Production, Storage and Delivery Of *Megaselia Scalaris* (Diptera: Phoridae) In Laboratory as Potential Food Source for Swiftlets (Aves: Apodidae)

Hadura Abu Hasan[1], Siti Aisyah Rahimah Md. Saad[1], and Hamdan Ahmad[2]

***Abstract*—**The production of *Megaselia scalaris* (Diptera: Phoridae), as potential food sources for swiftlets (Aves: Apodidae) was carried out in the laboratory. Pupae and adults *M. scalaris* were stored in an incubator in the laboratory at different temperatures ranging from 5 to 40˚C. The maximum length for pupae development was 13 days at 15˚C. The greatest mean emergence of adult *M. scalaris* was approximately 99% with number of females was always higher than males. The 100% emergence of adult *M. scalaris* obtained at 28 and 30˚C. The longevity of *M. scalaris* was greater at 20˚C with survivorship rate 6.5 (±0.29) days. The emergence of adults *M. scalaris* in the mobile insectarium was also high and similar to the production of this species in the laboratory. For delivery process, the release number of *M. scalaris* from mobile insectarium to a small cage was significantly different per minute time. Although the delivery process of adult *M. scalaris* was successfully carried out in the laboratory, further research is needed for transporting of this species in the field.

Keywords*—Megaselia scalaris*, mass production, storage, delivery, temperature.

I. Introduction

A SMALL-bodied diptera, *Megaselia scalaris* (Diptera: Phoridae), is a cosmopolitan and synantrophic species that has capability to explore to a variety of environments and ecological niche (Costa et al., 2007). Because of the potential of this dipteran species as food source for swiftlets (Aves: Apodidae), this study was undertaken to increase the basic knowledge available on the survival and development of this species in the laboratory.

Swiftlest are insectivorous and mostly found near places abundant with insects and water (Camfield, 2004). Study by Lourie and Tompkins (2000) discovered that dipteran species are greatly found in swiftlets diet. Few years ago, insect populations are decreasing because of the forest degradation and caves intrusion. Thus, the demands on food sources by swiftlets are now increased.

Hadura Abu Hasan[1], School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia.

Siti Aisyah Rahimah Md. Saad[1], School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia.

Hamdan Ahmad[2], Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia

The production of insects is not essentially a land based activity and does not require land clearing for extended production. The reproduction rate of insect is also high and making this species easier to produce in large numbers (Anankware et al., 2015). Therefore, the effective rearing method is currently developed to determine the mass production, storage and release system of *M. scalaris* as potential food source for swiftlets in the laboratory.

II. Materials And Methods

A. Production of M.scalaris

M. scalaris colony was provided by the Swiftlet Research Centres, Kampung Paya Jaras Hilir, Selangor under the Department of Veterinary Services and has been maintained in a continuous laboratory culture at Ecovet Consultancy in Kajang, Selangor. 200g of *M. scalaris* pupae (five days old) were placed in a container (28 cm × 20 cm × 6 cm) in an insect cage (180 cm × 160 cm × 90 cm). The colony has been maintained at 28±1ºC and 80±5% relative humidity with a photoperiod of light and dark (12:12).

350 g of oviposition medium was prepared using a mixing ratio of 1.1 kg of chicken pellets (broiler starter, brand GOLD COIN 201C), 1.8 litres of water and 20 g of milk powder inside a tray (21 cm × 14 cm × 4 cm) (modified from Hamdan (2008)). 18 trays were placed in the adult cage and taken out from the cage after at least 12 hours. The oviposition trays were placed in the cage for five days.

Larva diets were prepared by using a mixture of 1 kg chicken pellets, 1.8 litres of water and 20 g of milk powder inside a tray (47 cm × 33 cm × 4 cm). The previous oviposition medium was scraped slowly onto the larvae rearing medium. The *M. scalaris* larvae fed on the medium until they were ready to pupate in 5-6 days. Adult flies were then provided with 100g of sugar and 1000 ml of water in the cage.

The emergence of adult flies was determined by the numbers of pupae that emerged per day using a microscope (OLYMPUS SZX10). Empty pupal cases were recorded as ‘emerged’ and these empty pupal cases were taken out from the cages to prevent double counting. Non-emerged pupae were returned to the cages and will be counted on the following days. The emergence of adult flies was recorded until this species has completely emerged. The numbers of

adult flies were calculated once they were completely dead after 7 to 8 days of life cycle.

The males and females of *M. scalaris* were determined using a microscope based on scuttle flies taxonomy key (Disney & Sinclair, 2008). Five replicates were conducted for each test for 10 batches of *M. scalaris* production.

B. Storage of M. scalaris

For the effect of temperature on the emergence, 5 days old of 100 *M. scalaris* pupae were placed in a round container (3 cm height × 2 cm diameter). The container was then placed into a small cylinder cage (35 cm height × 20 cm diameter) with a front opening covered by a sock-like cloth. The cages were placed in an incubator (PROTECH SD-450) set at 5, 10, 15, 20, 25, 28, 30, 35 and 40°C. The emergence of adult flies was determined by examining the pupae under a microscope. Empty pupal cases were counted as 'emerged'. The pupae were counted daily until all the pupae had emerged. The pupae were considered as dead when no adult flies emerged after having transferred to room temperature within 30 days.

For the effect of temperature on pupal development, 5 days old of 100 *M. scalaris* pupae were placed into a round container (3 cm height × 2 cm diameter and the container was then placed into a small cage (35 cm height × 20 cm diameter). The cage was placed in a growth chamber set at 0, 5, 10, 15, 20, 25, 28, 30, 35 and 40°C. The emergence of adult flies was monitored daily starting at 09.00 until all the pupae had emerged.

For adult longevity, 5 days old of 100 *M. scalaris* pupae were put into a container (3 cm height × 2 cm diameter) and then placed in a small cylinder cage (35 cm height × 20 cm diameter). The cage also consists of two containers filled with 2 ml water and two containers with sugar cube. The cages were stored at 28°C until the emergence of adult flies (Emana, 2007). The adult flies were then stored at 0, 5, 10, 15, 20, 25, 28, 30, 35 and 40°C and the cages were checked daily for adult mortality. A total of four replicates were carried out for each test during the experiments.

C. Delivery of M. scalaris

Studies on delivery process of *M. scalaris* were conducted at Ecobina Consultancy at Permatang Pasir, Sungai Dua, Penang. In this study, portable insectarium was developed and this rearing cage is designed for mass production of *M. scalaris* specifically for use in farming industry (Figure 1a). The dimension of this rearing cage is 200 cm × 150 cm × 80 cm. It has four wheels and fitted with four small drawers inside it. The drawers are built to support trays for the development of larvae and pupae. This portable rearing cage is able to support up to 200 million *M. scalaris* adults at one time. A small opening (15 cm × 10 cm) on top of this rearing cage is used specifically to release the adult flies when it ready to transport to the swiftlets farm.

The number of eggs laid by *M. scalaris* was recorded from day 1 to day 5 of the experiments. Similar oviposition medium were prepared in portable rearing cage as in the laboratory. Mean number of eggs in these oviposition medium were recorded over a period of 5 days. The emergence of adult flies was determined by recording the number of emerged pupae per day under the microscope.

The percentage of adult release was recorded by placing a small cage on top of the opening of portable insectarium (Figure 1b). The cage was made by wood frames and covered with white netting. This small cage was attached securely to the portable insectarium by using ropes at each corner. Black netting was used to cover the portable insectarium in order to keep the interior of the insectarium being exposed to the light (modified from Kato *et al.* (1995)).

Adult *M. scalaris* were released at 1, 2, 3, 4 and 5 minutes intervals. The escaped adult flies inside the small cage were placed in the freezer so that the number of adults can be recorded. The percentage of adult released was calculated using the following formula:

$$\text{Percentage of adult release (First one minute)} = \frac{\text{Number of adults released form the cage}}{\text{Total number of adults in the cage}} \times 100$$

$$\text{Percentage of adult in the next release} = \frac{\text{Number of adults released form the cage}}{\text{(Total number of adults in the cage} - \text{Number of adults in previous release)}} \times 100$$

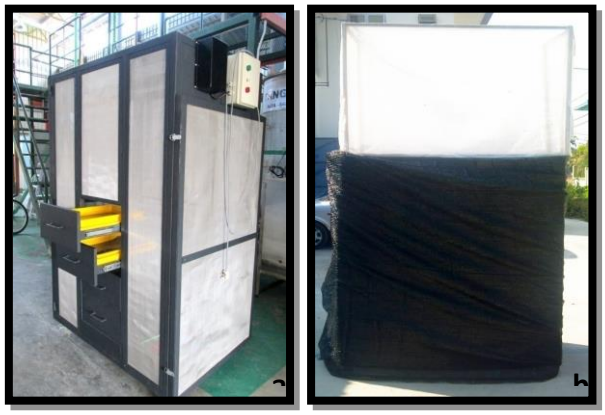

Fig. 1 a) Portable insectarium b) Small cage attached to the top of portable insectarium

D. Statistical analysis

The data were analysed using MINITAB 16 software. Chi-Square Goodness of Fit Test was used to compare the mean emergence of adult flies, mean fecundity and mortality of adult flies. Paired *t*-test was used to compare between males and females mean number of *M. scalaris.* One-way ANOVA was used to compare the mean of emergence of *M. scalaris* adults at different temperatures. One-way ANOVA was also used to compare the mean duration of storing *M. scalaris* pupae as well as the mean longevity of *M. scalaris* adults at different temperatures. Chi-Square Goodness of Fit Test was used to compare the mean emergence of adult flies in the portable insectarium. One-way ANOVA was used to analyse the mean number of eggs at different days and the mean percentage of adult flies released at different times. Statistical significance was accepted when *P* values were less than 0.05.

III. Results

A. Production of M.scalaris

Mean emergence of *M. scalaris* was not significantly difference (χ^2=0.0697, $P > 0.05$) between 10 batches. The highest mean emergence of *M. scalaris* was 99.2 ± 0.4%, while the lowest mean emergence was 98.6 ± 0.4% and this result showed that the greatest emergence of *M. scalaris* was obtained at 28±1°C in this current study.

The mean number of males and females *M. scalaris* were 33.8±0.4 and 66.2±0.4 respectively. The result showed that the number of females was significantly higher than males (t = 38.92, $P < 0.05$).

B. Storage of M. scalaris

The optimum temperature to store *M. scalaris* pupae was 28 and 30°C. 100% emergence of *M. scalaris* was obtained at these temperatures. There was no emergence occurred at 5 and 10°C. The result in this study also demonstrated that there was a significant difference in the emergence of adult flies at different temperatures (F = 3885.1, $P < 0.05$).

The longest pupal development time was 13 days at 15°C, whereas there was no pupal development recorded at 5 and 10°C. The pupal development time was significantly different at different temperatures (F = 233.49, $P < 0.05$).

In this study, *M. scalaris* survived 6.5±0.29 days at 20°C, whereas at 5 °C, this species survived 1.3±0.25 days. There was a significant difference in the longevity of *M. scalaris* adults at different temperatures (F = 30.10, $P < 0.05$).

C. Delivery of M. scalaris

The emergence of *M. scalaris* was 99.2 ±0.2% in the mobile insectarium. There was no significant difference in the emergence of adult flies between two mobile insectariums (F = 0.07, $P > 0.05$). The greatest mean numbers of eggs production was 40465±416 and there was a significant difference in the mean number of eggs between five days of rearing (F = 86.49, $P < 0.05$). Mean percentage of adults release was significantly different between minute 1 to minute 5 (F = 104.34, $P < 0.05$) and the greatest percentage adults released was recorded at minute 2 and 3 (0.09±0.01%).

The mean weight of adult flies released, the mean number of adult flies released, the total number of adult flies in the portable insectarium and the percentage of adult flies released at different times are summarized in Table 1.

TABLE 1
MEAN WEIGHT OF ADULT FLIES RELEASED, MEAN NUMBER OF ADULT FLIES RELEASED, TOTAL NUMBER OF ADULT FLIES IN PORTABLE INSECTARIUM AND PERCENTAGE OF ADULT FLIES RELEASED AT DIFFERENT TIMES

Time (m)	No. of adult flies in 0.01g	Mean weight of adult flies released (g)	Mean no. of adult flies released	Mean total no. of adult flies in portable insectarium (million)	Percentage of adult flies released (%)
1	32	0.13±0.012	416±37	1.9800	0.021±0.002
2	33	0.53±0.056	1749±184	1.9788	0.090±0.010
3	34	0.54±0.035	1824±120	1.9735	0.090±0.006
4	35	0.08±0.015	280±53.5	1.9683	0.014±0.003
5	33	0.01±0.003	42±11	1.9675	0.003±0.001

IV. Discussions

In this current study, the results showed that the greatest emergence of *M. scalaris* was obtained at 28±1°C in the laboratory. Similar result on temperature range for the greatest emergence of *M. scalaris* was found by Jensen et al., (2003) and Raja et al., (2012). Disney (2008) documented that there were several thermal values ranging from 15 to 37°C used to determine *M. scalaris* growth in the laboratory but, to compare this current finding to those previous studies is seemingly not feasible due to differences in geographical strains of *M. scalaris* and laboratory procedures being used. For mean number of male and females, the results showed that the number of females was significantly higher than males *M. scalaris.* Temperature also showed a significant role in the sex ratio of *M. scalaris*, but this factor has not been explored extensively in previous studies (Disney, 2008; Varney, 2010).

For the storage of *M. scalaris* in the laboratory, the optimum temperature to store pupae were at 28 and 30°C with 100% emergence of adults *M. scalaris* were obtained at these temperatures. Dillon & Frazier (2013) showed that the growth rate of insects will increase dramatically when the pupae are reared at optimum temperatures. In this study, the pupal development time was 13 days at 15°C, whereas there was no pupal development at 5 and 10°C. There was no emergence of *M. scalaris* adults at 5 and 10°C since this species is a tropical and subtropical species and thus they cannot tolerate too low temperature conditions (Batista-Da-Silva, 2012; Koch et al., 2013). Similar to the results of this study, there was also no development of *Megaselia spiracularis* pupae when reared at high temperature, 36°C (Feng & Liu, 2013). Mazyad and Soliman (2006) found that the pupal development time for *M. scalaris* is approximately 10 days at 25°C, which is slightly greater than the result in this current study at the same temperature. The development time of *M. scalaris* pupae was 5 and 16 days at 33 and 21°C, respectively (Feng & Liu, 2013). The discrepancies between the results of this study and those of previous studies may be attributed to variations in diet, differences in photoperiod and relative humidity. These factors are known to influence the development rate of pupae even though they are reared at the same temperature (Nabity et al., 2007; Kruger et al., 2011). For adult *M. scalaris*, the survival rate was 6.5 days at 20°C, whereas only 1.3 days at 5 °C. This is clearly showed that the temperature affects the development and survival rate of insects (Kemp & Bosch, 2005; Kalaitzaki et al., 2007; Byrd & Castner, 2012).

In mobile insectarium, the emergence of *M. scalaris* was similar to the number of *M. scalaris* produced in the laboratory. There was no significant difference in the emergence of adult flies between two mobile insectariums. However, the production of eggs was significantly different between five days of rearing. It is possibly due to the fact that there was inadequate space available for the females to oviposit their eggs as there was only one oviposition medium used in mobile insectarium for rearing *M. scalaris*. The results reveal that the percentage of adults released was significantly different at 1, 2, 3, 4 and 5 minutes time. It was hypothesized that the longer period that the adult flies are released, the higher number of adults will be caught within the small cage.

However, the results show that the number of *M. scalaris* adults trapped within the cage were higher at 2 and 3 minutes, but reduced at 4 and 5 minutes. It was observed that the adult *M. scalaris* consistently flew into the cage when the top of the insectarium was opened. However, it was observed that the adult flies avoided the small cage after 3 minutes and flew back to the mobile insectarium. This behaviour was observed in each replication of the experiment. Thus, it can be concluded that the space of the small cage is too crowded to accommodate more than 2,000 adult flies. Table 1 showed the percentage of adults released between 1 to 5 minutes and this data can be used to deliver *M. Scalaris* adults at the swiftlets' house. The swiftlets should be fed twice a day and the perfect time to deliver the adult flies are at dawn and dusk as this time the birds are actively foraging for food (Shukla, 2001; Goltenboth et al., 2006; Sia & Tan, 2012). Although the percentage of adults released at 5 minutes was low, it should be noted that the top of mobile insectarium is not covered if the adult release is conducted at the swiftlets' house. Therefore, the adult flies are able to fly out of from the mobile insectarium and re-calculation is required to estimate the release of adult flies. Delivery of insect must be conducted after the females begin to lay eggs, which is the second day after the females emerged (Disney, 2008). This is to ensure that the females have time to mate and oviposit their eggs in order to regenerate the population in the insectarium. For future studies, it is recommended that a comprehensive study on the delivery system and field release of *M. scalaris* should be carried out in the swiftlets' farm in order to determine the efficiency, effectiveness and feasibility of the system.

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