International Journal of Entomology Research
ISSN: 2455-4758
Impact Factor: RJIF 5.24
www.entomologyjournals.com
Volume 3; Issue 6; November 2018; Page No. 18-22

Biology of the Black Soldier Fly, *Hermetia illucens* (Linnaeus) (Diptera: Stratiomyidae) in Jaffna, Sri Lanka

Abirami Sivanantharaja[1], R Gnaneswaran[2]
[1, 2] Department of Zoology, University of Jaffna, Jaffna, Sri Lanka

Abstract
The Black soldier fly is known worldwide for its role in decomposing organic waste matters. However less effort has been done so far in studying its complete biology.
Adult insects lived on an average of 12-13 days under optimal conditions (31ºC and RH 80%) with lifespan decreasing to 6 days as RH goes down to 60%. Larva were observed to have a lifespan of 20.0 ± 1.05 days until they became Pre-pupa at the temperature 30.15 +- 0.26ºC. Larva were observed to have prolonged lifespan during the rainy season from October to January when the temperature went down to 28ºC. Adults were observed to lay their eggs even in the absence of decomposing wastes and eggs were collected from various places such as sponges, cardboards, and in the meshes of the nets used for caging. The egg count was found to be 477 ± 10.69 eggs per batch. When the environmental temperature was 30.15 +- 0.26ºC, eggs hatched in 4.5 days. The length of the freshly laid eggs was 0.901 ± 0.013 mm. Time taken for the adults to emerge from their pupal stage was 14.7 ± 1.07 days at 30.15 +- 0.26ºC. Total lifespan from egg to adults was found to be 57.8 days at 30.15 +- 0.26ºC. By using Dyar's law it was found that the larvae of BSF undergo five distinct morphological stages (Instars) during their larval period. The Black soldier fly larvae were found to have a strong positive olfactory reception to decomposed organic wastes than other food sources. The average length of the first, second, third, fourth and fifth instar lava were 2.35 ± 0.02, 6.45 ± 0.07, 10.26 ± 0.11, 15.92 ± 0.23 and 17.34 ± 0.09 mm. Mean length of the adult fly was 16.92 ± 0.21 mm, Mean wingspan of adult male was 12.25 ± 0.21 mm and of female was 13.02 ± 0.23 mm.

Keywords: black soldier fly, biology, decomposing, organic waste

Introduction
Waste management has become a challenge in developing countries due to increasing generation of wastes. Municipal authorities of developing countries like Sri Lanka often lack proper organization and financial resources. Improper Waste management often leads to various ill effects [4]. If they are not collected and treated in a proper manner, the organic solid waste fractions have proven to be a causative agent in spreading diseases by sheltering and feeding various organisms which act as disease vectors with adverse effects on the environment too. In contrast to collection methods of various waste streams in developed countries, most of the wastes from developing countries often end up in open dumps or other more unfavorable locations.
Even though composting and biogas production commonly used to recycle organic solid wastes, composting does not create a high value product and also it is also unusable for urban people who face lack of space as a major issue. Biogas production also requires a rather large initial investment to be a successful one. And also it has to be noted that the prices of chicken and fish feed from fishery resources are steadily rising due to overfishing and agricultural crop lands are becoming depleted of essential nutrients due to the exploitation of agricultural lands. Sustainable waste management often becomes an environmental friendly method in such type of phenomena as it deals with an efficient way of managing degradable organic solid wastes which are thrown out and neglected with less impact to the environment.
Composting with worms and grubs is a known method of organic waste treatment commonly used in rural areas since ancient times, most preferably in regions with high agriculture and livestock activities [1, 4, 7]. Besides the use of earthworms, grub composting too presents an innovative and less restrictive approach. The use of Black Soldier Fly Larva (BSFL) in grub composting has been documented in literature recently although being practiced informally across the world for many years [13]. The larvae of the fly spend the majority of their lifetime feeding on organic wastes, turning them it into fat, protein and calcium to morphing into pupae, and later, into adults [6, 13]. In their adult phase, Black Soldier Fly (*Hermetia Illucens* L) do not have functional mouthparts; therefore they do not bite nor feed, and hence are not associated with transmitting diseases [6]. BSFL are known for their ability to feed voraciously on a wide variety of organic wastes, including vegetables, fruits, meat, and manure [6].
As the larva of BSF begins feeding on the solid wastes, a form of liquid exudates begins to drain off which could be collected and applied to fields as a fertilizer. The fluid mostly consists of excreta of the worms together with undigested wastes and it is an excellent source of natural nitrogen to the soil. Using BSFL as an alternative for food waste disposal has the potential to bring environmental and economic benefits

including reduced Green House Gas emissions from landfills, decreased commercial fertilizer usage, decreased water use, increased soil carbon storage, and decreased soil erosion to be precise [9].

When the bionomics of an insect is fully understood it becomes easier to manipulate and culture them on large scale. So far there has been no complete research work done on black soldier fly bionomics except some from temperate countries Therefore this research was carried out to record complete biology of the BSF in the local environmental conditions In this view the presents study was carried out to record complete biology of BSF and the possibilities of maintaining culture in household wastes.

Materials and Methodology

The biology of Black Soldier fly was studied during 2016-2017 in the insectary of Department of Zoology, University of Jaffna, Sri Lanka. The culture was initiated by keeping household organic waste containing sour milk, tea leaves in a bucket covered by a lid to attract the adult flies to lay eggs. After few days the larvae in the buckets were transferred in to larval rearing bin which was designed in the shape of a rectangular wooden box with the dimensions of 2x1.5x1.5 feet with ventilation holes on the top lid, and a rectangular plank was placed at an inclined position making an angle of 45º with the bottom so as to facilitate the self-harvesting of mature larva as they turn into pre-pupa. Kitchen organic wastes were put into the rearing bin daily and allowed to be colonized naturally by the Black soldier fly larvae. After a few days as the wastes began to decompose, soldier flies were seen laying eggs inside the bin [10].

Mature prepupa of BSF were collected from thisstock culture and were transferred to the rearing cages once in 3 days to observe different life stages. The cage was placed inside the insectary. Prepupa were placed in a small plastic bucket containing soil and kept inside the rearing cage inorder to provide a place for pupation. Humidity of the cage was maintained at 70-80 % by keeping a water source with sponges soaked in it as well as by spraying water three to four times a day [2, 10, 15]. An artificial source of lighting was provided daily on 12 hour basis to stimulate adult mating. Card boards were hung in various locations to mimic ovipositional sites [10, 11]. Observations were recorded on hatching of eggs, larval, pupal and adult development period and the morphology of the life stages.

Sex ratio was determined by performing random sampling observing the genitalia of randomly collected adults. Newly emerged Adult flies were kept in pairs in ten sets of identical plastic containers of 2L in capacity for determining their mating frequency and fecundity. These setups were then placed in the insectary and were provided with artificial lighting (60W) and humidity (70-80 %) [2, 15] And observed every twelve hours to determine the Ovipositonal sites, ovipositional period and average life span. Eggs collected from this set up were allowed to hatch under varying conditions to determine their incubation period and their ability to tolerate unfavorable temperatures. Eggs and larva were collected daily from the rearing bin. Larvae were taken back to laboratory, washed thoroughly to remove impurities, knocked out by freezing and measured using coulometer to record total body length, body width, and length of mouth hook. The larval morphometric was used to determine the number of larval instars in its life cycle using Dyar's rule (Dyar, 1890) [3, 5, 8]. Feeding behavior and the preference of food waste by the BSFLaval stages were experimentally determined by using Olfactometer.

Results and Discussion

Oviposition

Oviposition was influenced by illumination, however the presence of artificial light stimulated mating and oviposition more than natural day light. When the room temperature was low (27.2 ± 0.30ºC) egg laying was rarely observed in the cages, however when water source was kept in the cage and water was sprayed at frequent intervals, egg laying was observed in the subsequent days. Under optimal conditions (30.15 ± 0.26ºC and 70% RH). Eggs were laid at various locations. Egg batches were observed in the Egg cards, Sponge, on the Lid of larval rearing bin and on the Interior walls of rearing bin. The number of eggs in a single batch was 477 ± 10.69 eggs per batch. In a single batch right after the first emergence, first four sampling attempts showed that all emerged insects were males. In the subsequent days, random sampling showed that most of the insects were females. Mean sex ratio was 1:2 in the environmental condition (30.15 ± 0.26ºC and 70% RH) conditions.

Mating frequency and oviposition of adult BSF

Adult insects were found to be sensitive to all sorts disturbances, hence chances of observing a mating pair was very rare except on a few occasions. Females laid eggs on the 6th to 7th day following their emergence. Egg batches were observed in the Egg cards, Sponge, on the Lid of larval rearing bin and on the Interior walls of rearing bin. More eggs were laid when the Male: Female ratio was 1:2 or higher and always a single female laid only a single batch of eggs. The number of eggs in a single batch was 477 ± 10.69 eggs per batch.

Incubation period Time period taken to hatch eggs were varied with room temperature.

During April to July (30.15± 0.26ºC) the incubation period was recorded as 4-5days, During October to December (27.2 ± 0.30ºC) no eggs were noticed in the bin. In January to February (29.71 ± 0.21ºC) eggs were laid but not hatch.

Number of larval instars

It was found that Dyar's law accurately modeled growth of BSF and instar number is easily determined by mouth hook length. Figure: 1.1) Based on the larval mouth hook length, it was confirmed that the larvae of BSF undergo five distinct morphological stages (Instars) during their larval period.

Morphology of egg, larvae and Adult

Eggs

The eggs looked like as tiny rice granules and are creamy yellow in color. Fresh eggs appeared as off white/pale yellow in color and became yellow in colour as they began to develop and by the time they were ready to hatch, they appeared as brown in colour. Eggs were always laid in clusters all at once and at the time of hatching, a black spot was observed in each egg. Eggs of Black Soldier Flies were about 0.901 ± 0.013 mm long.

Larva

There were five distinct larval stages First larval instar was 2.35 ± 0.02 mm long, Second larvae was 6.45 ± 0.07 mm long, Third stage larvae were 10.26 ± 0.11 mm long, Fourth larva were 15.92 ± 0.23 mm long and the fifth larvae were 17.34 ± 0.09 mm long. All five Instar stages of the BSF larva had 11 segments and between each segment on each lateral sides, brisk of hairs were found. Beside that the entire body was covered by minute hairs.

Body length and Hook length were positively correlated to each other. Even though the larvae increase in size as they grow, general morphology remained same. Larvae are segmented, pale brown in color with a pink colour hook which is slightly curved at the tip

Pre pupa, Pupa and Adult

Pre-pupa of BSF was black in color but similar in appearance to mature larvae. With the body length 17.64 ± 0.13 mm). Pupa looked like the pre-pupa except the fact that it was not immobile. The pupa had a ventrally bent hook region and this was considered as a distinct morphological character. Fully grown and mature pupa were 17.34 ± 0.09 mm long. Weight and size of the pupa was found to change based on various conditions such as food availability and environmental conditions.

Adult flies looked like wasps due to its narrow anterior abdomen and a fully grown adult was 16.92 ± 0.21 mm long. Mean wingspan of male was 12.25 ± 0.21 mm and of female was 13.02 ± 0.23 mm. The first sternum of the abdominal region was transparent/translucent in the Adult flies. The two terga of the thoracic region were fused together and appeared like an armour. The one pair of wings of the adults overlapped while at rest. Distal end of all legs were white/pale yellow in colour while the remaining parts alternated with black and white color. Compund eyes of the adult flies were not entirely black in colour, rather they appeared as a mixture of Blue and yellowish green.

The entire body was covered in minute microscopic hairs. Adults possessed a lapping mouthpart used solely for drinking water. Their Antenna was black in colour and made up of three segments. Male genitalia was flower shaped and protractible, and female genitalia was fork shaped and protrusible and in all, the genitalia was entirely covered by microscopic hairs .Average length of male genitalia was 0.77 ± 0.01mm and female was 0.94 ± 0.01mm.

Table 1: Biology of black soldier fly under laboratory condition **(**(30.15 ± 0.26ºC and 70% RH)

	Minimum	**Maximum**	**mean± SD (N=25)**
Egg period (in days)	4	5	4.5 ± 0.22
Larval period (in days)	18	24	20.0 ± 1.05
Pupal period (in days)	10	17	14.7 ± 1.07
Adult period (in days)	10	12	10.8 ± 0.37
Pre – oviposition period (in days)	6	7	6.4 ± 0.24
Fecundity (eggs/female)	454	517	477 ± 10.69

Pre-pupa was observed to possess wandering behavior seeking dry and dark places to settle, especially cracks, holes, under the stones and carpets. Pre-pupa was recorded to move 1.5 meter on a cement floor in search of a dark dry place to pupate. Pre-pupa used their bent hook to anchor themselves onto the ground and used it for locomotion.

Observation of feeding behavior

Feeding behavior of larva and Pre-pupa stages

BSF larvae were found to actively feed on the food source. Larvae were found decompose all forms of organic matter except plant material of structural composition containing cellulose and lignin as well as animal bones. They were found to be always near the surface of the food source to enable them to breathe naturally but buried to avoid sun light. Based on Lactometer experiment, (fig: 2) the larvae were observed to have a strong response towards decomposing organic wastes based on the sense of smell. Pre-pupa stopped feeding as they changed to black colour and began exhibiting wandering behaviours.

Feeding behavior of Adult

Adults avoided solid foods, but preferred water more. They drank water from sponges soaked in water or whenever their cage was sprayed with water. Keeping water in large cups resulted in high mortality of adult flies due to drowning.

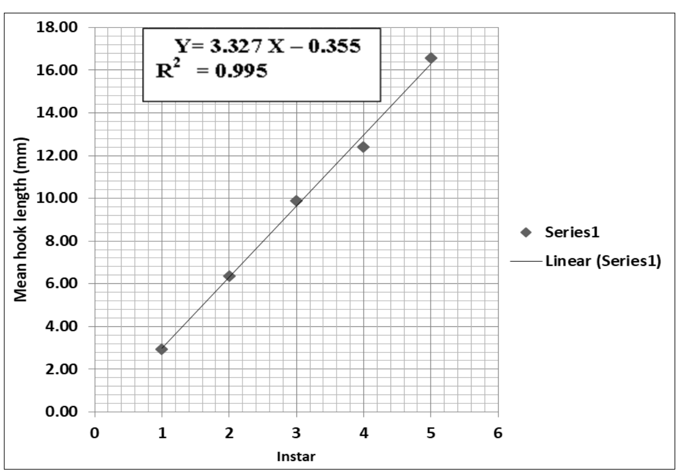


Fig 1. Relationship between mouth hook length and instar of BSF (*Hermetia illucens*)

1.1 Adult Black soldier fly (BSF
(16.92 ± 0.21 mm long)

Egg mass Eggs (0.9 mm)

1.2: egg mass and eggs of BSF

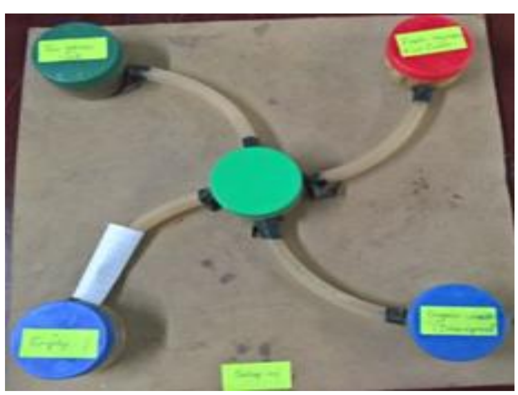
L=10.26 ± 0.11 mm L= 15.92 ± 0.23 mm
1. 3: 3rd and 4th instar larva of BSF

L=17.34 ± 0.09 mm
1.4: Fifth instar larva of BSF

1.4 pupa of BSF

Male Female

1. 5: Genitala of BSF



1.6 : Olfactometer experiment

Fig 1: Biology of Black Soldier Fly

Conclusion

The Black Soldier Fly (BSF) insect is well known for its pivotal role in sustainable waste management through the act of composting. However its complete biology had been a mystery as many researchers had not worked on its entire biology rather they had spent time analyzing various life stages which were of importance such as the larva. From this study, various aspects of this insect species has been clearly identified and evaluated.

Narrow elongated white eggs about 0.9 mm long and 0.12mm wide were laid in clusters of 480 eggs in cracks and crevices near the decomposing food waste. The mean Larval, Pre pupal and pupal period were found to be 20.0 ± 1.05 days, 7.8 ± 0.37days and 14.7 ± 1.07days respectively at 30.15 ± 0.26ºC. Fecundity was 477 ± 10.69 and the adult longevity was 10.8 ± 0.37days. The whole life cycle of BSF is spent in the decomposing waste and the rate of development is influence by the environmental conditions as temperature and humidity.

Acknowledgement

The authors are grateful to the Head, Department of Zoology, and University of Jaffna for the permission and facilities given for this study.

References

1. Appelhof M. Worms eat my garbage. Kalamazoo, MI: Flower Press, 1982.
2. Briscoe AD, Chittka L. The evolution of color vision in insects. Annual Review of Entomology. 2001; 46:471-510.
3. Craig Sheppard D, Jeffery KT, John AJ, Barbara CK, Sonya MS. 'Rearing Methods for the Black Soldier Fly (Diptera: Stratiomyidae)', J. Med. Entomol. 2002; 39(4):695-698.
4. EFL. Status of Waste Management in Sri Lanka, Available at, 2017, http://efl.lk/v3/2017/06/14/status-waste-management-sri-lanka/ (Accessed: 2nd September 2018).
5. Goldson SL, Neill MRM, Proffitt JR, Baird DB. Seasonal variation in larval –instar head –capsule sizes of Argentine stem weevil, Listronotus bonariensis (kuschel) (Coleoptera; Curculionidae). Australian J Entomol. 2001; 40(4):371-375.
6. Loerch CR, Cameron EA. Determination of larval instars of the bronze birch borer, Agrilus anxius (Coleoptera: Buprestidae). Ann Entomol Soc Am. 1983; 76(6):948-952.
7. Martin DL, Gershung G. The Rodale book of composting. Emmaus, PA: Rodale Press, V.
8. Mohammed SMG. Determination of Larval Instars of Black Cutworm Agrotis ipsilon (Hufnagel) (Lepidoptera, Noctuidae)', Jordan Journal of Biological Sciences. 2011; 4(3):173-176.
9. Olivier PA. Utilizing lower life forms for the bioconversion of putrescent waste. Black Soldier Fly Blog - Official Website, 2009.
10. Pedro CD, Mehab H, Guillermo FDJ, Selin Y. Development of a Food waste Composting system using Black Soldier Fly larvae. 3rd annual R&D Student Competition- Greenovate NYS [Online]. Available. 2014, at: https://www.rit.edu (Accessed: 30th September 2018).
11. Sheppard C, Newton GL, Thompson SA, Savage S. A value added manure management system using the black soldier fly. Bioresource Technology. 1994; 50:275-279.
12. Sheppard DC, Jeffery K, Tomberlin, Joyce JA, Kiser BC, Sonya M. 'Rearing Methods for the Black Soldier Fly (Diptera: Stratiomyidae)', J. Med. Entomol. 2002; 39(4):695-698.
13. Shields EB. Raising earthworms for profit. Eagle River, WI: Shields Publications, 1982.
14. Tomberlin Jeffery, Craig Sheppard D. Factors Influencing Mating and Oviposition of Black Soldier Flies (Diptera: Stratiomyidae) in a Colony. Journal of Entomological Science. 2002; 37:345-352.
15. Zhang J, Huang L, He J, Tomberlin JK, Li J, Lei C, Yu Z. An Artificial Light Source Influences Mating and Oviposition of Black Soldier Flies, *Hermetia illucens*. Journal of Insect Science. 2010; 10:202.