Survival and Development of *Menochilus sexmaculatus* (Fabricious) (Coleoptera: Coccinellidae) Larvae on Formulated Diet: An Attempt for Mass Rearing

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Abstract
Menochilus sexmaculatus (Fabricious) is an effective bio-control agent and requires mass rearing them to use in Augmentation Release. Rearing on natural prey demands the maintenance of plants and aphid cultures; hence, it is necessary to examine the possibility of mass rearing on artificial diets. The objective of this study was to examine the possible replacement of natural diet: aphids by cooked chicken liver. *M. sexmaculatus* larvae were provided with three different diets: D1live aphids, D2 Chicken Liver, D3 Chicken Liver mixed with adult aphids. These three diets were provided to larvae as nine treatments. The survival rates and development durations of larvae were recorded. Each treatment was replicated 15 times. The Data were analyzed using One way ANOVA followed by LSD mean separation using Minitab statistical software. The survival percentage of the larvae varied significantly among the treatments ($P<0.05$). The highest survival percentage (94 %) was recorded when the larvae were fed only on aphids. The lowest survival percentage (10%) was recorded when the larvae reared only on chicken liver diet. The survival percentage was significantly varied with treatments of L3 and L4 larval stages fed with chicken liver. Replacement of aphid by chicken liver for L3 and L4 was with a compromise of survival percentage of larvae. The total larval duration was significantly varied with different diet regimes ($P<0.05$). The fastest growth rate was recorded when all larval instars were fed exclusively on aphids. The longest duration was taken when L1 fed on Aphids and other three instars fed on the chicken liver. Chicken liver can be used for L3 and L4 larval that can be used in mass rearing with a compromise of survival rate.

Keywords: Chicken liver, Duration, Larvae, Survival
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Introduction
Larvae and adults of *Menochilus sexmaculatus* (Fabricious) predate on various important crop pests such as aphids, mealybugs, whiteflies and other small soft bodied insect pests. It is an effective bio-control agent and requires mass rearing for commercial use. Rearing on natural prey demands the maintenance of plants and aphid cultures; hence, it is necessary to examine the possibility of mass rearing of *M. sexmaculatus* on artificial diets or on alternative hosts. Food that sustains larval development and oviposition is considered as essential food while the food that serve only as a source of energy with prolong development period and poor survival is considered as alternative food . Aphidophagous coccinellids feed on wide range of arthropods, e.g. Stenorrhyncha (Psyllidae, Aleyrodidae, Coccidae), Acari, Thysanoptera and larvae of Diptera, Coleoptera and Lepidoptera (Hodek 1970). They are also known to feed on plant matters, such as pollen, nectar and fungal spores. Various formulations of artificial diets have been tested on *H. convergens* adults. A pork liver diet has been used for rearing the coccinellid, *Cleoboramellyi mulsant*. An artificial diet based on chicken liver has been used successfully to rear *M. sexmaculatus* larvae and adults (Hussein *et al.*, 1986). The objective of this study was to examine the possible replacement of natural diet: by cooked chicken liver.

Materials and Methods
The adults of *M. sexmaculatus* that obtained from laboratory cultures were sexed and confined them in pairs in Petri dishes (15 cm diameter) with aphids for oviposition. Egg masses were separated and incubated. After hatching of eggs, young larvae were transferred individually into the Petri dishes (15 cm diameter). Three diets were used to feed the larvae. D1 was live aphids. D2 prepared by boiling Chicken Liver (10g) in 60 ^{0}C hot water for 10 minutes and grind by using the motor and pestle. D3 prepared by boiling 10 g of Chicken Liver in 60 ^{0}C 100 ml hot water for 10 minutes and grind by using the motor and pestle until it becomes paste while adding 60 adult aphids. The three different diets were allocated as nine treatments (Table 1).

The survival rates *M. sexmaculatus* larvae and total development durations of larvae were recorded. Each treatment was replicated 15 times. Data were analyzed using one way

ANOVA, followed by LSD mean separation using Minitab Statistical software.

Table 1: Feeding plan for *M. sexmaculatus* larvae with aphids and cooked chicken lever.

Treatment	L1	L2	L3	L4
1	D2			
2	D1	D2		
3	D1		D2	
4	D1			D2
5	D3			
6	D1	D3		
7	D1		D3	
8	D1			D3
9	D1			

Results and Discussion

The survival percentage of the larvae varied significantly among the treatments ($P<0.05$). The highest survival percentage was recorded when the larvae were fed only on aphids (93.33 ± 2.35 %). The lowest survival percentage was recorded when the larvae reared only on chicken liver diet (10.00 ± 2.35 %). The survival percentage significantly varied with T3 and T4. Replacement of aphids by chicken liver for L3 and L4 was possible with a compromise of survival percentage of larvae.

The total larval duration significantly varied with different treatments ($p<0.05$). The fastest growth rate was recorded when all larval instars were fed exclusively on aphids and when L1, L2, and L3 instars were fed exclusively on aphids and L4 stage fed on D3. The longest duration was taken when L1 fed on aphids and other three instars fed on the chicken liver.

Mass rearing of different Coccinellid species was successful on different diets. Adults of *Coccinella septempunctata* L. and *Coccinella transversoguttata* Faldermann increase in body weight but fail to produce eggs when fed on weevil larvae (Richards and Evans 1998). Pollen is an unsuitable food because pollen becomes clumpy and adheres to larval cuticle. Subsequently, larvae become desiccated and die. This has been observed in *Coleomegilla maculate* De Geer (Michaud and Grant, 2005). Allen (1985) reported that beef liver is a nutritionally adequate diet for predator development but no egg production was found. It is evident that the artificial diet containing chicken liver, yeast and sucrose support the growth of *M. sexmaculatus* (Hussein *et al.*, 1986) and *H.convergens* .

Table 2. The total larval durations and survival percentages of *M. sexmaculatus* when reared on aphids (D1) chicken liver (D2), and their combination (D3)

Treatment	Larval Duration ±SE (Days)	Survival %± SE
T1	11.6 ± 0.5^{a}	10.0 ± 2.4^{a}
T2	12.2 ± 0.1^{a}	13.3 ± 2.4^{a}
T3	10.8 ± 0.1^{ab}	33.3 ± 1.7^{b}
T4	9.9 ± 0.1^{b}	58.9 ± 2.0^{c}
T5	8.8 ± 0.1^{c}	67.8 ± 1.5^{d}
T6	8.3 ± 0.2^{c}	67.8 ± 1.5^{d}
T7	8.0 ± 0.2^{cd}	78.9 ± 1.1^{e}
T8	7.3 ± 0.2^{d}	85.6 ± 1.8^{ef}
T9	7.4 ± 0.2^{d}	94.0 ± 2.4^{f}

Values within a column followed by the same letter were significantly different at 5% level

According to the present findings, it is observed that the most suitable diet for the predator is natural diet: aphids but chicken liver can be used to replace the natural diet to some extent for L3 and L4 instars of larvae. The best food source for the predator was aphids (94 % survival and seven days of larval duration). The survival percentage was significantly different with T3 and T4. The replacement of the aphid by using the chicken liver for L3 and L4 can be used as alternative approach for the development of mass rearing protocol for *M. sexmaculatus.*

Conclusions

M. sexmaculatus can be reared only on *Aphis craccivora* while maintaining the highest survival percent (94%) and fastest growth rate (7 days). the cooked chicken liver diet, can be a substitute for aphids at L4 and L3 larval stages. By replacing the aphids, by cooked chicken liver during L3 and L4 larval stage can be apply as the

approach for the development of mass rearing protocol for *M. sexmaculatus*.

Acknowledgement
Financial assistance received by NationalScience Foundation (Grant Number:NSF/RG/2014/AG/02) is highly appreciated.

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