adult aphids at the rates of 3.3 ± 0.6, 3.3 ± 0.6, 12.1 ± 0.9 and 25.1 ± 1.7 per day, respectively.

Female beetles consumed 1624.1 ± 0.2 nymphs and 1204.3 ± 1.3 adult aphids during their entire adult life span. Males consumed 1302.0 ± 1.5 nymphs and 1006.4 ± 0.4 adult aphids during their entire life span. The feeding efficacy increased with the larval instars. Feeding efficiency of *M. sexmaculatus* adults was higher than larvae. Saleem (2014) evaluated predatory efficacy of *Menochilus sexmaculatus* Fab. on rose aphid *Macrosiphum rosae*, at 27 ± 2°C and 62 ± 5% relative humidity (RH). Predatory efficacy of the lst, 2nd, 3rd and 4th instar larvae of *M. sexmaculatus* was recorded as 8.40±0.50, 13.60±0.81, 28.60±1.50 and 57.40±4.67 aphids, respectively and the predatory efficacy of male and female adults was found to be 802.40±2.56 and 916.60±1.69 aphids respectively. The results unveil the 4th instars larvae with the highest predation performance while the 1st larval instars reported the lowest. The female beetles were found to be more cogent in aphid predation as compared with the males.

Ahmed *et al.* (1990) observed that the predation efficiency of *Menochilus sexmaculatus* on brinjal aphid, *Aphis gossypii* was high 12 hours after predator release at both the high prey density and medium prey density by both the larva and adult. The surviving preys at both the high and medium density were possibly due to maximum prey density. The number of aphids consumed by the predator at high prey density was 13-20 per larva and 16-22 per adult in 12 hours of predator prey association. Although the two groups of predators controlled the prey almost at the same rate at both prey densities, the predation efficiency of adult predators was higher than larval predators. At low prey-density range, the brinjal aphids increased 0.14-0.52 times the initial numbers during the same period probably due to the absence of predators.

The predation efficacy of *Menochilus sexmaculata* at the high density of prey. Although same number of predator larvae used at high and low densities of aphids in caged bean plants, the degree of response by predator larvae varied. Aphidophagous coccinellids are attracted to high population of aphids (Ofuya and Akingbohungbe, 1988; Babu and Ananthakrishnan, 1993)

CHAPTER III

MATERIALS AND METHODS

The experiment were conducted in the laboratory of the Department of entomology and for collection of ladybird beetle and aphid cultivation of mustard was cultivated in the research field, Sher e Bangla Agricultural University, during Rabi season, 1st week of November 2017 to February 2018. To know the incidence of different species of ladybird beetle under field condition several untreated area of different crops (Bean, Brinjal, Radish, Bottle gourd, Chili, Quinoa, Mustard, Maize, Wheat, Sweet gourd, Cucumber) data was collected. The materials and methods those were used and followed for conducting the experiment have been presented under the following headings.

Location

Central laboratory, department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207.

Time duration of the study

The study was conducted during Rabi season. Field crop was cultivated at 1st week of November 2017 to last week of March 2018. Laboratory experiment was set up at last week of November 2017 and end at last week of March 2018.

Materials used

For the laboratory experiment, two species of ladybird beetle *Cheilomenes sexmaculata* (zigzag ladybird beetle), *C. sexmaculata* (Black ladybird beetle) and *Coccinella transversalis* (transverse ladybird beetle) and mustard aphid was collected from mustard field. Tori-7 mustard variety was cultivated in the field which was local and improved variety.

Design

The experiment was laid out in randomized completely block design (RCBD) with 3 replication for field experiment. For the laboratory study, the experiment was laid out in Complete Randomized Design (CRD) with 10 replications.

For mustard cultivation

Soil characteristics

The soil of the experimental area was silty loam belonging to the Non-Calcareous Dark grey Floodplain soils. Under the Agro Ecological Zone 12. The selected site was a well-drained medium high land.

Land preparation

The experimental plot was opened in the 2nd week of October 2017 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for sowing of mustard seeds.

Fertilizes and manure application

The fertilizers N, P, K, S, Zn and B in the form of Urea, TSP, MP, Gypsum, Zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land. Urea was applied in two equal installments at final land preparation and at 30 days of seed sowing. The dose and method of application of fertilizers are shown in Table 1 (Anon., 2005).

Fertilizers	Doses (Kg/ha)	Application (%)	
		Basal	Top dressing
Cow dung	4000	100	-
Urea	300	50	50
TSP	180	100	-
MP	100	100	-
Gypsum	180	100	-
Zinc Sulphate	07	100	-
Borax	15	100	-

Field layout

The field for this experiment was divided into 3 blocks aiming to reduce the heterogeneity of the land each block were sub divided into 4 plots. One meter block to block distance and 0.5 meter plot to plot distance. Plot size was $2m^2$.

Seed sowing

The seeds of Tori-7 variety of mustard was sown at 7 days of interval starting from 1^{st} week to 4^{th} week of November 2017.

Cultural practices

After establishment of seedlings, all intercultural operations such as thinning, weeding, irrigation were accomplished as and when necessary for better growth and development of the crop. Single irrigation was applied just once before flower initiation. Plots were provided with well-arranged drainage facilities. Weeding was done twice in the field to keep the plots free from weeds. The newly emerged weeds were uprooted carefully at flowering stage by mechanical means.

Collection of mustard aphid

Adult mustard aphid were collected from the infested area of the research field of Sher-e-Bangla Agricultural University. They were collected from the infested leaves, stems, pods, inflorescences from the respective unsprayed filed at daily basis and supplied as food.

Collection of predator

Pupa of ladybird beetle were collected by hand picking from the field for the experiment. Pupa was confined in several petridishes of 9×1cm. After hatching of the adult from pupa, same species of adult were separated from the petridishes to another petridish. In that petridish, one pair of male and female ladybird beetle were placed for the mating.

Each pair of beetle were provided with mustard aphid. Everyday fresh aphids were provided to the petridish as food for the predators. For oviposition the petridishes were examined regularly. After the observation of oviposition the male and female predator were transferred to another petridish to avoid damage of the eggs.

After hatching, the larvae were transferred to another petridish till adult emergence. Ten larvae of each species were reared. To get large number of larvae and adult this procedure was continued continuously.

Species identification

Before setting the experiment according to the basis of traditional taxonomy the collected predator and prey were identified at species level (Kapur, 1958; Rafi *et al*., 2005; Rahman and Aniszewski, 2015). Two species with one polymorph of ladybird beetle (*C. transversalis* and *C. sexmaculata*).

Genitalia examination

The genitalia examination was done by following the method of Majerus and Kearns (Majerus and Kearns, 1989).

Biology study of predator

Newly emerged adult beetles were sexed and confined in pairs for egg lying in petridishes. Ten petridish were maintained. Everyday morning fresh aphids were supplied in each petridish. Laid egg were separated from the beetles. Newly hatched larvae were transferred individually and maintained 10 petridishes.

For the determination of predation efficiency fresh aphid were supplied to the young larvae. To record predation, pupation, number of instars and instar period larvae are inspected twice daily. Pupation period was determined by kept the petridish undisturbed.

Mass rearing of predators

A large number of pupa of predator was reared in the laboratory in order to supply necessary insects for the experiment. Emerged adult from pupa, male and female adult were separated to other petridishes on the basis of their species and poly morph. From where male and female adult pair of ladybird beetle were separated to another petridishes for their mating. Observation was made thrice in a day. With the help of blotting paper (Watman filter paper no.1) bottom of the petridishes were covered. The adult male and female predator beetles were provided with mustard aphids. After hatching the eggs, the grubs were transferred to several petridishes and reared on mustard aphids until adult. The emerged adults were sexed and confined in pairs in the petridishes provided with aphids. Egg masses were collected and reared as above and continued for several times for obtaining large number of larvae and adult predators. Larvae were observed at 24^{th} hours intervals until pupation. The number of instars and duration of each instar were recorded by the examination of shed and caste exuv and the pupae were left undisturbed in the same petridishes until adult emergence. Accordingly, the pupal period was recorded. Newly emerged beetles were keenly observed and their pre-oviposition and oviposition periods were recorded while keeping them individually in petridishes providing aphids as a food source.

Predation efficiency of ladybird beetle

Predation efficiency of larvae

Newly hatched larvae of ladybird beetle that were transferred individually to 10 petridishes. Counted number of aphids were supplied as 30, 50, 80, 100 for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instars, respectively. Aphid were replaced after 24 hours and period of instar with consumption were recorded.

Predation efficiency of adult

For the determination of predation efficiency of adult beetle, newly emerged 10 adult beetles were transferred to other petridishes and cultured individually. 100 aphids were placed in each petridish and after 24 hours new aphid were introduced while rejecting the old one. Dead aphid were avoided. Aphids were counted under magnifying glass using hair pencil. This process were continued till the death of the beetles and consumption of aphid were recorded.

Data collection parameter

- Fecundity
- Length and breadth of egg
- Length and breadth of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instars larvae
- Length and breadth of pupae
- Length and breadth of newly emerged adult male and female
- Incubation period
- Larval period of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instars
- Pre-pupal period
- Pupal period
- Adult longevity of male and female
- Total life period of male and female beetle
- Pre-ovipositional period
- Ovipositional period
- Predation efficiency of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instars larvae
- Predation efficiency of adult male and female
- Predation efficacy of male and female beetle

Data collection procedure

Length and breadth of egg, larva, pupa and adult:

Length and breadth of egg, different instar of larva, pupa and adult were measured by using of Sterio microscope (Euromex) and its associated software.

Incidence of ladybird beetle in the field conditions

Incidence of ladybird beetle was recorded from mustard, bean, brinjal, raddish, bottle gourd, chili, quinoa, maize, wheat and sweet gourd field of experimental field of Sher-e-Bangla Agricultural University, Dhaka by visual observation. For each field $2m^2$ area was taken for the counting of ladybird beetle incidence. $1m^2$ stick was used for measuring area. The point where I was stand took as a center position and from the center position $1m^2$ land was taken from in front side, left and right side. Thus $2m^2$ land was taken. Then incidence of beetle was counted at the time of early morning and data was recorded.

Data analysis

All the collected data was analyzed following the analysis of variance (ANOVA) technique with the help of MSTAT-C Computer Package and the mean differences was adjusted by Least Significant Difference (LSD) technique.

Plate 1: Experimental mustard field

Plate 2: Ladybird beetle in mustard field

Plate 3: Emerged 1st instar grub of ladybird beetle from egg

Plate 4: Aphid infested mustard twig

CHAPTER-IV

RESULTS AND DISCUSSION

The experimental studies included investigation on the life cycle, predation efficiency feeding preference of zigzag ladybird beetle, black ladybird beetle and transverse ladybird beetle on mustard aphid. The data have been presented and discussed and possible interactions are made under the following sub-hadings:

4.1 Species diversity of Ladybird beetle in different crop fields in SAU Campus

To study the species diversity of ladybird beetle in different crop fields was carried out at experimental farm of SAU campus. Zigzag ladybird beetle and black ladybird beetle were found in different crop fields like bean, brinjal, radish, bottle gourd, chili, quinoa, mustard, maize, sweet gourd and cucumber fields. The population of zigzag ladybird beetle was high in the field of cucumber (52.0%) and followed by bottle gourd (42.0%), sweet gourd (41.7%), maize (36.2%) and bean (35.8%). On the other hand, lowest population was found in quinoa field (21.1%), chili (22.5%), mustard (23.0%), wheat (23.5%), brinjal (27.6%) and radish (28.9%) (Table 1). In case of the population of black ladybird beetle was high in the field of maize (63.8%), followed by bottle gourd (58.0%), radish (49.5%), cucumber (48.0%) and quinoa (43.8%). On the other hand, lowest population was found in wheat crop (21.0%), mustard (31.1%), brinjal (28.6%), chili (27.5%), sweet gourd (30.6%), and bean (40.3%) (Table 1).

The transverse ladybird beetle was found in different crop fields like radish, chili, quinoa, mustard, sweet gourd, and wheat and brinjal fields. The population of transverse ladybird beetle was found the highest in the field of chili (50.0%), followed by sweet gourd (27.8%). On the other hand, the lowest population was found in radish field (11.3%), quinoa (20.0%), mustard (22.1%), wheat (23.5%) and brinjal crop (26.7%) (Table 1).

In terms of spotless ladybird beetle, it was found in different crop fields like radish, mustard, and brinjal fields. The population of spotless ladybird beetle was high in the field of mustard (10.7%) and followed by brinjal (5.7%). On the other hand, the lowest population was found in radish crop (3.1%) (Table 1).

The seven spotted ladybird beetle was found in different crops like radish, mustard, and wheat fields. The population of seven spotted ladybird beetle was high in the field of wheat (34.6%), followed by radish (7.2%). On the other hand, the lowest population was found in mustard crop (5.7%) (Table 1).

Again the spotless black head ladybird beetle was found in different crop fields like bean, brinjal, quinoa and mustard crops. The population of spotless black head ladybird beetle was observed the highest in the bean crop (23.9%) and followed by quinoa (15.0%). On the other hand, lowest population was found in mustard crop (7.4%) and brinjal (11.4%) crop (Table 1).

According to this survey, the highest species was found in mustard but the lowest in bean, bottle gourd and maize. *Menochilus sexmaculaus* (zigzag ladybird beetle and Black ladybird beetle) was common in all crop fields. The highest and lowest population of this insects found in mustard and sweet gourd, respectively.

General characteristics of the ladybird beetle found from the above table are described below:

4.1.1 Characteristics of the species

4.1.1.1 *Coccinella sexmaculata*

The species is mostly reported with the name *Menochilus sexmaculatus* and this name is very common but the exact name according to the code of Zoological nomenclature is *Cheliomenus sexmaculatus*. Body nearly rounded and glabrous. Head yellowish brown, Pronotum yellowish brown with two transverse black brownish band.

Table1. Incidence of Ladybird beetle on different crops (4 observation No. / 2 square meter area)

Crops		Zigzag LBB	Black LBB	Transverse LBB	Spotless LBB	Seven spotted LBB	Spotless black head LBB
Bean	No.	24	27	0	0	0	16
	%	35.8	40.3	0	0	0	23.9
Brinjal	No.	29	30	28	6	0	12
	%	27.6	28.6	26.7	5.7	0	11.4
Radish	No.	28	48	11	3	7	0
	%	28.9	49.5	11.3	3.1	7.2	0
Bottle gourd	No.	29	40	0	0	0	0
	%	42.0	58.0	0	0	0	0
Chili	No.	9	11	20	0	0	0
	%	22.5	27.5	50.0	0	0	0
Quinoa	No.	17	35	16	0	0	12
	%	21.2	43.8	20.0	0	0	15.0
Mustard	No.	28	38	27	13	7	9
	%	23.0	31.1	22.1	10.7	5.7	7.4
Maize	No.	17	30	0	0	0	0
	%	36.2	63.8	0	0	0	0
Wheat	No.	19	21	13	0	28	0
	%	23.5	25.9	16.0	0	34.6	0
Sweet gourd	No.	15	11	10	0	0	0
	%	41.7	30.6	27.8	0	0	0
Cucumber	No.	13	12	0	0	0	0
	%	52.0	48.0	0	0	0	0

Elytra highly variable in colour but generally brownish yellow, spots black and decorated with transverse zigzag patches. On each elytron the first patch small, inverted V-shaped, the second complete W-shaped and the third rounded. Median lobe of male genitalia shorter than parameres. The size and colour pattern of the species are highly variable and there are 6 morphs of it. This is the commonest, highly misidentified coccinellid due to the occurrence of numerous colour variants. It is widely distributed throughout the country and reported almost by all previous workers from Pakistan (Saeed *et al*., 2016). It also distributed in Afghanistan, Bangladesh, Bhutan, China, India, Indonesia, Iran, Japan, Malaysia, Myanmar, Nepal, New Guinea, Oriental region; Philippines, Sri Lanka, Taiwan, Vietnam (Poorani, 2004).

Taxonomic classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Cheilomenes*

Species: *C. sexmaculata*

Plate 5: Adult of *C. sexmaculata*

Synonym:

Coccinella sexmaculata Fabricius, 1781

Cheilomenes quadriplagiata Dejean, 1837

Cheilomenes sexmaculata var. *flavofasciata* Mulsant, 1850

Orcus mollipes Olliff, 1895 (Pope, 1989)

Chilomenes hiugaensis Takizawa, 1917 (Sasaji, 1971)

Micraspis inops Chuniram and Sasaji, 1980

Menochilus sexmaculatus Fabricius, 1781 (Rafi *et al*. 2005)

4.1.1.2 *Coccinella transversalis*

Coccinella transversalis, commonly known as the transverse ladybird or transverse lady beetle is a species of ladybird beetle found from India across southern and southeastern Asia to Malesia and Australia. It is not to be confused with *Coccinella transversoguttata*, a widespread species in Europe and North America also known as the transverse ladybird. The transverse ladybird was first described by Danish zoologist Johan Christian Fabricius in 1781 as *Coccinella transversalis*. Australia, Bangladesh, China, India, Indochina, Indonesia, Japan, Nepal, New Zealand, Sri Lanka (Poorani, 2004) and Pakistan (Khan *et al.,* 2008). The transverse ladybird shows little variation across its wide range. It has a black head with predominantly bright red or orange elytra boldly marked with a black band down the midline and two lateral three-lobed markings. Body somewhat elongate, ventrally black. Head almost inserted, not visible from above. Pronotum black with anterio-lateral orange spots. Elytra dull orange to yellowish brown, with black spots variably arranged. Male genitalia with siphona l tube carrying transparent bubble like structure on dorsal side on sub distal portion. It is also variable in coloration especially in the elytral pattern (Saeed *et al.,* 2016).

Taxonomic classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Coccinella*

Species: *C. transversalis*

Plate 6: Adult of *C. transversalis*

Synonym:

Coccinella transversalis Fabricius, 1781

Coccinella transversalis Fabricius, 1966 (Saeed *et al*., 2016)

4.1.1.3 *Micraspis discolor*

Micraspis discolor is a species of ladybird. It was described by Johan Christian Fabricius in 1798. Adult M. discolor was oval, convex bodied with orange to red orange elytra. Male was usually smaller (3.64 mm long and 2.82 mm wide) than female (4.08 mm long and 3.24 mm wide). The beetles were cannibalistic in habit (Begum, *et al.*, 2002). Found from southern Asia to Oceania and originated from Hawaii.

Taxonomic classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Micraspis*

Species: *M. discolor*

Plate 7: Adult of *M. discolor*

4.1.1.4 *Coccinella septempunctata*

Coccinella septempunctata, the seven-spot ladybird (or, in North America, seven-spotted ladybug is the most common ladybird in Europe. Its elytra are of a red colour, but punctuated with three black spots each, with one further spot being spread over the junction of the two, making a total of seven spots, from which the species der ives both its common and scientific names (from the Latin*septem* = "seven" and *punctus* = "spot"). Body rounded oval, convex, almost hemispherical, and densely punctate. Head black with yellow hairs and a pair of yellow spots. Elytra glabrous, with 7 black spots,

one triangular common post scutellar, one on each elytron at middle near suture, 2 near lateral margins. Male genitalia with median lobe short than Parameres. Siphonal tube straight for most of its length, apex appears to be distorted at three points, apex flattened. It is cosmopolitan and adopted to almost all habitats of agricultural crops, range lands and forests (Saeed *et al*., 2016). It is distributed in Pakistan (Chaudhry *et al.*, 1966), Bhutan, India, Nepal, North America; Palearctic region; Sri Lanka, (Poorani, 2004).

Taxonomic classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Coccinella*

Species: *C. septempunctata*

Plate 8: Adult of *C. septempunctata*

Synonym:

Coccinella septempunctata Linnaeus, 1758

Coccinella divaricata Olivier, 1808

Coccinella confusa Wiedemann, 1823

Coccinella bruckii Mulsant, 1866

Coccinella septempunctata Brucki, 1932 (Saeed *et al*., 2016)

4.1.1.5 *Cycloneda sanguine*

Cycloneda sanguinea is a large ladybird beetle with red, unspotted elytra (wing covers). The color ranges from orange to deep red. The white and black marks on the head

and pronotum are very distinctive, and they are also gender-specific. Females and males both have white spots on the black part, but the female has black in the center, continuing down into the face, while the male has a white cleft above the head and a white face. These ladybugs are very often found feeding on aphids on milkweeds, but also occur on a number of other plants. Its pupae have the remarkable ability to "bite" potential predators using a device known as a "gin trap".

Taxonomic classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Cycloneda*

Species: *C. sanguine*

Plate 9: Adult of *C. sanguine*

4.1.2 Elytra formation of the species

In the laboratory and field conditions, zigzag ladybird beetle and black ladybird beetle shows elytral characteristics after mating. In the laboratory, two adult of zigzag ladybird beetle were mate. After mating, two elytra namely zigzag ladybird beetle and black ladybird beetle were found at the first generation. The ratio of elytra zigzag ladybird beetle and black ladybird beetle was 8:2 (10 replications were counted). Same things was observed in case of black ladybird beetle. Many researcher observed these elytra of different species of ladybird beetle (Maurice, N. 2011; Subramaniam, 1924).

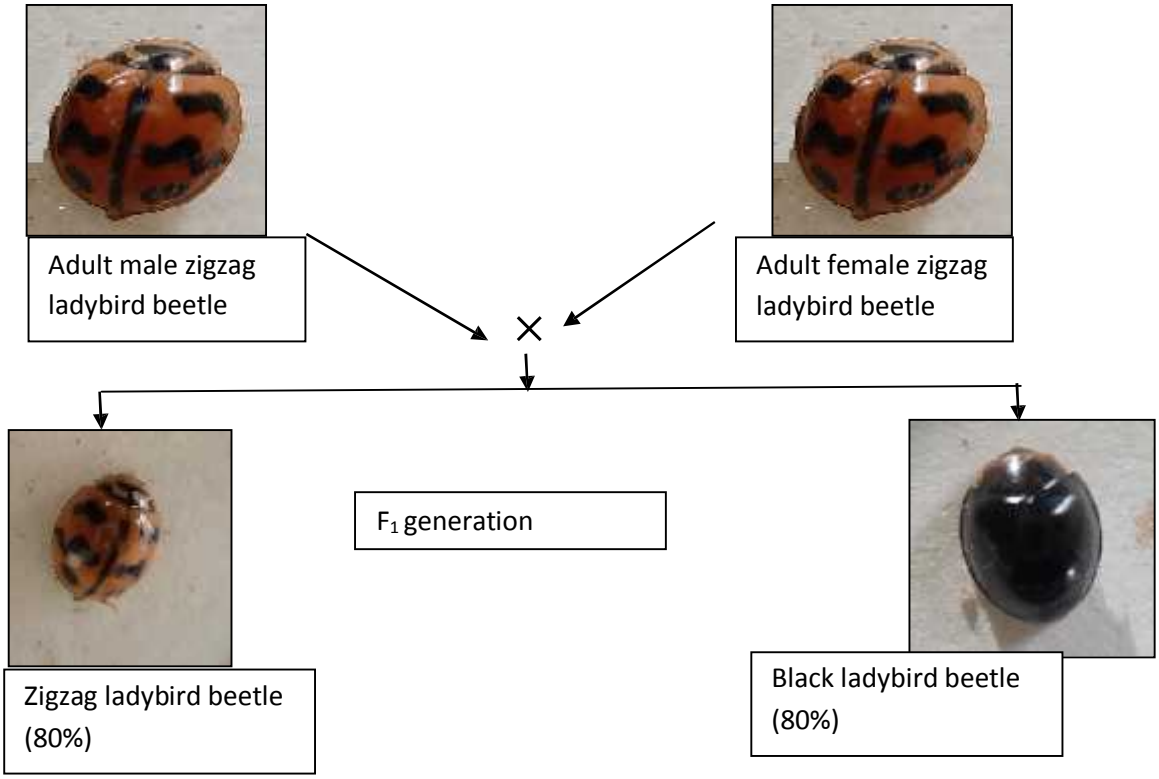

Figure 1: Elytra formation of zigzag ladybird beetle at F_1 generation

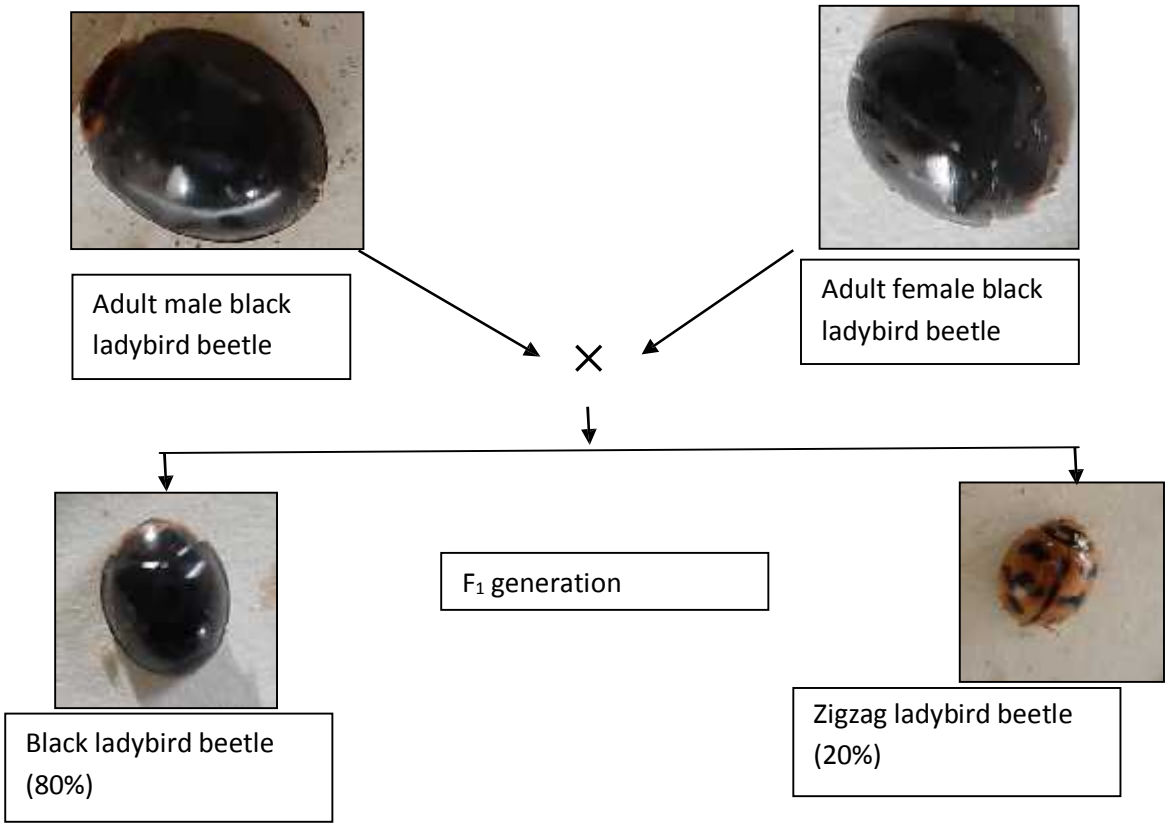

Figure 2: Elytra formation of black ladybird beetle at F_1 generation

4.2. Biology of the species (growth and development)

4.2.1 Mating behavior and fecundity

Mating took place generally within 3-4 days after emergence of adult beetles. Early morning is the right time for mating. The male beetle climbed on the back of the female beetle and hold her tightly during copulation. Male beetle curved downwards its abdomen while the female one bent its abdomen upward. Although, during copulation both sexes remain quiet but the female can walk or predate. The fecundity of *Menochilus sexmaculatus (*zigzag ladybird beetle), *Menochilus sexmaculatus* (black ladybird beetle) and *Coccinella transversalis* was 75 to 112, 80 to 117 and 175 to 214 while the average of 93.55 ± 10.78, 95.55 ± 11.25 and 194.33 ± 12.51, respectively (Table 2). This observations are more or less similar to the results of Akter (2018), Tank and Korat (2006), Zala (1995) and Patel (1985).

Table 2. Fecundity of adult female ladybird beetle

Species	Minimum	Maximum	Average ± SD
Zigzag ladybird beetle	75	112	93.55 ± 10.78
Black ladybird beetle	80	117	95.55 ± 11.25
Transverse ladybird beetle	175	214	194.33 ± 12.51

4.2.2 Egg

During the present study, it was observed that ladybird beetle did lay eggs where aphid colonies present in field conditions. In laboratory condition, the eggs were laid on the blotting paper (Whatman filter paper no.1) of petridishes. The eggs were usually laid in singly or in the groups. The freshly laid eggs of the beetles were cigar shaped, bright yellow in colour with smooth chorion and without any reticulations. The eggs were attached to the surface vertically. The eggs of *Coccinella transversalis* was darker than

the two others. The eggs turned blackish with advancement of age and became completely black before hatching.

Incubation period is the duration between the dates of eggs laying and egg hatching. Incubation period of zigzag, black and transverse ladybird beetle were 2 to 3 days, 2 to 3 days and 5 to 7 days with an average of 2.4 ± 0.516 days, 2.5±0.527 days and 5.8 ±0.788 days, respectively (Table 3). These observations were strongly supported by Jagadish *et al.* (1996) and Bhaduria *et al*. (2001).

Table 3: Incubation period of different species of ladybird beetle

Species	Incubation period (Day)		
	Maximum	Minimum	Mean ± SD
Zigzag ladybird beetle	2	3	2.4±0.52
Black ladybird beetle	2	3	2.5±0.53
Transverse ladybird beetle	5	7	5.8 ±0.79

a. b. c.

Plate 10: Egg of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

The length of eggs of *Menochilus sexmaculatus (*zigzag ladybird beetle), *Menochilus sexmaculatus* (Black ladybird beetle) and *Coccinella transversalis* were ranged from 0.92 to 1.12 mm, 0.96 to 1.15 mm, 1.15 to 1.36 mm, respectively. Average length of the eggs of ladybird beetle 1.048 ± .081 mm, 1.059 ±. 067 mm and 1.24 ± 0.069 mm were significantly similar (Table 4). The breadth of ladybird beetle were varied from 0.45 to 0.5 mm, 0.47 to 0.5 mm and 0.46 to 0.54 mm, respectively with an average of 0.475 ± .015 mm, 0.484 ± 0.018 mm and 0.49 ± 0.026 mm respectively which were also statistically similar (Table 4). This findings shows that eggs of *Coccinella*

transversalis is larger than *Menochilus sexmaculatus.* These observations are strongly supported by Tank and Korat (2006) and Sureja (1991).

Table 4. Eggs length and breadth of ladybird beetle

Species	Length of egg (mm)			Breadth of egg (mm)		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Zigzag ladybird beetle	0.92	1.12	1.05±0.08 a	0.45	0.5	0.48±0.02 a
Black ladybird beetle	0.96	1.15	1.06±0.07 a	0.47	0.5	0.48±0.02 a
Transverse ladybird beetle	1.15	1.36	1.24±0.07 a	0.46	0.54	0.49±0.03 a

4.2.3 Grub

The grub came out by making an irregular hole through the upper end from the egg shell and remain cluster almost half a day. In this period of time they eat the remaining of the eggs of their own.

4.2.3.1 First instar grub

The newly hatched grub was black in color with little transparency and for *Coccinella transversalis* dorsal part of the thorax was slightly yellowish with black in color. Within 1-2 days 4 lateral lobe of 1st and 4th abdominal segment became white in color in *Menochilus sexmaculatus* and orange color in *Coccinella transversalis.* The larval appearance of zigzag ladybird beetle and black ladybird beetle can't be distinguished.

The period of 1st instar grub of zigzag ladybird beetle, black ladybird beetle and transverse ladybird beetles were ranged from 1 to 2 days, 1 to 2 days and 2 to 3 days with an average of 1.5 ± 0.53 days, 1.6 ± 0.516 days and 2.6 ± 0.516 days, respectively (Table 5). This observations were supported by some authors. Debaraj and singh, (1990) showed that the mean developmental period of 1st instar grub of transverse

ladybird beetle was about 4.69 days and 1 to 2 days for zigzag ladybird beetle (Bhatt, 2005).

Table 5: First instar grub period of different species of ladybird beetle

Species	First instar grub period (Day)		
	Maximum	Minimum	Mean ± SD
Zigzag ladybird beetle	1	2	1.5±0.53
Black ladybird beetle	1	2	1.6±0.52
Transverse ladybird beetle	2	3	2.6±0.52

There have no significant variation among the different species of ladybird beetle in case of 1st instar grub length. The length of 1st instar grub of zigzag ladybird beetle, black ladybird beetle and transverse ladybird beetle were 1.45 to 2.5 mm, 1.5 to 2.35 mm and 1.66 to 2.23 mm with an average of 1.81 ± 0.34 mm, 1.90 ± 0.29 mm and 1.96 ± 0.19 mm, respectively, which were statistically similar among the three species (Table 6). The breadth of 1st instar grub of zigzag ladybird beetle, black ladybird beetle and transverse ladybird beetle were 0.45 to 0.6 mm, 0.45 to 0.65 mm and 0.51 to 0.70 mm with an average of 0.53 ± 0.05 mm, 0.54 ± 0.06 mm and 0.59 ± 0.06 mm, respectively (Table 6). Where the breadth of transverse ladybird beetle is higher than zigzag ladybird beetle and statistically similar with black ladybird beetle. This observations were supported by some authors (Zala, 1995 and Tank and Korat, 2006).

Table 6: Length and breadth of first instar of ladybird beetle

Species	Length (mm)			Breadth (mm)		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Zigzag LBB	1.45	2.5	1.81±0.34 a	0.45	0.6	0.53±0.05 b
Black LBB	1.5	2.35	1.90±0.29 a	0.45	0.65	0.54±0.06 ab
Transverse LBB	1.66	2.23	1.96± 0.19 a	0.51	0.7	0.59±0.06 a

a.  b.  c. 

Plate 11: First instar grub of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

4.2.3.2 Second instar grub

The 2nd instar grub had no distinguishing feature than 1st instar grub but the length of the grub. 2nd instar larval period ranged from 1 to 3 days, 1 to 3 days and 2 to 3 days with an average of 1.7 ± 0.66 days, 1.7 ± 0.82 days and 2.8 ± 0.63 days, respectively (Table 7). This observations are supported by some authors. Debaraj and singh, (1990) showed that the mean developmental period of 1st instar grub of transverse ladybird beetle was about 3.92 days and 1 to 2 days for zigzag ladybird beetle (Bhatt, 2005).

Table 7: Second instar grub period of different species of ladybird beetle

Species	Second instar grub period (Day)		
	Maximum	Minimum	Mean ± SD
Zigzag ladybird beetle	1	3	1.7±0.66
Black ladybird beetle	1	3	1.7±0.82
Transverse ladybird beetle	2	4	2.8±0.63

There was no significantly variation among the species of ladybird beetle in case of length of 2nd instar grub of ladybird beetle. The length of the 2nd instar grubs were 2.6 to 3.8 mm, 2.35 to 4.15 mm and 3.2 to 3.98 mm with an average of 3.17 ± 0.39 mm, 3.25 ± 0.67 mm and 3.53 ± 0.26 mm, respectively (Table 8). There was significantly variation among the species of ladybird beetle in case of breadth of the 2nd instar grubs of ladybird beetle. The breadth of transverse ladybird beetle is higher than zigzag ladybird beetle and black ladybird beetle, where zigzag ladybird beetle and black ladybird beetle both statistically similar. The breadth of the 2nd instar grubs were 0.57 to 0.98 mm, 0.59 to 1.1 mm and 0.9 to 1.2 mm with an average of 0.81 ± 0.14 mm, 0.84

± 0.188 mm and 1.01 ± 0.09 mm, respectively (Table 8). The breadth of transverse ladybird beetle is higher than zigzag ladybird beetle are statistically similar with black ladybird beetle. This observations are supported by some authors (Zala, 1995 and Tank and Korat, 2006).

Table 8: Length and breadth of the second instar of ladybird beetle

Species	Length (mm)			Breadth (mm)		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Zigzag LBB	2.6	3.8	3.17±0.39 a	0.57	0.98	0.81±0.14 b
Black LBB	2.35	4.15	3.25±0.67 a	0.59	1.1	0.84±0.19 b
Transverse LBB	3.2	3.98	3.53±0.26 a	0.9	1.2	1.01±0.09 a

a. b. c.

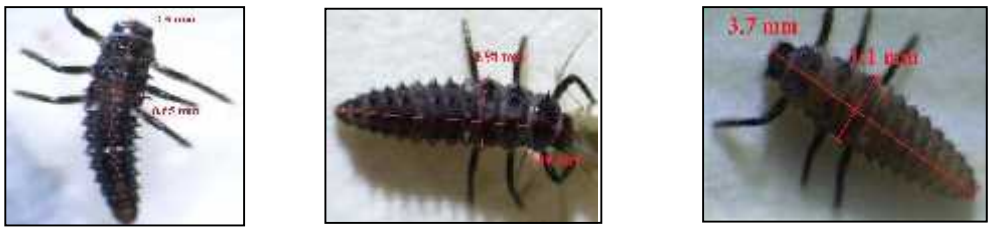

Plate 12: Second instar grub of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

4.2.3.3 Third instar grub

The 3rd instar grub was similar in general appearance to 2nd instar grub except larger in size. The 3rd instar grubs were spiny structure and little larger than 2nd instar. Freshly moulted 3rd instar grub was dark black in color. The 3rd instar grub period ranged from 2 to 3 days, 2 to 3 days and 3 to 5 days with an average of 2.5 ± 0.53 days, 2.4 ± 0.52 days and 4 ± 0.47 days, respectively (Table 9). Debaraj and singh, (1990) showed that the mean developmental period of 1st instar grub of transverse ladybird beetle was about 5 days and 1 day to 2 days for zigzag ladybird beetle (Bhatt, 2005).

Table 9: Third instar grub period of different species of ladybird beetle

Species	Third instar grub period (Day)		
	Maximum	Minimum	Average ± SD
Zigzag ladybird beetle	2	3	2.5 ± 0.53
Black ladybird beetle	2	3	2.4 ± 0.52
Transverse ladybird beetle	3	5	4 ± 0.47

There was statistically variation among the length of the 3rd instar grub of ladybird beetle. The highest length was found at transverse ladybird beetle than other species. On the other hand, zigzag ladybird beetle and black ladybird beetles were statistically similar. The length of the 3rd instar grub of ladybird beetle were 3.17 to 5.52 mm, 4.07 to 5.85 mm and 4.81 to 6.07 mm with an average of 4.73 ± 0.69 mm, 4.92 ± 0.54 mm and 5.57 ± 0.47 mm, respectively (Table 10). Again, there was statistically variation among the breadth of the 3rd instar grub of ladybird beetle. The highest breadth was found at transverse ladybird beetle than other species. On the other hand, zigzag ladybird beetle and black ladybird beetle were statistically similar. The breadth of 3rd instar grub of ladybird beetles were 0.58 to 1.7 mm, 1.02 to 1.52 mm and 1.34 to 1.8 mm with an average of 1.30 ± 0.25 mm, 1.3 ± 0.15 mm and 1.58 ± 0.15 mm, respectively (Table 10). The length and breadth of transverse beetle is higher than zigzag beetle and black ladybird beetle. But the length and breadth of zigzag beetle and black ladybird beetle were statistically similar. This observations are supported with Zala (1995) and Tank and Korat (2006).

Table 10: Length and breadth of the third instar of ladybird beetle

Species	Length (mm)			Breadth (mm)		
	Min.	Max.	Av. ± SD	Min.	Max.	Av. ± SD
Zigzag LBB	3.17	5.52	4.73±0.69 b	0.58	1.70	1.30±0.25 b
Black LBB	4.07	5.85	4.92±0.54 b	1.02	1.52	1.30±0.15 b
Transverse LBB	4.81	6.07	5.57±0.47 a	1.34	1.80	1.58±0.15 a

a.  b.  c. 

Plate 13: Third instar grub of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

4.2.3.4 Forth instar grub

The 4th instar grub was similar in general appearance to 3rd instar grub, excluding larger in size. Grubs were deep black in color, when freshly moulted but changed to black in color before pre-pupation. The 4th instar grubs lasted for 2 to 3 days, 2 to 3 days and 3 to 5 days with an average of 2.6 ± 0.52 days, 2.6 ± 0.52 days and 4.2 ± 0.79 days, respectively (Table 11). Total larval period ranged from 7 to 10 days, 7 to 9 days and 12 to 16 days with average of 8.3 ± 0.95 days, 8.2 ± 0.63 days and 13.8 ± 1.22 days, respectively (Table 17). Debaraj and singh (1990) showed that the mean developmental period of 1st instar grub of transverse ladybird beetle was about 7.69 days and 3 days to 4 days for zigzag ladybird beetle (Bhatt, 2005).

Table 11: Forth instar grub period of different species of ladybird beetle

Species	Forth instar grub period (Day)		
	Maximum	Minimum	Mean ± SD
Zigzag ladybird beetle	2	3	2.6±0.516
Black ladybird beetle	2	3	2.6±0.516
Transverse ladybird beetle	3	5	4.2±0.788

There was statistically variation among the length of the 4th instar grub of ladybird beetle. The highest length was found at transverse ladybird beetle than black ladybird beetle. Zigzag ladybird beetle was statistically similar with transverse ladybird beetle. The length of the 4th instar grub of ladybird beetles were 5.6 to 7.5 mm, 5.5 to 6.84 mm and 5.77 to 7.9 mm with an average of 6.52 ± 0.56 mm, 6.36 ± 0.42 mm and 6.96 ± 0.75 mm, respectively (Table 12). There was no significantly variation among the

species of ladybird beetle in case of breadth of 4th instar grub of ladybird beetle. The breadth of 4th instar grub of ladybird beetles were 1.4 to 2.25 mm, 1.51 to 2.27 mm and 1.63 to 2.6 mm with an average of 1.9 ± 0.31 mm, 1.9 ± 0.28 mm and 2.00 ± 0.42 mm, respectively (Table 12). The length of transverse ladybird beetle is higher than zigzag ladybird beetle and black ladybird beetle. But the length of zigzag ladybird beetle and black ladybird beetle were statistically similar. The breadth of ladybird beetle at 4th instar grub period was statistically similar. This observations were supported by some authors (Zala, 1995 and Tank and Korat, 2006).

Table 12: Length and breadth of forth instar of ladybird beetle

Species	Length (mm)			Breadth (mm)		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
Zigzag LBB	5.6	7.5	6.52±0.558 ab	1.4	2.25	1.9±0.31 a
Black LBB	5.5	6.84	6.36±0.42 b	1.51	2.27	1.9±0.276 a
Transverse LBB	5.77	7.9	6.96±0.75 a	1.63	2.6	2.00±0.42 a

a. b. c.

Plate 14: Forth instar grub of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

In all species and instar the length and breadth of *Coccinella transversalis* was higher than zigzag ladybird beetle and black beetle. And zigzag ladybird beetle and black ladybird beetle shows similar results. This observations are strongly supported by Patel (1998) and Tank and Korat (2006).

4.2.4 Pupae

While pupation occurred, the grub attach their last abdominal segment to the surface. Just prior to pupation, the spiny structure of the grub was disappeared. Freshly formed

Menochilus sexmaculatus pupae were shining yellow in colour and later on turned to pale orange yellow. There were symmetrically orange black spots on each segment. The body turned into orange in colour later on blackish orange in colour. There is no difference between the pupae of zigzag ladybird beetle and black ladybird beetle. Freshly pupa of *Coccinella transversalis* was black in color with orange spot in every segment. The time duration between the grub stop feeding and the day of pupation was considered as pre-pupal period. Pre-pupal period ranged from 1 day, 1 day and 1 day to 2 days, respectively. Pupal period ranged from 2 to 4 days, 2 to 4 days and 5 to 8 days with an average of 2.8 ± 0.63 days, 2.9 ± 0.74 days and 6.9 ± 0.99 days, respectively (Table 13). Many author reported more or less same result about the pupal period of different species of ladybird beetle. Santosh (2011) reported that, total pupal period of *C. transversalis* ranged from 2 to 4 days with an average of 2.62 ± 0.63 days and for *M. sexmaculatus* which varied from 3 to 4 days with an average of 3.95 ± 0.74 days (Bhatt, 2005).

Table 13: Pupal period of different species of ladybird beetle

Species	Pupal period (Day)		
	Maximum	Minimum	Mean ± SD
Pre-pupal period			
Zigzag ladybird beetle	1	1	0.91±0.14
Black ladybird beetle	1	1	0.88±0.16
Transverse ladybird beetle	1	2	1.4±0.52
Pupal period			
Zigzag ladybird beetle	2	4	2.8±0.63
Black ladybird beetle	2	4	2.9±0.74
Transverse ladybird beetle	5	8	6.9±0.99

There were statistically variation among the species of ladybird beetle in case of length and breadth of the pupa of ladybird beetle. The transverse ladybird beetle shows higher length and breadth of its pupa. Zigzag and black ladybird beetles were statistically

similar in the terms of length and breadth of the pupa of ladybird beetle. The length of the pupae of ladybird beetle were 3.8 to 5.2 mm, 3.9 to 5.3 mm and 5.0 to 6.6 mm with an average of 4.36 ± 0.49 mm, 4.47 ± 0.49 mm and 5.73 ± 0.53 mm, respectively (Table 14). The breadth of ladybird beetles were 3.0 to 4.1 mm, 3.0 to 4.2 mm and 3.7 to 4.9 mm with an average of 3.53 ± 0.35 mm, 3.62 ± 0.41 mm and 4.3 ± 0.38 mm, respectively (Table 14). In all species the length and breadth of pupa of *Coccinella transversalis* was higher than zigzag ladybird beetle and black beetle. On the other hand, zigzag and black ladybird beetles shows statistically similar results. This observations are strongly supported by Patel (1998) and Tank and Korat (2006).

Table 14. Pupal length and breadth of ladybird beetle

Species	Length (mm)			Breadth (mm)		
	Min	Max	Mean ± SD	Min	Max	Mean ±SD
Zigzag LBB	3.8	5.2	4.36 ± 0.49 b	3	4.1	3.53 ± 0.35 b
Black LBB	3.9	5.3	4.47 ± 0.49 b	3	4.2	3.62 ± 0.41 b
Transverse LBB	5	6.6	5.73 ± 0.53 a	3.7	4.9	4.3 ± 0.38 a

a.  b.  c. 

Plate 15: Pupa of a. zigzag ladybird beetle, b. black ladybird beetle and c. transverse ladybird beetle

4.2.5 Adult

Newly emerged adult was soft, yellowish, the elytra was without any markings which later become shiny yellow with black spots. The adult was small, and oval shaped. Abdomen and eyes were light yellow in color. Elytra and pronotum have zigzag markings of newly emerged adult with soft, yellowish. The elytra was without any markings which later become shiny yellow with black spots. The adult was small, and oval shaped. Abdomen and eyes were light yellow in color. Elytra and pronotum have

zigzag markings. Newly emerged adult was soft, yellowish, the elytra was without any markings which later become shiny yellow with black spots. The adult was small, and oval shaped. Abdomen and eyes were light yellow in color. Elytra and pronotum have zigzag markings.

Newly emerged adult of *Menochilus sexmaculatus (*zigzag ladybird beetle) was soft, yellowish, shiny yellow with black spots. The adult was small, and oval shaped. Abdomen and eyes were light yellow in color. Elytra and pronotum have zigzag markings. Newly emerged *Coccinella transversalis* adults of were soft bodied, yellowish in color which turned shining yellow with black spots which developed gradually. The adult was red and black colored, with elongate oval, convex shaped body. Head was black with a pair of creamy yellow, sub triangular frontal spots, one on either side of inner margins of eyes. Pronotum black, anterolateral corners light cream. Elytra bright carmine red or orange or yellow. The date, counted after newly adult emerged to the death of adult was known as adult longevity. Adult longevity of male beetle ranged from 17 to 22days, 17 to 23 days and 27 to 33 days with an average of 19.3 ± 1.77 days, 19.6 ± 2.12 days and 30.1 ± 1.91 days, respectively. Adult longevity of female beetle ranged from 19 to 25 days, 20 to 25 days and 31 to 36 days with an average of 22.2 ± 2.25 days, 22.3 ± 2.16 days and 33.3 ± 1.34 days, respectively (Table 15). Some author reported more or less similar result. Mari *et al.* (2004) recorded that average adult period of *M. sexmaculatus,* (female and male) was recorded as 34.9 ± 4.8 days and 29.7 ± 1.2 days, respectively. For *C. transversalis* adult male and female adult periods ranged from 26 to 38 days and 42 to 59 days with an average of 31.58 ± 3.22 days and 39.10 ± 3.37 days, respectively (Santosh, 2011).

Table 15: Adult longevity of male and female of different species of ladybird beetle

Species	Adult longivity (Day)		
	Maximum	Minimum	Mean ± SD
For male			
Zigzag ladybird beetle	17	22	19.3±1.77
Black ladybird beetle	17	23	19.6±2.12
Transverse ladybird beetle	27	33	30.1±1.91
For female			
Zigzag ladybird beetle	19	25	22.2±2.25
Black ladybird beetle	20	25	22.3±2.16
Transverse ladybird beetle	31	36	33.3±1.34

There were significant variation among the species of ladybird beetle. Transvarse ladybird beetle showed the highest length than others and zigzag ladybird beetle and black ladybird beetle were statistically similar. The length of newly emerged adult male of zigzag, black and transverse ladybird beetles were 3.8 to 4.4 mm, 3.8 to 4.6 mm and 5.0 to 5.4 mm with an average of 4.03 ± 0.19 mm, 4.11 ± 0.23 mm and 5.20 ± 0.14 mm, respectively. The breadth were 3.0 to 3.6 mm, 3 to 3.9 mm and 3.8 to 4.2 mm with an average of 3.25 ± 0.20 mm, 3.31 ± 0.28 mm and 4.0 ± 0.13 mm, respectively (Table 16). Again, there were significant variation among the species of ladybird beetles. Transvarse ladybird beetle showed the highest length than others. Zigzag ladybird beetle and black ladybird beetle were statistically similar. The length of newly emerged adult female of zigzag, black and transverse ladybird beetle were 4.1 to 5.4 mm, 4.16 to 5.5 mm and 5.35 to 6.7 mm with an average of 4.88 ± 0.47 mm, 4.98 ± 0.40 mm and 5.83 ± 0.40 mm, respectively. The breadth were 3.4 to 4.1 mm, 3.25 to 4.8 mm and 3.1 to 5.0 mm with an average of 3.88 ± 0.26 mm, 3.99 ± 0.42 mm and 4.4 ± 0.38 mm, respectively (Table 16). These results are strongly supported by Sureja (1991) and Zala (1995).

Table 16. Adult (newly emerged length and breadth): male and female

Species	Length (mm)			Breadth (mm)		
	Min	Max	Average ± SD	Min	Max	Average ±SD
For male						
Zigzag LBB	3.8	4.4	4.03 ± 0.19 b	3	3.6	3.25 ± 0.20 b
Black LBB	3.8	4.6	4.11 ± 0.23 b	3	3.9	3.31 ± 0.28 b
Transverse LBB	5	5.4	5.20 ± 0.14 a	3.8	4.2	4.0 ± 0.13 a
For female						
Zigzag LBB	4.1	5.4	4.88 ± 0.47 b	3.4	4.1	3.88 ± 0.26 b
Black LBB	4.16	5.5	4.98 ± 0.40 b	3.25	4.8	3.99 ± 0.42 b
Transverse LBB	5.35	6.7	5.83 ± 0.40 a	3.9	5	4.40 ± 0.38 a

4.2.6 Total life cycle

Total life cycle means the duration from the first day of egg hatched to death of an adult. Total life cycle of different species of ladybird beetle was ranged from 26 to 52 days. In case of zigzag ladybird beetle total life cycle of male adult was ranged from 24 to 32 days while for female was 26 to 35 days. For black ladybird beetle, total life cycle of male ranged from 24 to 32 days and for female 27 to 34 days. And 39 days to 49 days for male and 43 days to 52 days for female were the total life cycle of transverse ladybird beetle. The pre-ovipositional period of zigzag ladybird beetle, black ladybird beetle and transverse ladybird beetles were ranged from 3-5, 3-5 and 3-6 days; ovipositional period 13-17, 13-17 and 23-28 days and post-ovipositional period 3-5, 2-5 and 4-7 days, respectively (Table 17). Santosh (2011) also reported that the total life cycle of male and female of *C. transversalis* ranged from 42 to 59 days and 40 to 64 days with an average of 29.7 ± 1.2 and 34.9 ± 4.8 days, recpectively for *M. sexmaculatus* (Mari *et al.*, 2004).

Table 17. Developmental period of different stages of different species of ladybird beetle

Developmental range (day)	Zigzag LBB			Black LBB			Transverse LBB		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Incubation period	2	3	2.4±0.52	2	3	2.5±0.53	5	7	5.8 ±0.79
First instar	1	2	1.5±0.53	1	2	1.6±0.52	2	3	2.6±0.52
Second instar	1	3	1.7±0.68	1	3	1.7±0.82	2	4	2.8±0.63
Third instar	2	3	2.5±0.53	2	3	2.4±0.52	3	5	4±0.47
Forth instar	2	3	2.6±0.52	2	3	2.6±0.52	3	5	4.2±0.79
Total larval period	7	10	8.3±0.95	7	9	8.2±.63	12	16	13.8±1.22
Pre-pupal	1	1	0.91±0.14	1	1	0.88±0.16	1	2	1.4±0.52
Pupal	2	4	2.8±0.63	2	4	2.9±0.74	5	8	6.9±0.99
Adult longevity (male)	17	22	19.3±1.77	17	23	19.6±2.12	27	33	30.1±1.91
Adult longevity (female)	19	25	22.2±2.25	20	25	22.3±2.16	31	36	33.3±1.34
Pre-oviposition	3	5	3.5±0.71	3	5	3.6±0.70	3	6	4.5±0.85
Oviposition	13	17	14.9±1.13	13	17	15.2±1.31	23	28	25.8±1.75
Post-oviposition	3	5	3.8±0.75	2	5	3.7±0.95	4	7	5.1±1.20

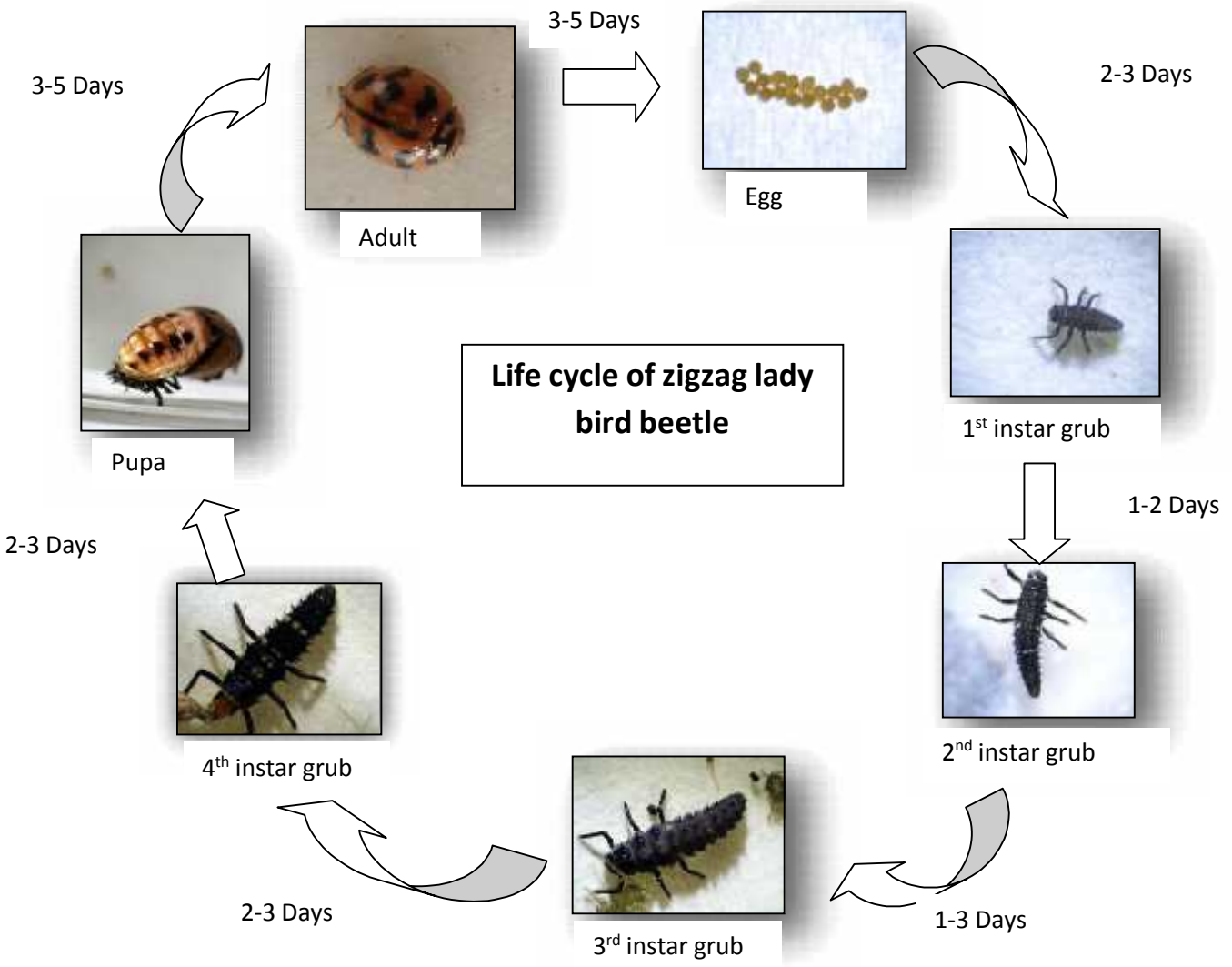

Plate 16: Total life cycle of zigzag ladybird beetle

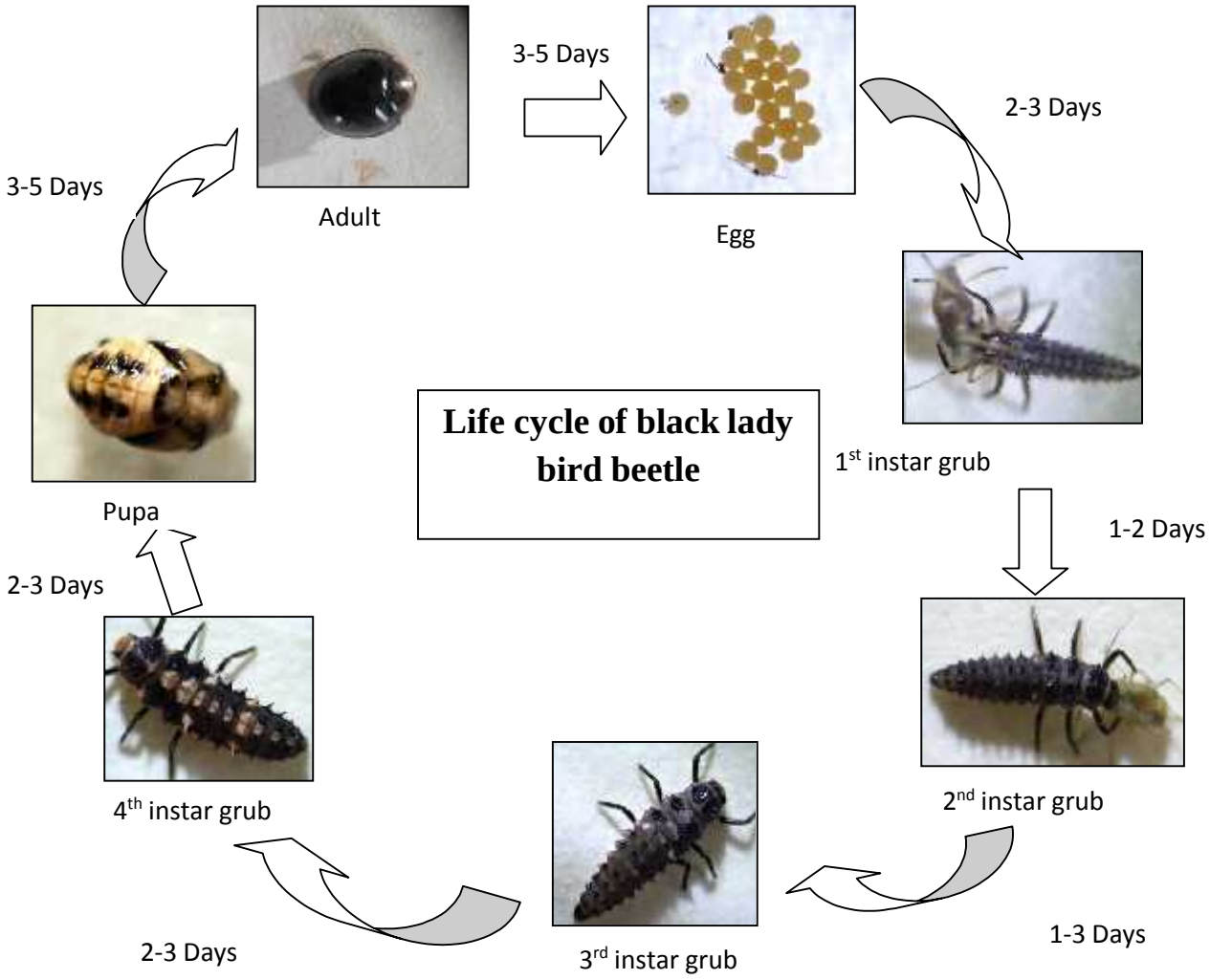

Plate 17: Total life cycle of black ladybird beetle

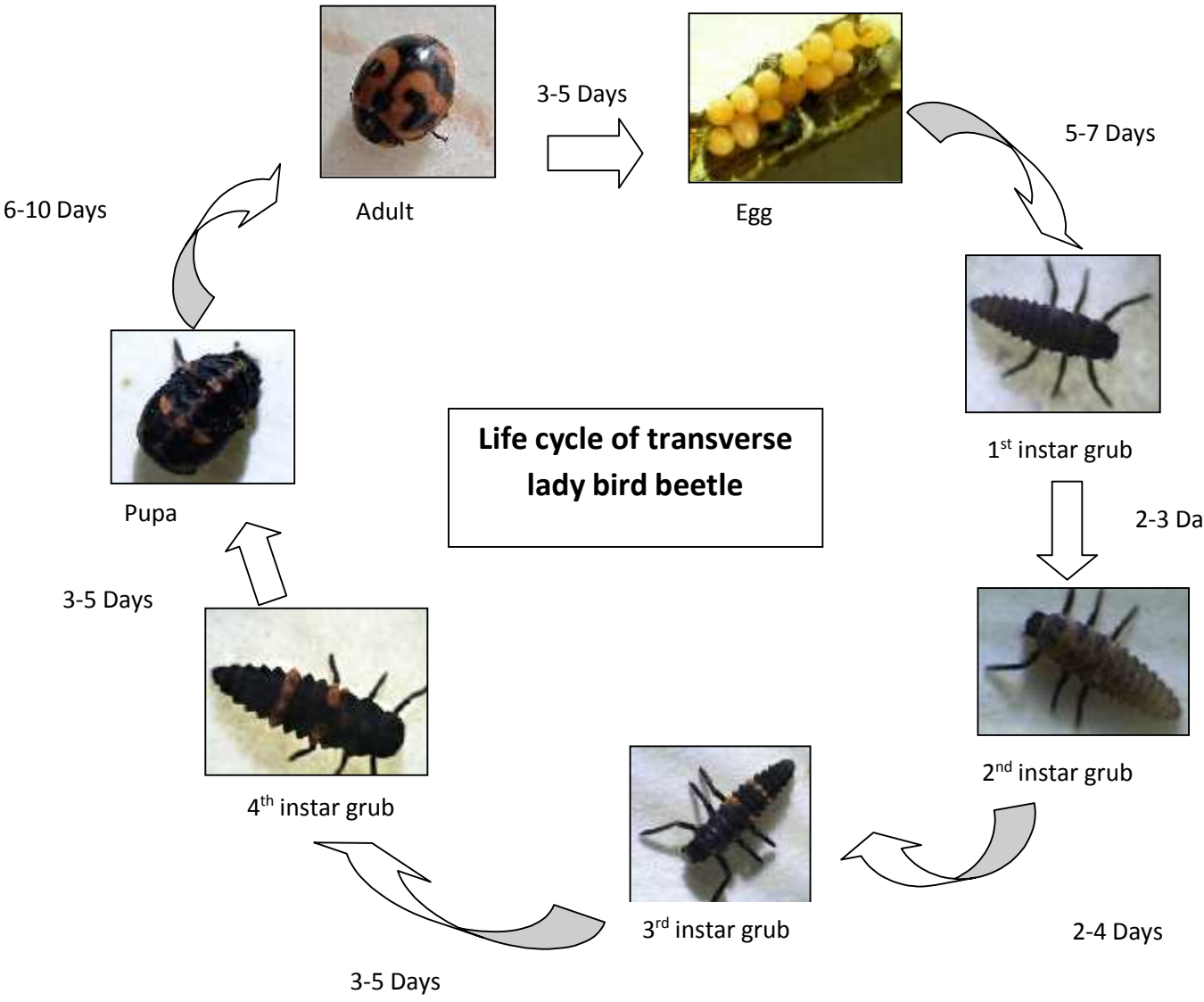

Plate 18: Total life cycle of transverse ladybird beetle

4.3 Predation efficiency

Predation efficiency of ladybird beetle depends on the searching behavior, size as well as on the surrounding nature of environment. The predation efficiency of grub and adult was ascertained by counting the total number of aphids engrossed by each instar of grub and adult within 24 hours. Both the grub and adult fed on aphid voraciously but their rate of feeding varied. They feed intermittently both day and night, but mainly in day time.

4.3.1 Predation efficiency of zigzag ladybird beetle

After hatching 1st instar grub of zigzag ladybird beetle was started to feed aphid. The rate of consumption of aphid was increased day by day. First instar grub consumed minimum 5 aphids to maximum 10 aphids and the average number of aphid consumption was 7.7 ± 1.64. The 2nd instar grub consumed minimum 11 aphids to maximum 17 aphids and the average number of aphid consumption was calculated as 14.5 ± 2.12. As well as 3rd and 4th instar grubs were consumed minimum 22 and 38 aphids while maximum 33 and 68 aphids. The average number of aphid consumption for 3rd and 4th instar grub was 28.4 ± 3.84 and 55.3 ± 8.43 aphids, respectively. The total 81-117 aphids were consumed by the grub of ladybird beetle at the time of grub development. Adult of zigzag ladybird beetle was consumed aphid voraciously and the rate become high. Adult male was consumed 750-795 aphids on an average 771.9 ± 13.60 aphids while adult female were consumed 875-907 aphids with an average 884.3 ± 10.85 aphids. So, male and female zigzag ladybird beetle were consumed minimum 847 aphids and 972 aphids to maximum 899 aphids and 1010 aphids respectively (Table 18). Some author also observed the same result (Islam, 2006).

Table 18. Predation efficiency zigzag ladybird beetle

Stages	Minimum	Maximum	Mean ±SD
First instar larva	5	10	7.7 ± 1.64
Second instar larva	11	17	14.5 ± 2.12
Third instar larva	22	33	28.4 ±3.84
Forth instar larva	44	62	55.3 ±8.43
Total larval predation	81	117	103.9 ±11.12
Adult male	750	795	771.9±13.60
Adult female	875	907	884.3±10.85
Lifelong predation (male)	847	899	875.8±16.62
Lifelong predation (Female)	972	1010	988.2±11.74

4.3.2 Predation efficiency black ladybird beetle

After hatching 1st instar grub of black ladybird beetle was started to feed aphid. The rate of aphid consumption was increased day by day. The 1st instar grub consumed minimum 5 aphids to maximum 10 aphids with an average number of aphid consumption by this stage was 7.7 ± 1.64. The 2nd instar grub consumed minimum 11 aphids to maximum 17 aphids and the average number of aphid consumption was 14.5 ± 2.121. As well as 3rd and 4th instar grub were consumed minimum 22 and 38 aphids but maximum 33 and 68 aphids. The average number of aphid consumption for 3rd and 4th instar grub was 28.4 ± 3.84 and 55.3 ± 8.43 aphids, respectively. 75-126 aphids were consumed by the grub of ladybird beetle at the time of development. Adult of black ladybird beetle were consumed aphid voraciously and the rate become high. Adult male was consumed 760-789 aphids on an average 775.9 ± 9.39 aphids while adult female consumed 875-910 aphids with an average 890.3 ± 12.10 aphids. So, male and female black ladybird beetle were consumed minimum 835 and 958 aphids to maximum 915 and 1020 aphids, respectively (Table 19). Some author also observed the same result (Islam, 2006).

Table 19. Predation efficiency black ladybird beetle

Stages	Minimum	Maximum	Mean ±SD
First instar larva	5	10	7.7 ± 1.64
Second instar larva	11	17	14.5 ± 2.12
Third instar larva	22	33	28.4 ± 3.84
Forth instar larva	38	68	55.3 ± 8.43
Total larval predation	75	126	105.7 ± 15.22
Adult male	760	789	775.9±9.39
Adult female	875	910	890.3±12.10
Lifelong predation (male)	835	915	881.6±16.43
Lifelong predation (Female)	958	1020	996±15.94

4.3.3 Predation efficiency of transverse ladybird beetle

After hatching 1st instar grub of transverse ladybird beetle was started to feed aphid. The rate of consumption aphid was increased day by day. 1st instar grub was consumed minimum 12 aphids to maximum 18 aphids and the average number of aphid consumption was 16 ± 1.63 aphids. The 2nd instar grub consumed minimum 30 aphids to maximum 41 aphids and the average number of aphid consumption was 35.4 ± 3.13 aphids. As well as 3rd and 4th instar grubs were consumed minimum 47 and 110 aphids and maximum number was 57 and 149 aphids. The average number of aphid consumption for 3rd and 4th instar grub was 51.3 ± 3.53 and 128.3 ± 14.29 aphids, respectively. Total 213-261 aphids were consumed by the grub of ladybird beetle at the time of total development. Adult of transverse ladybird beetle were consumed aphid voraciously and the rate become high. Adult male consumed 1858-2153 aphids on an average 1969.9 ± 103.91 aphids while adult female consumed 2190-2564 aphids on an average 2356.1 ± 133.01 aphids. So, male and female transverse ladybird beetle were consumed minimum 2073 and 2403 aphids to maximum 2394 and 2825 aphids, respectively (Table 20). Some author also observed the same result (Islam, 2006).

Table 20. Predation efficiency of transverse ladybird beetle

Stages	Minimum	Maximum	Mean ±SD
First instar larva	12	18	16 ± 1.63
Second instar larva	30	41	35.4 ± 3.13
Third instar larva	47	57	51.3 ± 3.53
Forth instar larva	110	149	128.3 ± 14.29
Total larval predation	213	261	232.2 ± 18.01
Adult male	1858	2153	1969.9±103.91
Adult female	2190	2564	2356.1±133.01
Lifelong predation (male)	2073	2394	2202.1±110.20
Lifelong predation (Female)	2403	2825	2591.3±147.79

From the above discussion we observed that the efficacy of predation is higher in transverse ladybird beetle and the efficiency of predation of zigzag ladybird beetle and black ladybird beetle were more or less same. But the zigzag ladybird beetle showed higher predation than black ladybird beetle.

CHAPTER V SUMMARY AND CONCLUSION

The biology and predation efficiency of ladybird beetle on mustard aphid were observed at the laboratory of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2017 to March 2018.

SUMMARY

The diversity of three different species of ladybird beetle of different crops were observed. Zigzag ladybird beetle and black ladybird beetle were found almost all crop fields viz. bean, brinjal, radish, bottle gourd, chili, quinoa, mustard, maize, wheat, sweet gourd and cucumber crop fields. The most favorite host of zigzag ladybird beetle was cucumber (52.0), maize (63.8%) for black ladybird beetle and chili (50.0%) for transverse ladybird beetle.

The average fecundity of zigzag, black and transverse ladybird beetle were observed 93.55 ± 10.78, 95.55 ± 11.25 and 194.33 ± 12.51 days, respectively.

The average incubation period of zigzag, black and transverse ladybird beetle were found 2.4 ± 0.52, 2.5 ± 0.53 and 5.8 ± 0.79 days, respectively.

1st instar grub period of zigzag, black and transverse ladybird beetle were recorded with an average of 1.5 ± 0.53, 1.6 ± 0.52 and 2.6 ± 0.52 days, respectively.

2nd instar grub period of zigzag, black and transverse ladybird beetle were recorded with an average of 1.7 ± 0.68, 1.7 ± 0.82 and 2.6 ± 0.52 days, respectively.

3rd instar grub period of zigzag, black and transverse ladybird beetle were recorded with an average of 2.5 ± 0.53, 2.4 ± 0.52 and 4 ± 0.47 days, respectively.

4th instar grub period of zigzag, black and transverse ladybird beetle were recorded with an average of 2.6 ± 0.52, 2.6 ± 0.52 and 4.2 ± 0.79 days, respectively. Total larval period with average of 8.3 ± 0.95, 8.2 ± 0.63 and 13.8 ± 1.22 days, respectively.

Pre-pupal period of zigzag, black and transverse ladybird beetle were recorded with an average of 2.8 ± 0.63, 2.9 ± 0.74 and 6.9 ± 0.99 days, respectively.

Adult male longevity of zigzag, black and transverse ladybird beetle were recorded with an average of 19.3 ± 1.77, 19.6 ± 2.12 and 30.1 ± 1.91 days, respectively and for female with an average of 22.2 ± 2.25, 22.3 ± 2.16 and 33.3 ± 1.34 days, respectively.

The pre-ovipositional period of zigzag, black and transverse ladybird beetle were ranged from 3-5, 3-5 and 3-6 days, respectively; ovipositional period were 13-17, 13-17 and 23-28 days, respectively; and post-ovipositional period were 3-5, 2-5 and 4-7 days, respectively.

Total life cycle of male of zigzag, black and transverse ladybird beetle were observed 24-32, 24-32 and 39-49 days, respectively and for female 26-35, 27-34 and 43-52 days, respectively.

The average length of egg of zigzag, black and transverse ladybird beetle were found 1.05 ± 0.08, 1.06 ± 0.07 and 1.24 ± 0.07 mm, respectively.

The average breadth of egg of zigzag, black and transverse ladybird beetle were found 0.48 ± 0.02, 0.48 ± 0.02 and 0.49 ± 0.03 mm, respectively.

The average length of 1st instar grub of zigzag, black and transverse ladybird beetle were found 1.81 ± 0.34, 1.90 ± 0.29 and 1.96 ± 0.19 mm, respectively.

The average breadth of 1st instar grub of zigzag, black and transverse ladybird beetle were found 0.53 ± 0.05, 0.54 ± 0.06 and 0.59 ± 0.06 mm, respectively.

The average length of 2nd instar grub of zigzag, black and transverse ladybird beetle were found 3.17 ± 0.39, 3.25 ± 0.67 and 3.53 ± 0.26 mm, respectively.

The average breadth of 2nd instar grub of zigzag, black and transverse ladybird beetle were found 0.81 ± 0.14, 0.84 ± 0.19 and 1.01 ± 0.09 mm, respectively.

The average length of 3rd instar grub of zigzag, black and transverse ladybird beetle were found 4.73 ± 0.69, 4.92 ± 0.54 and 5.57 ± 0.47 mm, respectively.

The average breadth of 3rd instar grub of zigzag, black and transverse ladybird beetle were found 1.30 ± 0.25, 1.30 ± 0.15 and 1.58 ± 0.15 mm, respectively.

The average length of 4th instar grub of zigzag, black and transverse ladybird beetle were found 6.52 ± 0.56, 6.36 ± 0.42 and 6.96 ± 0.75 mm, respectively.

The average breadth of 4th instar grub of zigzag, black and transverse ladybird beetle were found 1.9 ± 0.31, 1.9 ± 0.28 and 2.00 ± 0.42 mm, respectively.

The average length of pupal period of zigzag, black and transverse ladybird beetle were found 4.36 ± 0.49, 4.47 ± 0.49 and 5.73 ± 0.53 mm, respectively.

The average breadth of pupal period of zigzag, black and transverse ladybird beetle were found 3.53 ± 0.35, 3.62 ± 0.41 and 4.3 ± 0.38 mm, respectively.

The average length of adult male of zigzag, black and transverse ladybird beetle were found 4.03 ± 0.19, 4.11 ± 0.23 and 5.20 ± 0.14 mm, respectively and for female 22.2 ± 2.25, 22.3 ± 2.16 and 33.3 ± 1.34 days, respectively.

The average breadth of adult male of zigzag, black and transverse ladybird beetle were found 3.25 ± 0.20, 3.31 ± 0.28 and 4.0 ± 0.13 mm, respectively and for female 3.88 ± 0.26, 3.99 ± 0.42 and 4.40 ± 0.38 mm, respectively.

Predation efficacy of male zigzag, black and transverse ladybird beetle were recorded 847-899, 835-915 and 2073-2394 aphids, respectively with an average 875.8 ± 16.62, 881.6 ± 16.43 and 2202.1 ± 110.20 aphids, respectively.

Predation efficacy of female zigzag, black and transverse ladybird beetle were recorded 972-1010, 958-1020 and 2403-2825 aphids, respectively with an average 988.2 ± 11.74, 996 ± 15.94 and 2591.3 ± 147.79 aphids, respectively.

CONCLUSION

From this study we can concluded that, transverse ladybird beetle shows the highest longevity than zigzag ladybird beetle and black ladybird beetle. And zigzag ladybird beetle and black ladybird beetle showed more or less similar results. In case of the length and breadth of different ladybird beetle, transverse ladybird beetle showed highest result. Transverse ladybird beetle was found as the biggest among the species of ladybird beetle. Zigzag ladybird beetle and black ladybird beetle again showed more or less similar results. In case of predation efficacy, transverse ladybird beetle showed best performance than zigzag ladybird beetle and black ladybird beetle. But zigzag ladybird beetle and black ladybird beetle performed statistically similar. Zigzag ladybird beetle and black ladybird beetle have diversified host range than transverse ladybird beetle.

From this study following recommendations can be drawn:

1. Different species of ladybird beetle is the promising bio-control agent against mustard aphids for their excellent predation efficiency.
2. Further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

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CHAPTER VII

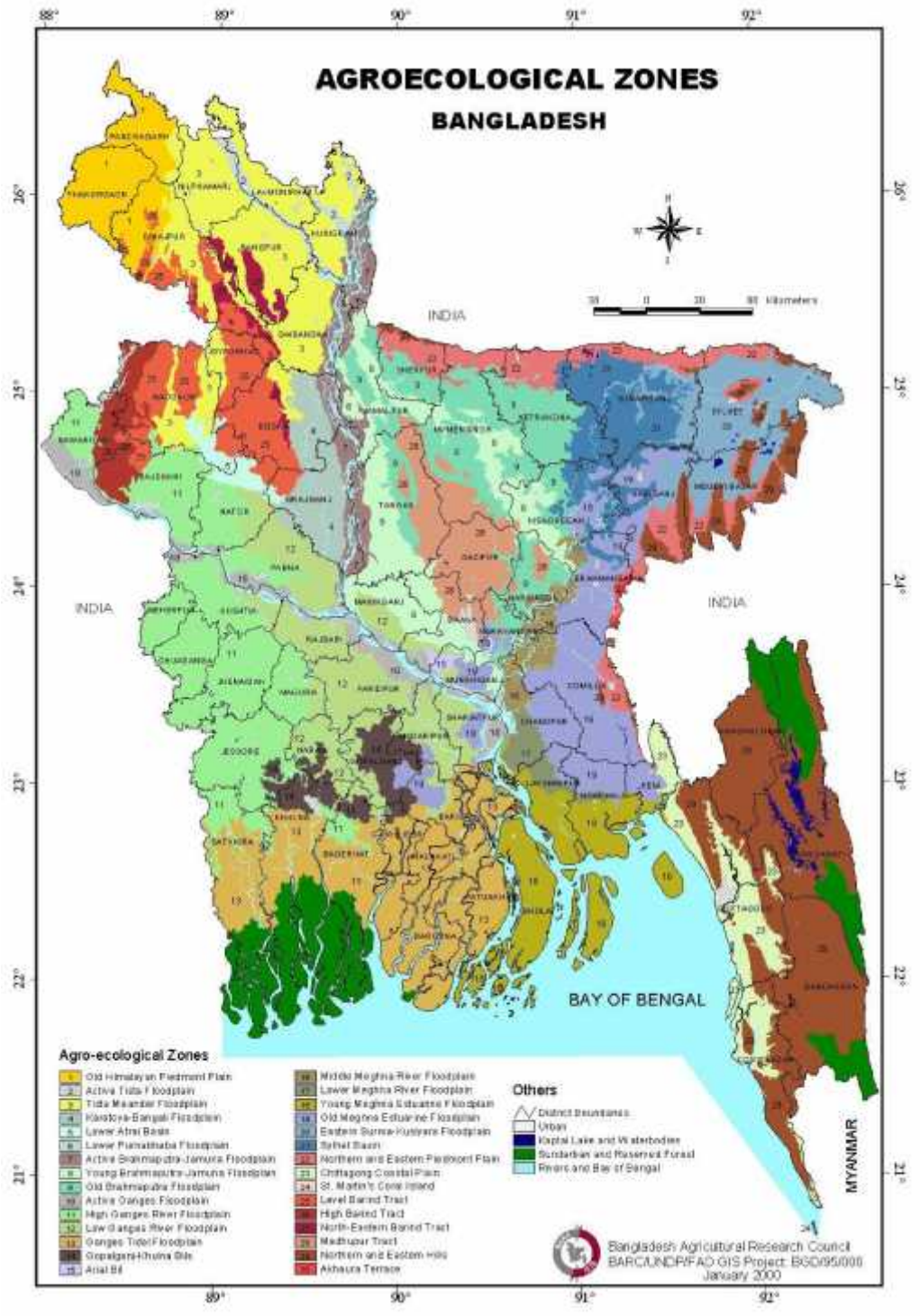
APPENDICES

Appendix I: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2017 to March 2018

Month	Temperature		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November	30.2	20.6	67	6.0
December	26.8	17.1	76	33.0
January	23.6	12.6	68	0.0
February	29.2	18.1	61	20.0
March	33.3	22.3	59	3.0

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207.

Appendix II. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

Appendix III. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka