Biological traits and predation efficiency of *Menochilus sexmaculatus* (F.) (Coleoptera: Coccinellidae) on different hosts

A THESIS

BY

MD. JAHANGIR ALAM

Registration No. 1405018

Session: July-December 2015

Thesis Semester: July-December 2015

MASTER OF SCIENCE (M.S.)

IN

ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2015

Biological traits and predation efficiency of *Menochilus sexmaculatus* (F.) (Coleoptera: Coccinellidae) on different hosts

A THESIS

BY

MD. JAHANGIR ALAM

Registration No. 1405018

Session: July-December 2015

Thesis Semester: July-December 2015

Submitted to the Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur in partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE (M.S.)

IN

ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2015

Biological traits and predation efficiency of *Menochilus sexmaculatus* (F.) (Coleoptera: Coccinellidae) on different hosts

A THESIS

BY

MD. JAHANGIR ALAM

Registration No. 1405018

Session: July-December 2015

Thesis Semester: July-December 2015

Approved as to style and contents by:

Prof. Dr. Md. Alamgir Hossain	**Dr. Md. Abdul Alim**
Supervisor	Co-supervisor

Prof. Dr. Hasan Fuad El Taj
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2015

ACKNOWLEDGEMENT

The author acknowledge and express his all praises due to the "Almighty Allah" who has created us to explore the hidden fact of the nature for the benefit of mankind and enabling me to complete this research work successfully in time.

It is his pleasure to express his sincere appreciation, heartfelt respect and indebtedness to his respectable teacher and supervisor, Dr. Md. Alamgir Hossain, Professor, Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his kind help, constant guidance, valuable advice, affectionate feelings, constructive criticism and encouragement throughout tenure of this research work and complete this thesis.

Heartiest gratitude and deep sense of admiration to his respected co-supervisor, Dr. Md. Abdul Alim, Associate Professor, Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his supports and day to day cooperation in successful completion of this work.

The author express his gratefulness to all the teachers of the Department of Entomology, HSTU, Dinajpur, for their inspiration encouragement, deep feelings and for improving academic skills in Entomology during the course of M.S studies and they were very kind to me. The author also express his gratefulness to his roommates and his friends for their loved and helped. The author would like to thank all the staffs of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University for their help and assistance during the period of the research.

The author express a deep appreciation to his parents, elder and younger sister for their endless love, support, encouragement and prayer. They have always encouraged me in all of his pursuits and without them none of this would have been possible. The author would like to give his thanks whole heartedly to all of his relatives, friends and well wishers for their co-operations, inspirations and affectionate feelings towards the successful completion of his study.

The Author

CONTENTS

CHAPTER	TITLE		PAGE NO.
	TITLE PAGE		**i-iii**
	ACKNOWLEDGEMENT		**iv**
	CONTENTS		**v**
	LIST OF TABLE		**vi**
	LIST OF PLATE		**vii**
	ABSTRACT		**viii**
CHAPTER 1.	**INTRODUCTION**		**1-3**
CHAPTER 2.	**MATERIALS AND METHODS**		**4-8**
	2.1	Cultivation of host plants for different aphid species	4
	2.2	Collection of tested aphid species and the *M. sexmaculatus*	4
	2.3	Mass culture of *M. sexmaculatus*	4-5
	2.4	Biology of *M. sexmaculatus* on three hosts	5
	2.5	Life table parameters	7
	2.6	Predation efficiency	7
	2.6.1	Predation efficiency of larvae and adults	7
	2.7	Statistical analyses	8
CHAPTER 3.	**REVIEW OF LITERATURE**		**9-13**
CHAPTER 4.	**RESULTS AND DISCUSSION**		**14-29**
	4.1	Mating	14
	4.2	Preoviposition period	15
	4.3	Oviposition period	15
	4.4	Egg	16
	4.5	Incubation period	17
	4.6	Larva	20
	4.7	Pre-pupa	21
	4.8	Pupal	21
	4.9	Life cycle	21-22
	4.10	Adult longevity	22
	4.11	Life table parameters	26-27
	4.12	Predation efficiency of larva	28
	4.13	Predation efficiency of adults	29
CHAPTER 5.	**SUMMARY AND CONCLUSION**		**30-31**
	REFERENCES		**32-37**

LIST OF TABLE

TABLE NO.	TITLE	PAGE NO.
1.	Effect of hosts of mating of *M. sexmaculatus*	15
2.	Effect of three hosts on the reproductive parameters (Mean± SE) of *M. sexmaculatus*	19
3.	Effect of hosts on the eggs length (mm) and breadth (mm) of *M. sexmaculatus*	19
4.	Summary of different stages of *Menochilus sexmaculatus* (F.) on bean, mustard and wheat aphid	23
5.	Effect of hosts (aphids) on the larval length (mm) and breadth (mm) of *M. sexmaculatus*	25
6.	Effect of hosts on the pre-pupa and pupal length (mm) and breadth (mm) of *M. sexmaculatus*	25
7.	Effect of hosts on the Adults length (mm) and breadth (mm) of *M. sexmaculatus*	26
8.	Life table parameters of *M. sexmaculatus* while fed on three aphid species	27
9.	Predation efficiency of larva of *M. sexmaculatus* as fed on three aphid species under ambient laboratory conditions	28
10.	Effect of hosts on predation efficiency of adult *M. sexmaculatus* under laboratory conditions	29

LIST OF PLATE

PLATE NO.	TITLE	PAGE NO.
1.	Infested Plant with bean, mustard, wheat aphid	6
2.	Mating of *M. sexmaculatus*	14
3.	Eggs of *M. sexmaculatus*	17
4.	Aphid infested bean twig	18
5.	Different instars of *M.sexmaculatus*	24

ABSTRACT

Menochilus sexmaculatus (Fab.) (Coleoptera: Coccinellidae) is an important bio control agent against bean aphid, mustard aphid, wheat aphid. A detailed research work was carried out in the laboratory of the Department of Entomology, HSTU, Dinajpur to study the Consequence of hosts on the Biology and predation efficiency of *Menochilus sexmaculatus* (Fab.) (Coleoptera: Coccinellidae) on three aphid species such as bean aphid, mustard aphid and wheat aphid (*Aphis craccivora*, *Lipaphis erysimi* and *Rhopalosiphum maidis*). During November 2014 to April 2015.The average incubation period was varied from 3.80 to 3.95 days on three different aphid species. The duration of first instar was maximum on *R. maidis* (2.60 days), while duration of second instar was maximum recorded on *L. erysimi i.e.* 2.70 days. Minimum duration of first and second instar larvae was observed on *Aphis craccivora* (2.40 and 2.50 days) respectively. The maximum duration of third and fourth instar larvae was found on *L. erysimi* (3.20 and 2.60 days) respectively. Significantly lowest total larval duration was found on *R. maidis* (9.70 days) while the highest on *L. erysimi* (11.00 days). Maximum pupal period was recorded on *R. meidis* (3.20 days) and minimum on *L. erysimi* (3.00 days). The average egg laying capacity of single female was 286.00 to 365.00 eggs, when reared on different aphid species. Adult longevity of the beetle was found maximum on *L. erysimi* (42.60 days), and minimum on *A. craccivora* (34.60 days).The duration doubling times varied significantly among the aphid species. The mean generation time (*T*) among the varieties of aphids were 29.299, 28.704, 29.299 days, respectively. The longest duration was found in wheat and mustard aphids respectively and the shortest duration was in bean aphid .The gross reproductive rate (*GRR*) was highest (257.13) for the wheat aphid and lowest (202.88) for the bean aphid. The average predation efficiency of mustard aphid (1660.80), wheat aphid (1465.00) and bean aphid (1624.90) respectively.

Key words: Biology, *M. sexmaculatus*, aphids, *coccinellids*, *A. craccivora*, *Lipaphis erysimi*, *Rhopalosiphum meidis*.

CHAPTER 1

INTRODUCTION

The term "Biological control" is comparatively recent vintage but it has had a long history. Continuously increasing costs and decreasing effectiveness of insecticides, focused on natural enemies for biological control of insect pests has generated much interest (Patterson *et al.*, 1981 ; Rutz and Patterson, 1990). The use of natural enemies has long been recognized as a fundamental aspect of insect pest management. But a very few system has been studied sufficiently for the pest natural enemies interactions to be adequately understood. To exploit biotic agents as a tool of biological suppression of insect pests is now recognized as accepted sustainable strategy for insect pest management. However, there has been concern about the quality of natural enemies that are mass reared for augmentation. Activity level has been suggested a useful and easily computed indicator of predator quality (Bigler *et al.*, 1988). The population suppression of insect pest by predator is one of the most important parameter.

Foods as well as the host can influence many aspects of the development, survival and reproduction of predators. In order to understand the behaviour, bio-ecology of insects and development of pest management strategies many researches have been done. It is important to have a good knowledge of the ways insects interact with their food sources. The suitability of a species of prey can be assessed by evaluating the effect feeding on it has on the life history attributes of the predator, namely development, survival, adult weight and reproduction. Kalushkov and Hodek (2001) suggested that quantitative data on a predator's rate of development, survival and reproduction indicated the adequacy of the prey. The influence of food quality on growth, development and reproductive success is well studied (Gilbert and Owen, 1990). Reproduction requires high-energy resources that are supplied by food, which is a major regulatory factor of reproductive success (Hodek, 1996). Owing to their economic and biological importance, prey-dependent responses have been evaluated for a number of ladybird beetles.

Menochilus sexmaculatus (Fab.) (Coleoptera: Coccinellidae) commonly known as lady bird beetle is a predator of different important pests of agricultural crops. This predator is widely distributed in Southeast Asia, Indonesia, Philippines and South Africa as a most efficient and common aphid feeding species (Thomson and Simmonds, 1965; Chambers *et al.,* 1983; Rahman *et al.,* 1993). Both the larvae and adults coccinellid are voracious predators on aphids, mealy bugs, scale insects, whiteflies, thrips, mites and a number of other pest species (Hodek, 1996).This predator was found in association with those insects infesting wheat, bean, mustard, tobacco, cotton, maize, potato, lathyrus, lentil, mustard, citrus, pigeon pea, cucurbit, groundnut, cabbage, safflower, cassava, date palm and Cumin (Gupta and Yadava, 1986; Saxena *et al.,* 1980; Sharma *et al.,* 1991; Duffied, 1995; Gautam *et al.,* 1995).

Aphids (Aphididae: Hemiptera) are one of the most destructive pests and distribute worldwide (Singh, 1987; Begum *et al.,* 1991). They are small, shiny and black colored, soft bodied prolific breeder and produces offspring parthenogenetically. Both the nymphs and adults cause damage by sucking sap from flowers, buds, pods and tender shoots of the plants and reduce the vitality of crops (Thakur *et al.,* 1984). The young plant suffers heavily from the attack of aphid and even may die (Alam *et al.,* 1964). In addition, aphid injects a toxic substance through salivary secretion into the plants while feeding which causes chlorosis at the feeding site, yellowing of the veins and leaf curling, loss of vitality and reduction of growth (Jayappa and Lingappa, 1988). They attack various plants parts and cause considerable losses yield and when severely attacked the plants fail to give flowering and pods resulting in 20-40% yield loss in Asia (Singh and Allen, 1980). They also cause indirect damage by release sticky honey dew which acts as a medium of sooty mould fungus growth resulted reduces photosynthetic efficiency of the plants (El-Defrawi, 1987; El-Fatah, 1991; Rizkalla *et al.,* 1994). This pest is known to transmit a number of virus diseases in different crops.

The control of aphids in Bangladesh is principally carried out by the conventional uses of insecticides. But indiscriminate use of the insecticides have created several problems in agro-ecosystem such as direct toxicity to beneficial organisms (Predators, parasitoids, pollinators, etc) insecticide resistance (Schmuterer, 1987) out breaks of secondary pests. At present emphasis is being given on the use of ecologically sound safe pest control methods. The predacious coccinellid beetles are considered to be of great economic importance in the agro-ecosystem. They have been successfully employed in the biological control of many injurious insects (Nasiruddin and Islam, 1979; Agarwala *et al.,* 1988). This control option offers several advantages over conventional chemical insecticides and has been proven to be economical and does not involve any extra cost. It becomes promising in all places and a key of permanent control tactics.

To successfully mass rear predatory natural enemies for biological control, it is necessary to estimate the vital statistics, such as intrinsic rate of increase, generation time, finite rate of increase, and doubling time, which helps to explain oscillations in population density and provide a better understanding of the population dynamics of a species. Only a life table can provide a comprehensive description of the species development, survival, and fecundity. Correlating studies on the predation rate and life table can be effectively characterized to obtaining information on the biology of this predator on three host's viz. *Aphis craccivora*, *Rhopalosiphum maidis* and *Lipaphis erysimi* as food. Such information would be helpful in mass culturing of this predator under laboratory conditions.

Keeping these in view, the present study is designed primarily to provide data on biology and predation efficiency of *M. sexmaculatus* using three species of aphids under laboratory conditions.

Research objectives

1. To study the biology and life table parameters of *M. sexmaculatus*.

2. To observe the predation efficiency of *M. sexmaculatus* on three aphid species.

CHAPTER 2

MATERIALS AND METHODS

The experiment was carried out in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during November 2014 to April 2015.To determine the biological trait and predation efficiency of *M. sexmaculatus* on three different aphid species the experiment was conducted at ambient room temperature and relative humidity (20^{o} C ± 2^{o} and 70% ± 5%RH).

2.1 Cultivation of host plants for different aphid species

Country bean, *Lablab perpureas* L., mustard, *Brassica napus* L. and wheat, *Triticum aestivum* L. were cultivated as host plants intended for three different species of aphid's viz. bean aphid (*Aphis craccivora)*, mustard aphid (*Lipaphis erysimi)* (Kalt.) and wheat aphid (*Ropalosiphum maidis*) in the field laboratory at the department of Entomology of HSTU farm. Host plants were cultivated simultaneously one month intervals from November 2014 to January 2015 for constant and continuously supply of respective aphid's species to fulfill the experimental goal. Proper crop production practices were maintained to cultivate the host plants as per necessary. No pesticides were used for the production of host plants.

2.2 Collection of tested aphid species and the *M. sexmaculatus*

Three different species of aphids namely *Aphis craccivora*, *Lipaphis erysimi*, *Rhopalosiphum maidis* were collected from the respective cultivated host plants. Those aphids were collected from different parts of infested plants as experimental required.

2.3 Mass culture of *M. sexmaculatus*

Previously collected adult male and female beetles of *M. sexmaculatus* were paired (one male and one female) for mating in several Petri dishes. Everyday three species of fresh adequate number of aphids with respective plant parts were supplied separately for the beetles as food. The oviposition of beetles was examined daily. After oviposition, the beetles were transferred in the new Petri dishes and the eggs laid by them were counted and left undisturbed for hatching. The newly hatched larvae were then transferred into the new Petri dishes until adult emergence. The newly emerged adults were sexed and confined in pairs into the Petri dishes for mating and egg laying again. This procedure was continued for obtaining large number of larvae and adults for experimental uses.

2.4 Biology of *M. sexmaculatus* on three hosts

For the biological study of *M. sexmaculatus* on three hosts the laboratory cultured newly emerged adult beetles were collected. They were sexed and then confined in pair (one male and one female) for mating in each Petri dish (9.0 cm $\times$ 2.0 cm height). Infested plant parts with three species of aphids were placed every morning to the adult in each Petri dish to ensure availability of food. After oviposit, the beetles were transferred daily into the new Petri dishes. The date of egg laying and hatching period were recorded separately for each host. Eggs were counted and recorded from each of the Petri dish separately and kept undisturbed. Hatching period were also recorded separately. After hatching of eggs, each young larva was then transferred carefully with the help of soft camel brush into the separate Petri dishes for each host. 100 fresh aphids of each host were placed in each Petri dish to provide food for one larva at every morning. The larvae were observed twice daily until pupation to record the time of molting, number of instars and duration of each larval instar. After completion the larval period the pupae were kept undisturbed in the respective Petri dishes until the emergence of adult to record the prepupal and pupal stages. After adult emergence, three species of aphids were supplied separately to an adult until its death and the duration of each male and female beetle was counted for the observation of adult longevity. Ten observations were used for each case for each host separately.

Plate 1: Infested plant with bean (A), mustard (B) and wheat aphid (C)

2.5 Life table parameters

Life history including adult fecundity and longevity were observed to construct a time-specific life table for *M. sexmaculatus* under ambient laboratory conditions. Observations were carried out for the actual death occurred in the egg and immature stages when the female survival rate in each host was determined.

Life table parameters including intrinsic rate of natural increase (r_m), net reproductive rate (R_0), doubling time (DT), finite rate of increase (λ) and the generation time (T) were estimated. The life table parameters for females held on three aphid species were estimated using the Birch (1948) equation:

$$\sum e^{-r_m x}\, l_x\, m_x = 1$$

Where, x = age in days, l_x = the age-specific survival rate, m_x = the age-specific fecundity. The intrinsic rate of natural increase ($r_m = \ln(\sum l_x m_x)/T$), the finite rate of increase ($\lambda = e^r$), the net reproductive rate ($R_0 = \sum l_x m_x$), the mean generation time ($T = \sum X l_x m_x / R_0$), and the gross reproductive rate (GRR) is the mean total number of eggs produced by a female over its lifetime, ($GRR = \sum m_x$) measured in female eggs/ female/generation. Doubling time is the time required for a given population to double its number, [$DT = (\ln 2)/r$] measured in days was calculated as described by Mackauer (1983).

2.6 Predation efficiency

2.6.1 Predation efficiency of larvae and adults

Immediately after hatching, young larvae were transferred individually into the Petri dishes. The numbers of aphids 150 were supplied every morning for the 1st instar larvae. The food was changed in every 24 hours. The numbers of aphids consumed within 24 hours were recorded. Similar numbers of three tested aphids were provided for 2nd, 3rd and 4th instar larvae and number of preys consumed by each larva of each instar were counted and recorded.

For the predation efficiency of adults, same numbers of aphids of each three species were also supplied as food. The number of aphids consumed by adult were recorded every 24 hours and continued until death. Ten replications were maintained for each treatment.

2.7 Statistical analyses

The collected data were statistically analyzed by completely randomized design (CRD) with MSTAT program. The treatment mean values were adjusted by Duncan’s New Multiple Range Test (DMRT).

CHAPTER 3

REVIEW OF LITERATURE

Patel *et al.*, (2015) reported that freshly laid eggs of *M. sexmaculatus* were cigar shaped, yellow in colour with smooth chorion without any reticulation. The average incubation period was varied from 3.08 to 3.60 days on different aphid species. Freshly emerged grub was dark grey in colour with shining dark head capsule and legs. The duration of first instar was maximum on *Lipaphis erysimi* (2.68 days), while duration of second instar was maximum recorded on *L. erysimi* and *Aphis nerri* i.e. 2.88 days. Minimum duration of first and second instar grub was observed on *A. nerri* (1.96 days) and on *A. gossypii* (2.32 days), respectively.

Muhammad *et al.*, (2014) reported that evaluation of efficacy of the zigzag beetle [*Menochilus sexmaculatus* (Fab.)] on rose aphid [*Macrosiphum rosae* (L.)] a laboratory experiment was conducted during 2012 in an average temperature and average relative humidity (27± 2° C and 62 ± 5%), respectively, at Entomological Research Institute, Ayub Agriculture Research Institute, Faisalabad, Pakistan. Predation efficiency of the 1st, 2nd, 3rd and 4th instar larvae of *M. sexmaculatus* were 8.40 ± 0.50, 13.60 ± 0.81, 28.60 ± 1.50 and 57.40 ± 4.67 aphids, respectively. The predation efficiency of male and female adults was 802.40 ± 2.56 and 916.60 ± 1.69 aphids respectively. The predation was found proportional with the age of the larvae. The female beetles were more cogent in aphid predation as compared to the males.

Ibrahim *et al.*, (2013) experienced that the effects of sublethal exposure to imidacloprid (Kendor 18.3SL) on the biological performance of the ladybird beetle, *Menochilus sexmaculatus* (Fab.), the most common coccinellid beetle found feeding on aphids, were studied under ambient laboratory conditions of 27-32˚C and 50-75% RH. The corn leaf aphid, *Rhopalosiphum maidis*, was offered as prey. The LC_{50} obtained from the contact bioassay at 24 h post-treatment for the regression slope, b=1.08, indicated that imidacloprid was likely to be selective. Sublethal exposure to imidacloprid caused reduction in survival with the females reaching 50% mortality by the 24th day, while that of the control was the 36th day. The net reproductive rate (R_o) value indicated that the control female was capable of producing 17.59 female offspring but treated female could only produce 2.55 female (Rm) offspring during their generation time (T) of 25.17 and 23.04 days, respectively.

Ali *et al.*, (2012) reported that the biological parameters of *Menochilus sexmaculatus* (Fab.), as influenced by different temperature regimes and host were studied at Insectary-Biological Control Laboratories, National Agricultural Research Centre (NARC), Islamabad, Pakistan. The results revealed that there was a significant effect of different temperature regimes on the development and predatory potential of *M. sexmaculatus* reared on *Rhopalosiphum padi.* The egg incubation period of predator beetle was 4.16, 3.66 and 2.24 days at 22 ± 1°C, 28°C and 34°C, respectively. Mean fecundity was 430.53, 548.67 and 432.43 eggs, respectively. Percentage egg hatchability of the predator was significantly higher at 28 ± 1°C. The total larval duration of predator was 9.47, 7.70 and 5.49 days, respectively. Duration of pupal period ranged between 2.21 and 4.35 days on *R. padi* at three temperatures. The pre-oviposition, oviposition and post-oviposition periods were between 4.64 and 7.48, 24.99 and 39.93 and 4.76 and 8.09 days, respectively on *R. padi*. Mean predatory potential of all larval instars ranged from 148 to 162 aphids, respectively. The prey consumption of female beetle was significantly higher than male.

Nyukuri *et al.*, (2012) stated that the coccinellids consumed more aphids at higher aphid densities (24.05 aphids) than at lower aphid densities (9.44 aphids) over the same period of time. Rainfall and relative humidity had significant ($F = 3.675$; $P < 0.05$) effects on the abundance of Coccinellids. Temperature had significant ($F = 3.58$; $P < 0.05$) effect on the abundance of Coccinellids though at a lower level. Rainfall ($r = -0.162$) and relative humidity ($r = -0.084$) were both inversely correlated with the abundance of coccinellids. On the other hand, temperature was positively correlated ($r = 0.159$) with the prevalence of coccinellids indicating that warmer and drier conditions favored their multiplication.

Jih-Zu *et al.*, (2012) reported that the life histories and predation rates of the ladybird beetle *Harmoni adimidiata* (F.) were compared among beetles kept at 15, 20, and 25°C. The beetles were fed on *Aphis gossypii* and were maintained at 70 ± 10% RH and a 14:10 (L:D) h photoperiod. According to the age-stage, two-sex life table, the net reproductive rates (R_0) were 147.4, 98.7 and 62.5 offspring for beetles kept at 15, 20 and 25°C, respectively.

Wigunda *et al.*, (2012) evaluated by examining the effect of prey consumption on the performance of lady beetle larvae. Results demonstrated that *A. gossypii* from *Solanum. xanthocarpum* was more suitably for larval growth than *A. gossypii* from, Chromolaena *odorata*, with faster development time and higher larval survival of both lady beetle species. Consistent with the results of larval performance, larvae of *M. sexmaculatus* showed feeding preference on *A. gossypii* from, *S. xanthocarpum* over *A. gossypii* from *C. odorata*. For *M. discolor,* however, longer development time of larvae when reared on *A. gossypii* from, *C. odorata* result higher consumption on *A. gossypii* from, *C. odorata.* Regardless of lady beetle species and aphid, 4^{th} larval instar was the most voracious. *Menochilus sexmaculatus* was likely resistant to toxic of host plant of aphid, *C. odorata,* while *M. discolor* was susceptible to noxious allelochemicals of *C. odorata* distinctly. The different of essential prey and alternative prey of both lady beetle species was discussed in this study.

Saleem *et al.*, (2014) reported that Evaluation of efficacy of the zig zag beetle [*Menochilus sexmaculatus* (Fab.)] on rose aphid [*Macrosiphum rosae* (Linnaeus)] a laboratory experiment was conducted during 2012 in an average temperature and average relative humidity (27± 2° C and 62 ± 5%), respectively, at Entomological Research Institute, Ayub Agriculture Research Institute, Faisalabad. Predation efficiency of the 1st, 2nd, 3rd and 4th instar larvae of *M. sexmaculatus* were 8.40 ± 0.50, 13.60 ± 0.81, 28.60 ± 1.50 and 57.40 ± 4.67 aphids, respectively. The predation efficiency of male and female adults was 802.40 ± 2.56 and 916.60 ± 1.69 aphids respectively. The predation was found proportional with the age of the larvae. The female beetles were more cogent in aphid predation as compared to the males.

Mojib *et al.*, (2011) concluded that development and reproductive potential of the *Coccinella septempunctata* (L.) was highly significant (*Rhopalosiphum maidis*) 32.2 aphids per day as compared to other treatments. Oviposition response was the maximum on these beetles which consumed 1^{st} and 2^{nd} instars of *Macrosi phonroseae*. *C. septempunctata* reared under artificial diet showed more longevity 41.6 days on plain water. Greater emphasis was pertinent on evaluation of predator specificity, understanding of colonization in new environments and assessment of community-level interactions to maximize the use of coccinellids in biological control (BC).

Muhammad and Saqib (2009) studied that seven-spotted ladybird beetle *Coccinella septempunctata* (L.), a natural enemy of aphids, had been reared on natural and alternative artificial foods. Both larvae and adults of *C. septempunctata* fed on aphid and artificial diet, the predator normally completed its development from egg to adulthood in 20.6 days on aphid prey, in contrast to 29.0 days, when fed on artificial diet. These results indicated that artificial diet containing important ingredients for adults and larvae of *C. septempunctata* can serve as substitute food for the coccinellids, and reproduction nevertheless can occur in the absence of preferred aphid prey. The present findings can best be utilized for effective mass production of coccinellids species intended for biological control of insect pests.

Jogender *et al.*, (2009) reviewed that the seven-spotted ladybug, *Coccinella septempunctata* (L.) has maximum (average: 6.7 ± 0.77cm; n = 15) and *Adaliate traspilota* (Hope) has minimum (average: 4.2 ± 0.15cm; n = 14) body length. Moreover, transverse ladybird, *Coccinella transversalis* (Fab.) has maximum (average: 4.8 ± 0.35cm; n = 10) and *Oenopiasauzeti* (Mulsant) (n = 9) or adonis ladybird, *Hippodamia variegate* (Goeze) (n = 10) hasminimum (3.1 cm) body width. Except six-spotted zigzag ladybird, *Menochilus sexmaculatus* (Fab.) (n = 12), all collected species have black head, varied but attractive and dark in color pronotum and elytra, black scutellum except in fifteen-spotted ladybird, *Harmonia dimidiate* (Fab.) (n = 10) which was brownish.

Rakhshan *et al.*, (2009) reported that the greater consumption of *A. craccivora* was observed by both adult and grubs on *Phaseolus sinensis* (717. 0 ± 10.33 aphids) followed by *L. purpureus* (655.8 ± 18.19 aphids), *V. radiate* (620.8 ± 5.04 aphids) and *V. mungo* (546.2 ± 12.39 aphids).

Chowdhury *et al.*, (2008) observed that the mean pre-oviposition period of the ladybird beetle *Micraspis discolor* was 5.1 ± 0.48 days and the oviposition period was 40.10 ± 0.46 days. The female beetles laid on an average 235.50 ± 7.96 eggs and the hatching % was 83.93 ±2.11. The average incubation period was 3.1 ± 0.22 days and the duration of total the larval period from egg to adult was 10.76 ± 1.35 days. The pre-pupal and pupal periods were 1.50 ± 0.20 and 2.60 ± 0.21days, respectively. The mean longevity of the male and the female beetles were 40.20 ± 1.0 and 47.50 ± 0.82 days, respectively.

Seubsaiboonsong *et al.*, (2006) studied about population density of pest and their natural enemies on two chili cultivars; Huarua and aromatic chili under organic agriculture system. They found pest and natural enemy density were higher in aromatic chili.

Mari *et al.*, (2004) reported that biology of *Menochilus sexmaculatus* (Fab.) and *Coccinella undecimpunctata* (L.) on alfalfa aphid *Therioaphistri folii* Monell were investigated during winter season at Tando Jam, Sindh, Pakistan. The latent period of *M. sexmaculatus* was 31.7 ± 0.3 and C. *undecimpunctata* 6.7 ± 0.1 seconds. Duration of copulation in *M. sexmaculatus* and *C. undecimpunctata* were 81.8 ± 5.4 and 64.5 ± 6.1 minutes. The oviposition and post-oviposition period of *M. sexmaculatus,* were *27A ± 4.1* and 4.5 ± 0.3 days and *C. undecimpunctata,* were 19.9 ± 5.2 and 3.8 ± 0.4 days. Fecundity per female was observed 602 ± 75.3 for *M. sexmaculatus* and 761 ± 85.2 for C. *undecimpunctata.* The mean egg periods of *M. sexmaculatus* and *C. undecimpunctata* were 8.6 ± 1.2 and 7.3 ± 1.0 days.

Basant *et al.*, (2001) reprted that effects of prey density and adult predator size on food consumption and oviposition were evaluated in an aphidophagous ladybird beetle, *Menochilus sexmaculatus* (F.), from tropical Asia. Both the functional response and reproductive numerical response showed an upper asymptote at 40 adullt *Aphis craccivora* Koch /female/150 cm^2. Proportions of aphids consumed and eggs laid by female beetles were highest at lower aphid densities, i.e., five or 10 adult aphids. Ratio of eggs laid to aphids consumed, by dry weight, was highest at the lowest aphid density, i.e., five adult aphids. Larval food supply significantly influenced the size of adult females.

Charernsom and Suasaard (1994) investigated natural enemy complex as biological control agents in cowpea fields for insect pest management. The result showed that the important pest and natural enemy of cowpea was *Aphis craccivora* Koch and *Menochilus sexmaculatus* (Fab.), respectively.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Mating

The mating period of *Menochilus sexmaculatus* on three different species of aphids not varied significantly ($P < 0.05$) which is found in Table 1. The mating period ranged from 30 to 50 minutes among the treatments. The average mating period revealed that the highest period was observed on mustard aphid (40.50 minutes) and the lowest was on bean aphid (39.50 minutes). The present result differed with the findings of Mari *et al.*, (2004).They reported that duration of copulation in *M. sexmaculatus* and *C. undecimpunctata* were 81.8 ± 5.4 and 64.5 ± 6.1 minutes respectively. This difference might be due to the difference of host species and different environmental condition , food quantity consumed by the lady bird beetle.

Plate 2: Mating of *M. sexmaculatus*

Table 1: Effect of hosts on the mating duration of *M. sexmaculatus*

Hosts	Mean ± SE/Mating period in minutes
Bean	39.50 ± 2.29 a (30-50)
Mustard	40.50 ± 1.89 a (35-50)
Wheat	40.00 ± 2.36 a (30-50)
LSD	11.60
CV%	17.31
Level of significance	NS

Not significantly different (P < 0.05) parenthesis indicated ranges value.

4.2 Preoviposition period

The preoviposition period of *Menochilus sexmaculatus* on three different species of aphids not varied significantly (P < 0.05) Table 2. Among the treatments the pre-oviposition period ranged from 2.0 to 5.0 days. The pre-oviposition period was observed the highest on wheat aphid (3.60 days) and the lowest on mustard aphid (3.30 days). Mari *et al.* (2004) reported that the pre-oviposition period of *M. sexmaculatus* on alfa aphid, *Therioaphis trifolii* was 4.5 ± 0.30 days which is more or less close to the present findings. Verma *et al.* (1993) studied the pre-oviposition period of *M. sexmaculatus* which was 3.6 ± 1.0 days. Jagadish and Jayaramaiah (2004) reported that pre-oviposition period of *M. sexmaculatus* was lowest at 25 - 30^{0}C.

4.3 Oviposition period

The oviposition period of *M. sexmaculatus* on three different species of aphids differed significantly (P< 0.05) among the treatments (Table 2). The oviposition period was found the highest on wheat aphid (22.50 days) and the lowest on mustard aphid (20.00 days). This result is comparable with the finding of Mari *et al.* (2004). They opined that the oviposition period of *M. sexmaculatus* was 27.4 ± 4.1 days when they fed on alfalfa aphid, *T. trifolii* and the oviposition duration was higher than that of the present study which might be associated with the most species and environmental factors. Gautam (1990) also concluded that the oviposition period of same insect was 36.23 days, when they fed on cotton aphid, *Aphis gossypii*.

4.4 Egg

The female did not show any preference during the egg deposition. Females laid eggs on the bottom, on the upper and lower leaf surface of the leaf, sometimes on stem or on the walls and surface of the rearing Petri dishes in all hosts. Usually the female laid eggs in rows. Normally they laid 20 to 30 eggs in a cluster (Plate 3). But sometimes the number of eggs per cluster was founded 7 as minimum and 34 as maximum. The female laid maximum number of eggs during the first few days of oviposition and then this rate decreased gradually.

The fecundity of *M. sexmaculatus* varied significantly ($P< 0.05$) while fed on three species of aphids (Table 2). The number of eggs deposited per female (over an oviposition period) ranged from 286.00 to 365.00. On three aphid species the highest number of fecundity was recorded when female fed on wheat aphid (350.5 ± 3.34) but the lowest on mustard aphid (304.6 ± 3.45). The egg viability of the beetle was found the highest (96.78%) while fed on bean aphid but the lowest (93.59%) on wheat aphid. The average length and breadth of eggs did not varied significantly ($P< 0.05$) while fed on three different species of aphids (Table 3). The highest length was found while fed on mustard aphid (0.98 ± 0.02) mm and the lowest in wheat aphid (0.93 ± 0.02) mm. On the contrary, the highest and lowest breath was observed while fed on bean and mustard aphid species respectively.

Mari *et al.* (2004) observed that the fecundity per female was 602.0 ± 75.3 of *M. sexmaculatus* when they fed on alfalfa aphid, *Therioaphis trifolii* Monell. Haque and Islam (2010) also reported that the number of eggs laid per female was 208.6 on same species. Ngammuang (1987) found that the mean hatching percentage was 83.93 ± 2.11. He (1987) reported that the number of eggs deposited per female of another ladybeetle, *Micraspis discolor* was 181.07 ± 66.37 on *A. craccivora* and 70.15% eggs were hatched. Prodhan *et al.* (1995) observed that the fecundity of female varied form 200-300 eggs with mean of 270.5 and with an average 70.15% egg were hatched. These results seem to be close with the present findings.

4.5 Incubation period

The incubation period of the beetle were not differed significantly (P< 0.05) among three different species of aphids (Table 2). The incubation period was the highest on wheat aphid (3.95 ± 0.07) and the lowest on both mustard and bean aphid (3.80 ± 0.07).

Ali *et al*. (2012) opined that egg incubation period of *Menochilus sexmaculatus* was 4.16, 3.66 and 2.24 days at 22 ± 1°C, 28°C and 34°C, respectively. Chowdhury *et al.* (2008) also observed that the average incubation period of above said predator was 3.1 ± 0.22 days. Solangi *et al.* (2005) opined that the average incubation period of *M. sexmaculatus* beetle was 3.6 ± 1.03 days when they fed on mustard aphid, *Lipaphis erysimi*. Prodhan *et al.* (1995) mentioned that the incubation period of *M. sexmaculatus* and *M. discolor* were 2 and 3 days, respectively using bean aphid as host. Nathapol and Pensook (1991) found that the incubation period of *M. sexmaculatus* was 2 to 3 days on cotton aphid. These findings are close proximity with present investigation.

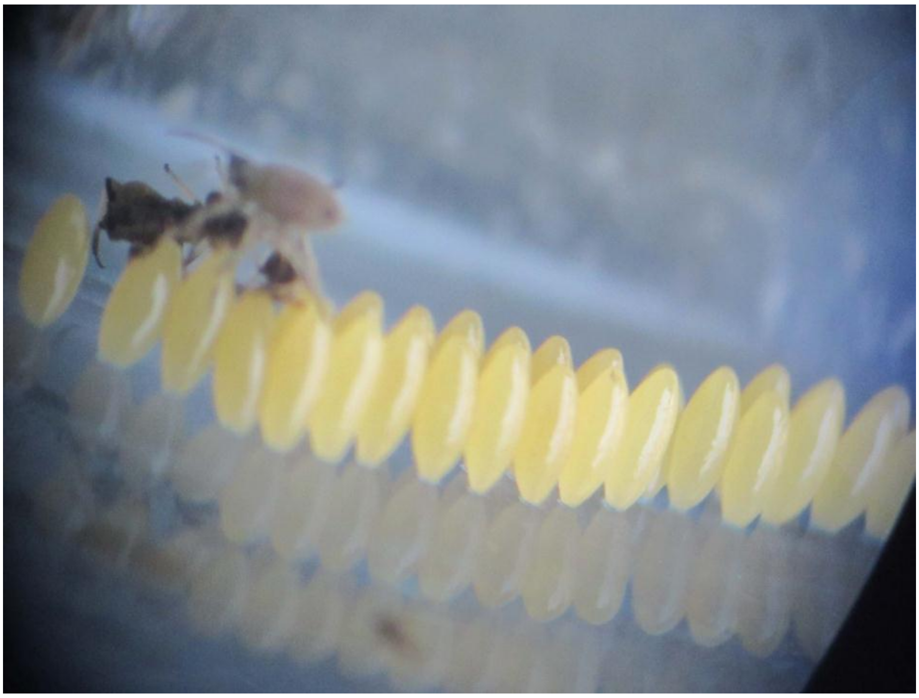


Plate 3: Eggs of *M. sexmaculatus*

Plate 4: Aphid infested bean twig

Table 2: Effect of three hosts on the reproductive parameters (Mean± SE) of *M. sexmaculatus*

Hosts	Pre-oviposition (days)	Oviposition (days)	Incubation period (days)	Fecundity (no.)	Egg hatching (%)
Bean aphid	3.50 ± 0.38 a (2-5)	22.30 ± 0.65 a (19-25)	3.80 ± 0.076 a (3-4)	315.20 ± 4.27 b (286-335)	96.78 ± 0.38 a (94.87 – 97.43)
Mustard aphid	3.30 ± 0.26 a (2-4)	20.00 ± 0.52 b (18-23)	3.80 ± 0.076 a (3-4)	304.60 ± 3.45 c (290-320)	96.20 ± 0.43 a (92.3 – 94.87)
Wheat aphid	3.60 ± 0.34 a (2.0-5.0)	22.50 ± 0.61 a (20-26)	3.95 ± 0.076 a (3.5-4)	350.50 ± 3.34 a (335-365)	93.59 ± 0.44 b (94.64 – 98.21)
LSD	0.65	1.74	-	10.12	1.218
CV%	20.02	8.76	5.97	3.41	1.39
Level of significance	NS		NS		

Mean in the same column followed by different letters are significantly different (P < 0.05). Parenthesis indicated ranges value.

Table 3: Effect of hosts on the eggs length (mm) and breadth (mm) of *M. sexmaculatus*

Hosts	Length (Mean ± SE)	Breadth (Mean ± SE)
Bean	0.94 ± 0.02 a (0.8-1.1)	0.46 ±.02 a (0.4-0.6)
Mustard	0.98 ± 0.02 a (0.9-1.1)	0.51 ±.03 a (0.4-0.6)
Wheat	0.93 ± 0.01 a (0.8-1.0)	0.50 ± 0.01 a (0.4-0.5)
LSD	0.07	0.06
CV%	8.13	13.34
Level of significance	NS	NS

Mean in the same column followed by different letters are significantly different (P < 0.05). Parenthesis indicated ranges value.

4.6 Larva

The development of larva of *M. sexmaculatus* on three different aphids species were not varied significantly ($P< 0.05$) (Table 4).which is found in (Table 4). All instars showed minimum of 2 days and maximum of 3 days duration while feeding 3 hosts the highest duration of larval development intended for 1st, 2nd, 3rd and 4th instars were on wheat (2.60 ± 0.16 days), mustard (2.70 ± 0.15 days), mustard (3.20 ± 0.20 days) and mustard aphid (2.60 ± 0.16 days), respectively. On the other hand, in that order, the lowest were found on bean aphid (2.40 ± 0.17 days), wheat aphid (2.20 ± 0.13 days), bean aphid (2.40 ± 0.16 days) and bean aphid (2.50 ± 0.17 days). The total larval period of *Menochilus sexmaculatus* on three different species of aphids was the highest on mustard aphid (11.00 ± 0.21 days) and the lowest it was on wheat aphid (9.70 ± 0.21 days). The length and breadth of different larval instars of *M. sexmaculatus* on three species of aphids are represented in (Table 4). The length of the instars measured from 1.1 to 6.3 mm (Table 4). The highest length was measured as 6.09 a ± 0.04 mm on wheat aphid for fourth instar. And the breadth varied from 0.4 to 1.95 mm while the highest was on wheat aphid of same instar with 2.07 ± 0.03 mm (Table 4). During the development of 1st to 4th instars, the lowest length was found on wheat aphid intended for first instar as 1.23 ± 0.02 mm. And the lowest breath was found on bean aphid on behalf of first instar which was as 0.49 ± 0.03 mm (Table 4).

This result is comparable with those of Chowdhury *et al.* (2008) who observed that the average duration of total the larval period from egg to adult was 10.76 ± 1.35 days. Again, Solangi *et al.* (2005) found that the duration of first, second, third and fourth instar larva of *M. sexmacutatus* were 2.7 ± 0.48, 3.20 ± 0.63 and 3.8 ± 0.78 days when they fed on mustard aphid, *L. erysimi*. The present findings are parallel to the observations of Mari *et al.* (2004) who found the larval duration of first and fourth instars larvae of *M. sexmaculatus* was 7.3 ± 0.6 and 6.7 ± 1.1 days, respectively on alfalfa aphid, *T. trifolii.* Nevertheless, the result of the present findings slightly differed from the observation made by Islam and Nasiruddin (1978) who found that the average duration of the 3rd instar larvae of *Verania discolor* was 2.0 days. This variation might be due to variation of food and environmental factors etc.

4.7 Pre-pupa

The pre-pupal period of *M. sexmaculatus* was found non significant (P< 0.05) on three different species of aphids (Table 4). The pre-pupal period was the highest on both mustard and bean aphid (1.30 ± 0.15 days) and the lowest on wheat aphid (1.20 ± 0.13 days).

The length and breadth of prepupa on three different species of aphids among the treatments presented in (table 4). The highest length of pre-pupa was found 4.33 ± 0.08 mm as fed on mustard aphid where as the breath it was 2.34 ± 0.10 mm on mustard. This result is comparable with Amir (2014), who experienced the mean duration of pre-pupal stage was 1.0 ± 0.0 days on same insect. Solangi *et al.* (2005) found that the average body length of the male pupa was 5.05 ± 0.04 mm having 2.48 ± 0.02 mm in breadth, while the female pupa measured 5.79 ± 0.02 mm in length and 2.78 ± 0.02 mm in breadth which is closest to the present findings.

4.8 Pupa

Like pre-pupa, the pupal duration also insignificantly (P< 0.05) due to three different hosts (Table 4). The pupal period was the highest in wheat aphid (3.20 ± 0.13 days) and the lowest was in mustard aphid (3.00 ± 0.13 days). The length and breadth of pupae were measured on three different species of aphids among the treatments presented in table 3. At this stage, it was observed and the highest length (4.56 ± 0.11 mm) on mustard aphid since the breath it was 2.57 ± 0.26 on bean aphid.

Solangi *et al.* (2005) found that the average pupal duration of *M. Sexmaculatus* was 6.50 ± 0.28 days on mustard aphid, *Lipaphis erysimi.* Chowdhury *et al.* (2008) observed that the pupal periods was 2.60 ± 0.21days, respectively. Mari *et al.* (2004) also reported that the pupal period of same species was 3.60 ± 0.30 days when they feed on alfalfa aphid, *T. trifolii,* which are closer to the present findings.

4.9 Life cycle

The larval developmental period on three hosts varied significantly (P< 0.05) which is found in (Table 4). The highest duration was detected on wheat aphid (11.00 ± 0.21 days) but it was the lowest as 9.70 ± 0.21 days on bean aphid. Development period from egg to adult of the beetle on three hosts was found insignificant (Table 4). The highest duration of development was detected on mustard aphid (19.10 ± 0.25 days) but it was the lowest as 17.85 ± 0.2 days on wheat aphid. The length and breadth of adult of *M. sexmaculatus* on three different species of aphids was insignificant which is summarized in Table 8. The ranges of lengths were from 4.4 to 5.9 mm although the breadths from 2.0 to 3.7 mm. The highest length (5.13 ± 0.20 mm) was found on mustard aphid but the lowest on wheat aphid (2.80 ± 0.20 mm).

Present conclusion of life cycle is comparable with Ali *et al*. (2012) who experienced that the total larval duration of the predator *M. sexmaculatus* on wheat aphid, *Rhopalosiphum padi* was 9.47 days.

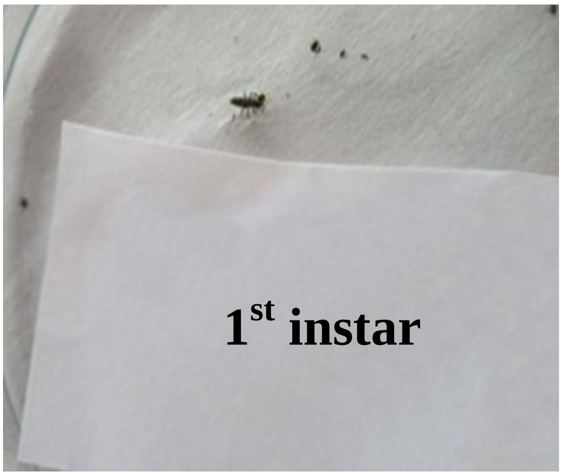
4.10 Adult longevity

The adult longevity of the beetle varied significantly ($P< 0.05$) due to host species of aphids (Table 4). The highest longevity was markedly longer on mustard aphid (42.60 ± 0.54 days) although shorter on bean aphid (34.60 ± 0.45 days). The results of the present findings is almost similar with Chowdhury *et al.* (2008) who observed that the longevity of the male and the female beetles were 40.20 ± 1.0 and 47.50 ± 0.82 days, respectively.

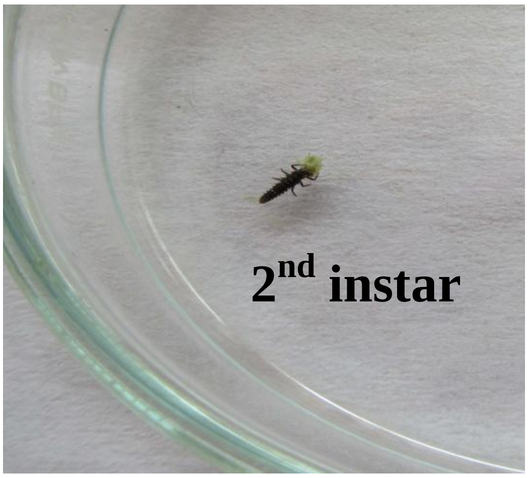
Table 4: Summary of different stages of *Menochilus sexmaculatus* (F.) on bean, mustard and wheat aphid

Stages	Hosts (aphids)	Duration in days		Mean ± SE	CV (%)
		Minimum	Maximum		
1st instar	Bean	2	3	2.40 ± 0.17 a	20.67
	Mustard	2	3	2.50 ± 0.17 a	
	Wheat	2	3	2.60 ± 0.16 a	
2nd instar	Bean	2	3	2.50 ± 0.17 a	19.98
	Mustard	2	3	2.70 ± 0.15 a	
	Wheat	2	3	2.60 ± 0.17 a	
3rd instar	Bean	2	3	2.40 ± 0.16 b	20.41
	Mustard	2	4	3.20 ± 0.20 a	
	Wheat	2	3	2.20 ± 0.13 b	
4th instar	Bean	2	3	2.40 ± 0.16 a	20.80
	Mustard	2	3	2.60 ± 0.16 a	
	Wheat	2	3	2.50 ± 0.17 a	
Larval development	Bean	8	11	9.80 ± 0.33 b	7.96
	Mustard	10	12	11.00 ± 0.21 a	
	Wheat	9	11	9.70 ± 0.21 b	
Pre-pupal period	Bean	1	2	1.30 ± 0.15 a	36.59
	Mustard	1	2	1.30 ± 0.15 a	
	Wheat	1	2	1.20 ± 0.13 a	
Pupal period	Bean	2.5	4	3.15 ± 0.13 a	13.61
	Mustard	2.5	4	3.00 ± 0.13 a	
	Wheat	2.5	4	3.20 ± 0.13 a	
Developmental period (egg to adult)	Bean	16	20.5	17.90 ± 0.48 a	6.03
	Mustard	18	20	19.10 ± 0.25 a	
	Wheat	16.5	19	17.85 ± 0.27 a	
Adult longevity	Bean	32	37	34.60 ± 0.45 c	4.23
	Mustard	40	45	42.60 ± 0.54 a	
	Wheat	35	40	37.70 ± 0.54 b	

Mean in the same column followed by same letter are not significantly different ($P < 0.05$). Parenthesis indicated ranges value.



First instar



Second instar

Third instar

Fourth instar

Plate 5: Different instars of *M.sexmaculatus*

Table 5: Effect of hosts (aphids) on the larval length (mm) and breadth (mm) of *M. sexmaculatus*

Host	1st instar		2nd instar		3rd instar		4th instar	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
Bean Mean ±SE	1.36 a ± 0.08 (1.1-1.8)	0.49 a ± 0.03 (0.4-0.6)	2.74 a ± 0.03 (2.6-2.9)	1.00 a ± 0.03 (0.9-1.1)	3.78 a ± 0.04 (3.6-3.9)	1.15 a ± 0.03 (1.0-1.3)	6.01 a ± 0.05 (5.8-6.3)	3.11 a ± 0.05 (2.9-3.3)
Mustard Mean ±SE	1.31 a ± 0.05 (1.1-1.5)	0.55 a ± 0.02 (0.5-0.6)	2.68 a ± 0.05 (2.5-2.9)	0.83 b ± 0.03 (0.7-0.9)	3.47 a ± 0.33 (3.5-3.9)	1.02 b ± 0.02 (0.9-1.1)	6.04 a ± 0.07 (5.7-6.3)	2.14 b ± 0.04 (2.0-2.3
Wheat Mean ±SE	1.23 a ± 0.02 (1.1-1.3)	0.52 a ± 0.02 (0.4-0.6)	2.56 b ± 0.04 (2.4-2.7)	0.74 b ± 0 .75 (0.5-0.9)	3.77 a ± 0.02 (3.6-3.9)	1.12 a ± 0.04 (1.0-1.3)	6.09 a ± 0.04 (6.0-6.3)	2.07 b ± 0.03 (1.95-2.2)
LSD	0.16	0.07	0.11	0.09	0.56	0.09	0.16	0.12
CV%	13.34	13.34	4.71	10.89	16.66	8.54	2.89	5.34
Level of significance	NS	NS			NS		NS	

Mean in the same column followed by same letter are not significantly different (P < 0.05). Parenthesis indicated ranges value.

Table 6: Effect of hosts on the pre-pupa and pupal length (mm) and breadth (mm) of *M. sexmaculatus*

Hosts	**Pre-pupa** (Mean ±SE)		**Pupa** (Mean ±SE)	
	Length	Breadth	Length	Breadth
Bean aphid	4.01 ± 0.41 b (4.0-4.3)	2.43 ± 0.26 a (2.1-2.7)	4.40 ± 0.44 a (4.2-4.6)	2.57 ± 0.27 a (2.5-2.8)
Mustard aphid	4.33 ± 0.08 a (4.0-4.6)	2.34 ± .09 a (2.0-2.7)	4.56 ± 0.11 a (4.1-4.9)	2.47 ± 0.13 a (2.0-2.8)
Wheat aphid	3.94 ± 0.41 b (3.0-4.2)	2.58 ± 0.25 a (2.5-2.6)	4.18 ± 0.42 b (4.1-4.2)	2.48 ± 0.25 a (2.4-2.6)
LSD	0.30	0.23	0.20	0.23
CV%	8.03	10.36	5.12	9.95
Level of significance		NS		NS

Mean in the same column followed by same letter are not significantly different (P < 0.05). Parenthesis indicated ranges value.

Table 7: Effect of hosts on the Adults length (mm) and breadth (mm) of *M. sexmaculatus*

Hosts	Length(Mean ±SE)	Breadth(Mean ±SE)
Bean aphid	5.13 ± 0.17 a (4.5-5.8)	2.98 ± 0.23 a (2.1-3.6)
Mustard aphid	5.13 ± 0.20 a (4.4-5.9)	2.970 ± 0.25 a (2.0-3.7)
Wheat aphid	5.06 ± 0.17 a (4.5-5.7)	2.80 ± 0.21 a (2.1-3.6)
LSD	0.54	0.66
CV%	11.45	24.77
Level of significance	NS	NS

Mean in the same column followed by same letter are not significantly different ($P < 0.05$). Parenthesis indicated ranges value.

4.11 Life table parameters

Life table parameters were estimated on three different aphid species (Table 8). The net reproductive rate (R_0) was the highest (257.88) while fed on wheat aphid and the lowest (242.00) on mustard aphid. Intrinsic rate of natural increase (r_m) was maximum (0.18) on aphid species and the minimum (0.19) on bean aphid. The intrinsic rate of natural increase (r_m) was highest (0.19) on wheat aphid. The r_m value of *Menochilus sexmaculatus* on aphids varied significantly. Normally, higher r_m is related to shorter developmental and generation times (Tanigoshi *et al.*, 1975; Sabelis, 1981). The mean generation time (*T*) among the varieties of aphids were 29.30, 28.70 and 29.30 days on mustard, bean and wheat aphids, respectively. The longest duration was found in wheat and mustard aphids respectively and the shortest duration was in bean aphid.

Finite rate of increase (λ) was the highest 1.21, 1.20, 1.21 while fed on both mustard and wheat aphid and the lowest (1.20) on bean aphid. It is similar to the finding by Pietrosiuk *et al*., (2003) on bean at 25°C (1.2) and the latter is in agreement with Rezaie (2010).

Population doubling times, *DT* was the longest (3.75) on bean aphid and shortest (3.66) while fed wheat aphid. Besides the findings of Razmjou *et al*. (2009) showed *DT* for *T. urticae* varied from 2.34 to 3.0 on three legumes (at 25°C). Population density doubling (*DT*) was 3.22 days at 30°C, while the longest period was 12 days at 15°C on others aphids.

Preceding studies of the three aphids feeding by *Menochilus sexmaculatus.* The duration doubling times varied significantly among the aphid species. The gross reproductive rate (*GRR*) was highest (256.13) for the wheat aphid and lowest (202.88) for the bean aphid. The intrinsic rate of natural increase is an important parameter, describing the growth potential of a population under climatic and food conditions, because it reflects the overall effects of temperature and food on development, reproduction and survival characteristics of the population (Southwood, 1978). Meanwhile, demographic parameters including the net reproductive rate (R_o), generation time (T), innate capacity of increase (r_m) and the finite rate of increase (λ) of the females were quite satisfactory.

Table 8: Life table parameters of *M. sexmaculatus* while fed on three aphid species

Hosts	R_0	r_m	T	λ	DT	GRR
Bean aphid	202.88	0.19	28.70	1.20	3.75	202.88
Mustard aphid	242.0	0.19	29.30	1.21	3.70	241.50
Wheat aphid	257.88	0.19	29.30	1.21	3.66	256.13

R_0 = Net reproductive rate

r_m = Intrinsic rate of natural increase

T = Mean generation time

λ = Finite rate of increase

DT= Population doubling times

GRR = Gross reproductive rate

4.12 Predation efficiency of larva

The hosts feeding by the larvae of *M. sexmaculatus* on three different species of aphids caused by all instars varied significantly (P< 0.05) among the treatments (Table 9). The consumption of aphids amid all the instars i.e. 1^{st}, 2^{nd}, 3^{rd} and 4^{th} was patchily distributed. At the early larval stages, the predation efficiency of the grub was low on all host species. As well as the later instars, since the larval body increased, the feeding efficiency also raised. Among the instars of immature stages, the total highest aphid consumptions was observed on bean aphid (205.9 a ± 1.73) but the lowest it was 187.8 ± 8.74 on wheat aphid.

Predation efficiency of the present findings is parallel to Ali *et al*. (2012) who conclude that the mean predatory potential of all larval instars of *M. sexmaculatus* ranged from 148 to 162 wheat aphids *Rhopalosiphum padi*, respectively. Mari *et al.* (2004) studied of the feeding efficiency of *M. sexmaculatus* and reported that the per day aphid consumed by the zigzag beetle against the first**,** second, third and fourth instars were 11.8, 26.8, 43.4 and 141.5, respectively. However, variation of aphid consumption of the immature stages might be associated with environmental conditions, prey species etc.

Table 9: Predation efficiency of larva of *M. sexmaculatus* as fed on three aphid species under ambient laboratory conditions

Stages	Hosts			LSD	CV (%)
	Bean aphid	Mustard aphid	Wheat aphid		
1st instar	25.00 ± 0.65 a (21-27)	14.70 ± 0.50 c (12-17)	19.30 ±0.37 b (16-21)	1.50	8.31
2nd instar	56.00 ± 1.03 b (50-59)	53.20 ± 0.55 c (51-56)	64.10 ± 0.53 a (60-69)	2.15	4.06
3rd instar	70.40 ± 0.97 a (65-75)	70.20 ± 0.56 a (63-78)	49.50 ± 0.63 b (45-51)	2.15	3.7
4th instar	54.50 ± 0.40 b (50-58)	49.70 ± 0.26 b (44-55)	68.00 ± 5.14 a (22-76)	8.66	16.44
Total	205.90 ± 1.73 a	187.8 ± 8.74 b	200.00 ± 7.40 ab	14.02	3.55

Mean in the same column followed by different letter are significantly different (P < 0.05). Parenthesis indicated ranges value.

4.13 Predation efficiency of adults

The predation efficiency of adult beetle by *M. sexmaculatus* was varied significantly (P< 0.05) among the treatments which are highlighted in (Table10). The ranges of aphid consumption in three different hosts by the beetle was 1245 to 1490. The highest predation was experienced on mustard aphid (1660.80 ± 32.47). Nevertheless, the lowest predation was found on wheat aphid (1465.00 ± 58.52).

Muhammad *et al.* (2014) detected the efficacy of the zigzag beetle, *Menochilus sexmaculatus* on rose aphid, *Macrosiphum rosae* under laboratory conditions (27± 2° C and 62 ± 5%). They cited that the functional response of the adult beetle was 802.40 to 916.60 aphids. Nathpol and Pensook (1991) opined that the average predation capacity of same beetle in the adult stage of male and female were 1012.7 and 1106.9 aphids, respectively.

Rakhshan *et al.* (2009) studied the predation efficiency of *M. sexmaculatus* and reported that the males of the zigzag beetle consumed 88.2 aphids on 18th days and the females consumed 99.21 aphids on the 18th days.

Table 10: Effect of hosts on predation efficiency of adult *M. sexmaculatus* under laboratory conditions

Hosts	Adults	Total (larva-adult)
Bean aphid	1419.00 ± 4.33 b (1399-1435)	1624.90 ± 94.22 a
Mustard aphid	1473.00 ± 2.73 a (1455-1490)	1660.8 ± 32.47 a
Wheat aphid	1265.00 ± 3.20 c (1245-1278)	1465.00 ± 58.52 b
LSD	10.76	12.51
CV%	0.85	3.95

Mean in the same column followed by different letter are significantly different (P < 0.05). Parenthesis indicated ranges value.

CHAPTER 5

SUMMARY AND CONCLUSION

The coccinellid beetle, *Menochilus sexmaculatus* (Fab.) (Coleoptera: Coccinellidae) commonly known as lady bird beetle is one of the most beneficial insect of different agricultural crops. A detailed research work was carried out in the laboratory of the Department of Entomology, HSTU, Dinajpur to study the effect of host on the biology and life table parameters of *Menochilus sexmaculatus* ,on three aphid species such as bean aphid (*Aphis craccivora*), mustard aphid (*Lipaphis erysimi*) and wheat aphid (*Rhopalosiphum maidis*). During November 2014 to April 2015. Mating generally took place within the period of 3 to 4 days of the emergence of the beetles and lasted from 30 minutes to 50 minutes. The mating period was observed the highest on mustard aphid 40.50 minutes and the lowest on bean aphid 39.50 minutes. The average egg laying capacity of single female was 286.00 to 365.00 eggs, when reared on different aphid species. Adult longevity of the beetle was found maximum on *L. erysimi* (42.60 days), and minimum on *Aphis craccivora* (34.60 days). The incubation period was the highest in wheat aphid (3.95 days) and the lowest in both mustard and bean aphid (3.80 days). The highest duration of development was detected on mustard aphid (19.10 days) but it was the lowest as (17.85 days) on wheat aphid. The ranges of lengths were from 4.4 to 5.9 mm although the breadths from 2.0 to 3.7 mm. The highest length (5.13 mm) was found on mustard aphid but the lowest on wheat aphid (2.80 mm).The hatching percentage of eggs was also varied significantly. The hatching percentage was the highest in bean aphid which was 96.78% and the lowest was in wheat aphid which was 93.59%. Variations of life table parameters were estimated on three different aphid species. The net reproductive rate (R_0) was the highest (257.88) while fed on wheat aphid species and lowest (242.00) on mustard aphid. Intrinsic rate of natural increase (r_m) was maximum (0.18) on aphid species and the minimum (0.19) on bean aphid. The intrinsic rate of natural increase (r_m) was highest (0.19) on wheat aphid. The r_m value of *M. sexmaculatus* on aphids varied significantly. The mean generation time (T) among the varieties of aphids were 29.299, 28.704, 29.299 days. Finite rate of increase (λ) was the highest 1.21, 1.20, 1.21 while fed on both mustard and wheat aphid and the lowest (1.20) on bean aphid. The duration doubling times varied significantly among the aphid species. The gross reproductive rate (*GRR*) was highest (257.13) for the wheat aphid and lowest (202.88) for the bean aphid.

Meanwhile, demographic parameters including the net reproductive rate (R_o), generation time (T), innate capacity of increase (r_m) and the finite rate of increase (λ) of the females were quite satisfactory. Both the larvae and adult beetles of *M. sexmaculatus* were voracious predators. The average predation efficiency of mustard aphid (1660.80), wheat aphid (1465.00) and bean aphid (1624.90) respectively. The findings of the present study indicated *that M. sexmaculatus* might play a significant role in aphid management as a part of IPM program. However, before releasing it as a biological agent in the agro-ecosystem further researches on its host preferences and susceptibility to insecticides in field level needs to be investigated.

REFERENCES

Agarwala, B. K., Das, S. and Senchowdhuri, M. 1988. Biology and food relation of *Micraspis discolor* (Fab.) an aphidophagous coccinellied. *Indian J. Aphidology*. 2(1-2): 7-17.

Alam, M. Z., Ahmed, A. and Islam, M. A. 1964. A. Review of Research, Division of Entomology, Agricultural Research Institute, Gazipur. 76 p.

Ali, A. and Rizvi, P. Q. 2012. Age and stage specific life-table of *Coccinella transversalis* with regards to various temperatures. *Tunisian J. Plant Protec.* 4: 211-219.

Amir 2014. Biology and predation efficiency of *Menochilus sexmaculatus* (F.) on bean aphid, *Aphis craccivora. M.S Thesis, Department of Entomology, HSTU,* Dinajpur, Bangladesh.

Basant, K., Agarwal, B.K. and A.K .Ghosh. 2001. Prey records of aphidophagous *coccinellidae* in India. A review bibliography, *Tropical pest management* 34 (1):1-14.

Begum, E., Hussain, M. and Talucdar, F. A. 1991. Relative effectiveness of some granular insecticides against mustard aphid, *Lipaphis erysimi* (Kair.). *Bangladesh. J. Agril. Sci.* 18: 49-52.

Bigler, F., Bieri, M., Fristschy, A. and Seidal, K. 1988. Variation in locomotion between laboratory strains of *Trichogramma maidis* and its impact on parasitism of eggs of *Ostrinia nubilalis* Hbn. in the field. *Entomol. Expt. Appld*. 49: 283-290.

Birch, L. C., 1948. The intrinsic rate of natural increase of an insect population. J. Animal Ecol. 17: 15-26.

Chambers, J.M., Cleveland, W.S., Kleiner, B. and Tukey, P.A. (1983) Graphical Methods for Data Analysis. Belmont, CA: Wadsworth.

Charernsom, K. and Suasaard. W. 1994. A list of natural enemies of insect pests in Thailand. Special Publication No 6. National Biological Control Research Center, National Research Council of Thailand. 144 pp.

Chowdhury, S. P., Ahad, M. A., Amin, M. R and Hasan, M. S., 2008. Biology of lady beetle, *Micraspis discolors* (Fab.) (Coccinellidae: Coleoptera). 3: 39-44.

Duffied, S. J. 1995. Crop-specific difference in the seasonal abundance of four major predatory groups on sorghum and short-duration pigeon pea. International Chickpea and Pigeonpea Newsletter. 2: 74-76.

El-Defrawi, G. M. 1987. Studies on insect vectors of virus diseases infesting Leguminoceae in Egypt. Ph. D. thesis. Fac. Agric, Ain, Shams Univ. Egypt.

El-Fatah, A. S. M. 1991. Studies on insect infesting leguminous plants. M.S. Thesis, Fac. Agric. Zagazic Univ. Egypt.

Gautam, R. D. 1990. Effects of substrata and age of *Menochiluss sexmaculatus* (Fab.). (Coleoptera: Coccinellidae) on its opposition. *J. Biol. Cont.* 4(1): 8-10.

Gautam, R. D. Subhash-Chander, Sharma V. K. and Singh. 1995. Aphids infesting safflower, their predator complex and effect on oil content. Annals of Plant Protection Sciences. 3(1): 27-30.

Gilbert, F. S. and Owen, L. 1990: Size, shape, competition, and community structure in hoverflies (Diptera: Syrphidae). *J. Anim. Ecol.* 59: 21-39.

Gupta, B. M. and Yadava, C. P. S. 1986. Role of Coccinellid predators on regulating the aphid *Myzus persicae* Solz. population on cumin. *Indian J. Ent.* 51(1): 24-28.

Haque and Islam, 2010. Efficacy of cypermethrin, deltamethrin and nimbi code on fecundity and egg viability of *Tribolium castaneum* (herbs) (Coleoptera: Tenebrionidae). Univ.J. zool. Rajshahi. Univ. Vol. 29, pp 23-28.

Hodek, I. 1996. Coccinellids and the modern pest management. *Bioscience*. 20: 543-552.

Ibrahim, Y. B. and Kueh, T. F. 2013. Biological performance of *Menochilus sexmaculatus* Fabricius (Coleoptera: Coccinellidae) upon exposure to sublethal concentration of imidacloprid. *Pertanika J. Trop. Agric. Sci*. 36(1): 51- 60.

Islam, M.A. and Nasiruddin, M. 1978. Life history and feeding habit of *Verania discolor* F. *Bangladesh J. Biol. Sci*. 6-7(1): 48-49.

Jagadish, B. G. and Jayaramaiah, S. 2004. Screening of cowpea germplasm for resistance to *Aphis craccivora* Koch. in India. *Trop. Pest Manage.* 34(1): 62.

Jayappa, B. G. and Lingappa S. 1988. Causes of resistance to *Aphis craccivora* Koch. in cowpea germplasm in India. *Trop. Pest Manage*. 34(1): 59-61.

Jih-Zu Yu, Chi. H, and Chen. B. H. 2012. Comparison of the life tables and predation rates of *Harmonia dimidiata* (F.) (Coleoptera: Coccinellidae) fed on *Aphis gossypii* Glover (Hemiptera: Aphididae) at different temperatures. Biological Control. 64:1-9.

Jogender, S. Rana, 2009**.** Response of *Coccinella septempunctata* and *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) to their aphid prey, *Lipaphis erysimi* (Hemiptera: Aphididae) in rapeseed-mustard. *Eur. J. Entomol.* 103: 81-84.

Kalushkov, S.P. and Hodek, S.C. 2001. Life history and development of *Scymnus frontalis* F. (Coleoptera: Coccinellidae) on four species of aphid. *J. Kans. Entomol. Soc.* 65: 410-415.

Mackauer, M., 1983. Quantitative assessment of *Aphidius smithii* (Hymenoptera: Aphidae): fecundity, intrinsic rate of increase, and functional response. Canadian Entomologist. 115: 399-415.

Mari, J. M., Nizamani, S. M., Lohar, M. K. and Khuhro, R. D. 2004. Biology of *Menochilus sexmaculatus (*Fab.) and *Coccinella undecimpunctata* L. (Coccinellidae: Coleoptera) on alfalfa aphid *Herioaphis trifolii* Monell. *J. Asia Pacific Entomol*. 7(3): 297-301.

Mari, J. M., Rizvi, N. H., Nizamani, S. M., Qureshi, K. H. and Lohar, M. K. 2004. Predatory efficiency of *Menochilus sexmaculatus* Fab. and *Coccinella undecimpunctata* L. (Coccinellidae: Coleoptera) on alfalfa aphid *Herioaphis trifolii* Monell. *Asian J. Plant Sci.* 4(4): 365-369.

Mojib, Z. H. G. and Yousefpour, M. 2011. Effects of feeding from different hosts on biological parameters of the lady beetle *Hippodamia variegate* (Goeze) in the laboratory conditions. *Int. J Agri Crop Sci*. 4(12), 755-759.

Muhammad, S., Saqib, M. M. 2009. Rearing of predatory seven spotted ladybird beetle *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on natural and artificial diets under laboratory conditions**.** *Pakistan J. Zool.* 42(1): 47-51.

Muhammad, S., Saqib, M. M. 2014. Rearing of predatory seven spotted ladybird beetle *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on natural and artificial diets under laboratory conditions**.** *Pakistan J. Zool.* 42(1): 47-51.

Nasiruddin, M. and Islam, M. A. 1979. *Verania discolor* Fab. (Coleoptera: Coccinellidae) an effective predator on different species of aphids. *Bangladesh J. Zool.* 7(1): 69-71.

Nathapol, W. and Pensook, T. T. 1991. Preliminary study on the predacious coccinellid *(Menochilus sexmaculatus)* in control of groundnut aphid, *Brevicoryne brassicae* L. *J. Ent. Res.* 20(1): 23-25.

Ngammuang Pa-Nan (1987). Study on the coccinellidae, Micraspis discolor (F.) (Coleoptera: Coccinellidae) and its role as biological control agent. Bankok (Tailand) 64

Nyukuri RW, Wanjala FME, Cheramgoi E, Odhiambo J, Kirui S . 2012 .Effects of Different Agro ecosystems on Prevalence of Different Species of Pests and Coccinellid Predators in Agricultural Science and technology. PP 776 – 783.

Patel, *et.al*. 2015. Comparative Biology of Ladybird Beetle, M. Sexmaculatus Fab. on Different Aphid Species. ISSN: 2321-8169 Volume: 3 Issue: 6 4392 - 4396

Patterson R. S., Koehler P. G., Morgan, P. B. and Harris, R. L. 1981. Proc. workshop on status of biological control of filth flies, 4-5 February 1981, Gainesville, Fl. USDA, Science and Education, New Orleans, LA.

Pietrosiuk, A., M. Furmanowa, D. Kropczynska, B. Kawka and H. Wiedenfeld 2003. life history parameters of the two-spotted spider mite, *Tetranychus urticae* feeding on bean leaves treated with pyrrolizidine alkaloids. Journal of Applied Toxicology. 23: 171-175.

Prodhan, N. Z. H., Haque, M. A., Khan, A. B. and Rahman, A.K.M.M. 1995. Biology of *Micraspis discolor* Fab. (Coleoptera: Coccinellidae) and its susceptibility to two insecticides. *Bangladesh J. Ent*. 5(1-2): 11-17.

Rahman, M. H., Sardar, M. A., Mian, M. R. U. and Kamal, N. Q. 1993. Consumption rate of *Aphis medicaginis* by the grub of *Menochilus sexmaculatus* (Fab.) (Coleoptera: Coccinellidae). *Bangladesh J. Zool*. 21(1): 185-187.

Rakhshan, E. A. M. 2009. Predatory efficiency of *Cheilomenes sexmaculata* (Fabricius) (Coleoptera: Coccinellidae) against *Aphis craccivora* Koch. on various host plants of family Fabaceae. 11(18): 1857-7881.

Razmjou, J., H. Tavakkoli and M. Nemati, 2009. Life history traits of *Tetranychus urticae* Koch on three legumes (Acari: Tetranychidae). Mun. Ent. Zool. Vol. 4(1): 204-211.

Rezaie, M., 2010. Life table parameters of *Tetranychus urticae* Koch on different host plants. 19th Iran Plant Protection Cong., Tehran, Iran.pp: 392.

Rizkalla, L.R., K.M. Makkour, M.A. Madkour, M.H. El-Sherbeeny and M.B. Soih, 1994. A new virus disease affecting faba bean (*Vicia faba*L.) in Egypt. 6th Annual Report of Nile valley Regional Program on Cool Season. Food Legumes, pp: 197-203.

Rutz, D.A., Patterson, R.S., 1990. Biological Control of Arthropods Affecting Livestock and Poultry. Westview, Boulder, CO

Sabelis, M. N. 1981. Biological control of two-spotted spider mites using phytoseiid predators. PartI: Modeling the predator-prey interaction at the individual level. Agricultural Research Reports, 910. Centre for Agricultural Publishing and Documentation, Wageningen.

Saleem, M.; Hussain, D. and Anwar, H. 2012. Predation efficacy of *Menochilus sexmaculatus* Fabricus (Coleoptera: Coccinellidae) against *Macrosiphum rosae* under laboratory conditions. 2(3): 160-163

Saxena, R.C., N. J. Liquido and H. D. Justo, 1980. Neem seed oil an antifeedant for brown plant hopper. Proc. 1st Int. Neem Conf. Rottach Egern. 171-188.

Schmutterer, H. and K. R. S. Eds. Ascher, 1987. Natural pesticides from the neem tree and other tropical plants. Proceedings of the 3rd Int. Neem Conf. Nairobi, GTZ Schriftenreih, Eschborn.

Seubsaiboonsong, R., N. Siri, T. Jamjanya and S. Techawongsatien 2006. Natural Enemies and Pest on Hua-rua and Aromatic Chili Under Organic Agriculture System, in The 6th National Horticultural Congress: Towards Innovation in Horticulture for Safety Food and Self-Sufficient Economy, November 7-10, 2006, Lotus Hotel Pang Suan Kaew, Chiang Mai, Thailand, p. 52.

Sharma, V.P. and Ansari, M.A., 1994. Personal protection from mosquitoes (Diptera: culicidae) by burning neem oil in kerosene. J. Med. Entomol., 31: 505–507.

Singh, S. R. 1987. Resistance of pests of cowpea in Nigeria. *African Crop Science Journal, Vol. 4. No. 3, pp. 345-350.*

Singh, S. R. and Allen, D. T. 1980. Pests, disease resistance and protection in cowpeas. In : Adv. legume Sci. Ed. Summerfield, England. 419-443pp.

Solangi, B. K., Lohar, M. K., Lanjar, A.G. and Mahar, M. D. 2005. Biology of zigzag beetle, *Menochilus sexmaculatus* Fab. (Coccinellidae: Coleoptera) on mustard aphid *Lipaphis ensimi* Kalt. *Sarhad J. Agric.* 21(2): 261-264.

Southwood, T. R. E., 1978. Ecological Methods, with particular reference to the study of insect population. 2nd edition. Chapman and Hall, New York, NY.

Tanighoshi, L. K., S. C. Hoyt, R. W. Browne and J. A. Logan, 1975. Influence of temperature on population increase of *Tetranychus medanieli* (Acarina: Tetranychidae). Ann. Entomol. Soc. America. 68: 972-978.

Thakur, B. S., Verma, R., Paritunda, A. and Rawat, R. R. 1984. Chemical control of aphid, *Aphis craccivora* Koch on Lentil. *Ind. J. Ent.* 4: 103-105.

Thompson, W. R. and Simmonds, F. J. 1965. *A Catalogue of the Parasites and Predators of Insect Pests.* Commonwealth Agricultural Bureau, Burks, United Kingdom.

Verma, G. C., Vyas, R. S. and Bran, K. S. 1993. Biology of *Menochilus sexmaculatus* (Fab.) (Coccinellidae: Coleoptera). Univ. Panjab Agril. 30(1-2): 27-31.

Wigunda, R., 2012. Host plants dependent prey suitability of predatory lady beetles. *J. Entomol. Res. Soc.* 14(3): 29-37.