Developmental Biology and Feeding Efficiency of *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) (Fabricius) reared on *Aphis craccivora* (Hemiptera:Aphididae) (Koch)

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ABSTRACT: *Menochilus sexmaculatus(Fabricius) predates on soft bodied, plants sap feeding insect pests. This species is a potential biocontrol agent to use in augmentative release programmes and requires more biological and ecological data. The objective of this study was to examine the development biology of M. sexmaculatus and to assess its suitability as a biocontrol agent. The study was conducted in the Entomology Research Laboratory, Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya from January to June, 2015. All the experiments were conducted under laboratory conditions at 27ºC and 80 % RH. Mean incubation period of eggs was 3.0 ± 0.4 days. The total larval duration was 7.1 ± 0.5 days; L1, L2, L3 and L4 durations were 2.1 ± 0.3, 1.1 ± 0.4, 1.9 ± 0.3 and 1.9 ± 0.3 days, respectively. The pre-pupal and pupal periods were 1.1 ± 0.3 and 3.1 ± 0.3 days, respectively. Mean longevity of male and female beetles were 38.0 ± 0.6 and 47.3 ± 1.0 days, respectively. Mean pre-oviposition period was 3.0 ± 0.1 days and the oviposition period was 43.3 ± 1.0 days. The mean body length of L1, L2, L3 and L4 instars were 1.9 ± 0.1, 2.7 ± 0.3, 6.0 ± 0.1 and 7.8 ± 0.5 mm while, the mean width were 0.4± 0.1, 0.9 ± 0.0, 1.2 ± 0.1 and 3.3 ± 0.1 mm. Mean length and width of adult females were 6.2 ± 0.2 and 4.5 ± 0.3 mm respectively, and those of the males were 4.3 ± 0.5 mm and 3.2 ± 0.3 mm, respectively. L1, 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 ± 3.1per day, respectively. L1, 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 ± 1.7per 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 Efficacy of M. sexmaculatus adults was higher than larvae.*

Keywords: *aphid biocontrol, coccinellidae, life cycle stages, predation*

INTRODUCTION

The ladybird beetles (Coleoptera: Coccinellidae) have diverse food habits and live in variety of habitats. Majority of the species are beneficial being predators of small arthropod pest of agricultural crops. Both adults and larvae feed on small soft bodied insects or their

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developing stages such as aphids, mealy bugs, scale insects, whiteflies, thrips, leafhoppers, and mites (Omkar and Pervez, 2000). It is known to prey on about 39 arthropod species (Gautam, 1989). The predatory coccinellids are common in all countries of Asia (Islam and Nasiruddin, 1978). About 36 species of aphidophagous coccinellids are reported from Indian subcontinent (Baskaran and Subramanyan, 1992). In Sri Lanka, fifteen different coccinellid species belonging to 12 genera in four tribes and three sub families have been recorded from the Mid country namely, *Anegleis cardoni*, *Coccinella transversalis*, *Coccinella octomaculata*, *Illies cincta*, *Micraspis discolor*, *Propylea dissecta*, *Synonycha grandis*, *Brumoides suturalis*, *Chilocorus nigritus*, *Cryptogonus orbiculus*, *Pseudaspidimerus trinotatus, Axinoscymnus puttradrihai*, *Scymnus latemaculatus*, *Scymnus nubilis* and *Coccinella sexmaculata* (Mayadunnage *et al*., 2007).

M. sexmaculatus (Fabricius) is known to be the predominant species in India, Nepal, Japan, Indonesia and China (Poorani, 2002). This species voraciously feeds on a wide range of prey including aphids, coccids, diaspids and aleyrodids etc. (Agarwala and Yasuda, 2000).

Nymphs and adults of *Aphis craccivora* (Koch) attack beans and other leguminous crops causing significant damage by sucking the sap of the flowers, buds, pods, tender shoots which reduce the market value (Srivastava and Singh, 1986). When infested, plants fail to produce flowers and pods resulting in 20-40% yield loss (Islam, 2007). At present, Sri Lankan farmers rely mainly on insecticides to control *A. craccivora*.

Insecticidal control is not only expensive but also pollutes the environment and also leads to many health problems. Indiscriminate use of pesticides causes phytotoxicity and destruction of beneficial organisms such as predators, parasitoids, microorganisms and pollinators (Luckman and Metcalf, 1978). Subsequently, Integrated Pest Management has been opted in which biological control as one of the strong components (Debach and Rosen, 1991).

Coccinellid beetles are considered to be of great economic importance in agro-ecosystem as they have been successfully used in biological control of many injurious insects (Agarwala and Senchowdhuri, 1988). Augmentation and release of the biological control agent is one of the feasible approaches of biological control that can be practiced under Sri Lankan conditions. Toward this endeavor, life cycle data of the predator is essential as well as assays of its efficacy. The Present study examines the development biology of *M. sexmaculatus* and assesses its efficiency as a biocontrol agent of aphids.

MATERIALS AND METHODOLOGY

The study was conducted in the Entomology Research Laboratory, Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya from January to June, 2015. All the experiments were conducted under laboratory conditions of 27ºC and 80 % RH.

A culture of *M. sexmaculatus* was established in the laboratory in order to obtain insects for the experiments. The culture was established using the adults, collected from Gannoruwa, Dodangolla, Galagedara and Kundasale. The identity of the species was confirmed using available taxonomic keys, descriptions and pictorial guides. A culture of *A. craccivora* was initiated using field collected aphids from Mung bean and they were maintained on bean cotyledons. Coccinellid beetles were fed on these aphids. Life history, morphometric

measurements, sex ratio and feeding efficiency of *M. sexmaculatus* larvae and adults were assessed through a series of laboratory experiments.

Life history and Morphometric measurements of *M. sexmaculatus*

Laboratory reared newly emerged *M. sexmaculatus* adults were allowed to mate and fed on aphids and held in Petri dishes (15 cm diameter) until oviposition. Freshly laid egg masses were separated and incubated in Petri dishes. On hatching of eggs, newly emerged larvae were transferred individually into the Petri dishes containing wet cotton plugs, aphids on a fresh bean shoots were supplied as food. Larvae were observed at 12 h intervals (morning and evening) until pupation. The number of instars and duration of each instar were recorded by examination of shed exuvea and the pupae were left undisturbed in the same Petri dishes until adult emergence. Accordingly, the pupal period was recorded. Newly emerged beetles were closely observed and their pre-oviposition and oviposition periods were recorded while keeping them individually in Petri dishes providing aphids as a food source. Twenty five individuals of *M. sexmaculatus* were examined in this manner. In order to assess the sex ratio, hundred laboratory reared beetles were observed.

Morphometric measurements such as width and length of male, female, egg, larva (all four instars) and pupa were made using twenty five individuals under a dissecting microscope.

Feeding rates of Life cycle stages of *M. sexmaculatus*

Freshly laid eggs of *M. sexmaculatus* were incubated to obtain neonate larvae for the experimentation. Feeding rates of larval instars (L1, L2, L3 and L4) were assessed by providing an ample supply of aphid nymphs in Petri dishes (15cm diameter). Daily aphid consumption by predatory larvae was calculated by counting aphids before and after the feeding. The total consumption for each instar was calculated. Aphid consumption was assessed by examining twenty five larvae which are considered as twenty five replicates. A similar procedure was carried out for adults (male and female) of *M. sexmaculatus* and their daily consumption of aphids was calculated.

Feeding efficiency of *M. sexmaculatus*

A. craccivora and *M. sexmaculatus* were held in clear plastic Petri dishes. Fifteen aphids were exposed to a single predator. The time taken to feed on one aphid was recorded. Feeding duration of the predator was assessed using both nymph and adult aphid. L1, L2, L3, L4, male and female of *M. sexmaculatus* were tested in this experiment. Twenty five individuals were examined.

RESULTS AND DISCUSSION

Life history and Morphometric measurements of *M. sexmaculatus*

Eggs

The eggs were laid in clusters: 6 to 12 clusters/day. Each cluster contained 4 to 28 eggs. Similar observations have been made by Zala (1995) and Patel (1998).The freshly laid eggs of *M. sexmaculatus* are cigar shaped and bright yellow with a smooth chorion. There were no reticulations on the surface. Eggs turned blackish with age and became completely black

before hatching. The mean length of eggs was 1.0 mm, and the width was 0.4 ± 0.1 mm. The similar observations on egg laying pattern, shape and colour of eggs was also reported by Tank and Korat (2007).

The mean incubation period of *M. sexmaculatus* was 3.0 ± 0.4 days. According to Patel (1998), incubation period varied from 1 to 3 days with an average of 1.4 ± 0.7 days. The hatching percentage of eggs of *M. sexmaculatus* varied from 84 to 88% with an average of 85.86% which is an agreement with the findings of Patel (1998) and Zala (1995).

First Instar Larvae

Newly emerged larvae are dark grey in colour with a shiny dark head capsule and legs. Similar descriptions have been given by Tank and Korat (2007) and Subramanyam (1923). Mean length and width of first instar larvae were 1.9 ± 0.1 and 0.4 ± 0.1 mm respectively. The mean head capsule length was 0.2 mm. According to Tank and Korat (2007) the mean length and width of the body and the head capsule width were 1.4 ± 0.2 mm, 0.4 mm and 0.3 mm respectively.

The duration of development of first instar larvae of *M. sexmaculatus* ranged from 2 to 3 days with a mean of 2.1 ± 0.3 days. The development period was recorded as 1.8 ± 0.5 days by Tank and Korat (2007). The duration recorded during the present study was longer than the reported values, likely due to variability in food and temperature.

Second Instar Larvae

Freshly emerged second instar larva was black in colour with yellow coloured head capsule and black legs. Development of colour patches was observed on meso- and metathorax and fourth and sixth abdominal segments. Mean length and width of larva were 2.7 ± 0.3 and 1.0 mm, respectively. Tank and Korat (2007) reported, those measurements as 4.3 ± 0.2 and 0.7 ± 0.2 mm. Head width was 0.3 to 0.4 mm with an average of 0.4 mm. The duration of second instar larvae was 1 to 2 days with a mean of 1.1 ± 0.4 days. Duration of the second instar larvae was recorded as 1.7 ± 0.5 days by Tank and Korat (2007).

Third Instar Larvae

Newly emerged third instar larva are dull black with a yellow head capsule. Presence of white spots mid dorsally on segments except the prothorax is a specific morphological feature. Mean width and length of larva were 1.2 ± 0.1 mm and 6.0 ± 0.1 mm respectively. Tank and Korat (2007) reported the mean length and width as 0.8 ± 0.1 mm and 5.8 ± 0.3 mm. The duration of the third instar larvae ranged from 1 to 2 days with a mean of 1.9 ± 0.3 days. Tank and Korat (2007) reported that the third instar larvae of *M. sexmaculatus* lasted 1.9 ± 0.5 days when reared on *A. craccivora*.

Fourth Instar Larvae

Fourth instar larvae are black in colour, and the prepupae change into dark grey or milky in colour. Mean width and the length of larvae were 3.3 ± 0.1 mm and 7.8 ± 0.5 mm, respectively. Mean head width was 0.6 mm. Mean body width and length of fourth instar larvae of *M. sexmaculatus* were 1.3 ± 0.1 mm and 7.2 ± 0.2 mm respectively according to Tank and Korat (2007). The duration of fourth instar larvae of *M. sexmaculatus* ranged from

1 to 2 days with a mean of 1.9 ± 0.3 days. Mean duration of 1.9 ± 0.7 days was reported when reared on *A. gossypii* by Tank and Korat (2007).

The total larval development period of *M. sexmaculatus* varied from 6 to 8 days with a mean of 7.1 ± 0.5 days when reared on *A. craccivora*. The total larval period reported by Tank and Korat (2007) ranged from 5 to 10 days with an average of 7.4 ±1.2 days agrees with the present findings.

Pre-pupa Stage

The final instar larvae stopped feeding and searched for a suitable place for pupation and became stationary and sluggish. The body shrunk during the formation of pre-pupa. Pre-pupa formed by *M. sexmaculatus* larvae as "C" shaped. The colour of the prepupa was same as that of the fourth instar. Similar observations have been made by Tan and Korat (2007). The prepupal period varied from 1 to 2 days with a mean of 1.1 ± 0.3 days. A prepupal period was 1.7 ± 0.5 days as reported by Tank and Korat (2007).

Pupal Stage

When the pre- pupal stage was about to pupate, the spiny structure disappeared. Freshly formed pupae are shiny yellow and later became pale orange. It attached itself to dry surface. The pupal width and length of *M. sexmaculatus* was 2.8 ± 0.5 mm and 3.6 ± 0.3 mm respectively. According to the Tank and Korat (2007) mean width and length are 2.3 ± 0.5 mm and 3.9 ± 0.2 mm respectively. The present findings agree with these results.

Adults

Newly emerged adult is soft, yellowish, the elytra was without any markings which later become shiny yellow with black spots. The adult is small, and oval shaped. Abdomen and eyes were light yellow in color. Elytra and pronotum have zigzag markings. Similar descriptions were made by Tank ad Korat (2007) and Patel (1998). Average length and width of female were 6.2 ± 0.2 mm and 4.5 ± 0.3 mm, respectively, and in the male, it was 4.3 ± 0.5 and 3.2 ± 0.3 mm. These measurements are in agreement with the Tank and Korat (2007), Zala (1995) and Patel (1998).

The longevity of the male ranged from 37-40 days with a mean of 38 ± 0.7 days when reared on *A. craccivora*. The longevity of the female was from 45 to 50 days with a mean of 47.3 ± 0.9 days. The reported adult life span of male and female was 29.7 ± 2.2 and 34.2 ± 2.5 days, respectively (Tank and Korat, 2007). The pre-oviposition ranged varied from 2-3 with a mean of 3.0 ± 0.1 days when reared on *A. craccivora*. The oviposition period ranged from 40- 45 days with a mean of 43.3 ± 0.9 days. Tank and Korat (2007) recorded oviposition period of *M. sexmaculatus* as 16.1 ± 2.5 days when reared on *A. craccivora*.

Hundred beetles were considered when calculating the sex ratio. Where 47 were male and 53 were female. Sex ratio was 1: 1.12 for *M. sexmaculatus* when reared on *A. craccivora*. It was reported as 1:1.35 by Tank and Korat (2007) when reared on *A. gossypi*.

Feeding rates of *M. sexmaculatus*

Of the four different larval instars, fourth instar larvae consumed the highest number (69) of aphid nymphs per day. Females (1624) consumed more aphids than males (1300). Feeding rates of the males and females did not vary significantly (Table 1).

Table 1. Consumption rates of *M. sexmaculatus* when fed on aphid, *A. craccivora* within an experimental arena (140cm^2) under laboratory conditions at 27°C at 80% RH.

Instar / Stage of *M. sexmaculatus* (n=25)	Duration of development (d)	Consumption rate per individual	
		Nymphs	Adults
L1	3	10.3 ± 1.8	3.3 ± 0.6
L2	4	7.5 ± 1.3	3.3 ± 0.6
L3	2	38.1 ± 3.5	12.0 ± 0.9
L4	2	69.1 ± 3.1	25.1 ± 1.7
Adult Male	30	1300.0 ± 1.5	1006.4 ± 0.4
Adult Female	35	1624.1 ± 0.2	1204.3 ± 1.3

Coccinellid beetles, *Micraspis discolor, Coccinella transversalis, Coclophora cardini, Aspidimenes circumflexus* and *Thea cinctayiere* were also found feed on bean aphids (*Aphis craccivora*). *M. sexmaculatus* showed higher feeding potential than *Micraspis discolor, Coccinella transversalis, Coclophora cardini, Aspidimenes circumflexus* and *Thea cinctayiere* (Watagodakumbura and Ahangama, 2001). Consumption of aphids increased with larval development and the average daily consumption of aphids by an adult was higher than that of the larvae. Both larvae and adults of *M. sexmaculatus* consumed higher number of prey and laid higher number of eggs in the presence of more prey.

Feeding rates of *M. sexmaculatus*

Feeding efficiency of *M. sexmaculatus* is higher in the adult than in the larvae when feeding on aphids. Feeding efficiency increases with increasing larval instars and the shortest time (168 seconds) was taken by the fourth instar larva.

Table 2. Average time duration taken for the consumption of different life forms of *A. craccivora* by *M. sexmaculatus* in an experimental arena (140cm^2) under laboratory conditions at 27°C, and 80% RH.

Life stage	Time (seconds)		
	Nymph	Adult	Winged
L1	1960	3083	-
L2	1110	2669	-
L3	203	564	-
L4	168	347	-
Male adult	80	113	132
Female adult	9	95	142

CONCLUSIONS

M. sexmaculatus is an efficient predator of *Aphis craccivora* with a high consumption rate and a short life cycle. During the entire larval development period, one individual consumes 124.8 ± 0.6 nymphs and 43.7 adults. During the adult life span one female consumed 1624.1 ± 0.2 nymphs and 1204.3 ± 1.3 adults while single male consumed 1302 ± 1.5 nymphas and 1006.4 ± 0.4 adults. Consumption rate of the larvae increases with the instars with the highest mean daily consumption rate of fourth instar larvae. *M. sexmaculatus* took 14.1 ± 0.3 days to complete development from egg to adult. Adults live one month. Adult coccinellid beetle feed more efficiently on aphids than the larval instars. The feeding efficiency increased with the larval instar. These biological information reveals the potential of *M. sexmaculatus* to use as a biocontrol agent in augmentative release programme to manage aphid, *A. crassivora.*

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