



BIOLOGY OF THE MELON WORM, *DIAPHANIA HYALINATA* L. (LEPIDOPTERA: PYRALIDAE), ON CUCURBITS IN GEZIRA STATE, SUDAN

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Abstract: The melon worm, *Diaphania hyalinata* Lepidoptera: Pyralidae considered as an insect pest that infests cucurbits and causes serious damage to them. Despite the importance of this insect, it has not received adequate study. This study was conducted under laboratory conditions with 28±1.2 and 20-25% room temperature and relative humidity respectively, to determine melon biology of melon worm on six species of cucurbits namely; snake cucumber, squash, pumpkin, sweet melon, watermelon, and tibish. The study revealed that the average duration of the developmental stages i.e. egg, larva, and pupa were 2.5±0.25, 11.4±0.13, and 7±0.15 days, respectively. The fecundity and fertility were 90.4±7.60 eggs and %73.6±3.63, respectively. The life cycle (from egg-laying to adult emergence) was completed in 20-23 days with a mean of 21.37±0.22 days when the larvae were fed on leaves of snake cucumber. The sex ratio was 1:0.8 male to female. The type of food had significant effects on larval, pupal period, and life cycle. A clear impact on the duration of the life cycle was found when larvae were fed on leaves of snake cucumber, squash, pumpkin, sweet melon, watermelon, and tibish compared when fed on fruits of the same cucurbits above. It was found that snake cucumber and sweet melon were the most preferred by females for egg laying compared to the other cucurbits in laboratory studies.

Keywords: Melon worm, Life cycle, Cucurbits, Host preference, *Diaphania hyalinata*

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1. Introduction

The family cucurbitaceae is considered as a large family which includes about 130 genera and 900 species (Jeffrey, 1980). Only 30 species of 9 genera under this family are cultivated (Esquinas-Alcazar and Gulick, 1983). They are essential source of vitamins and minerals and are useful in neutralizing the acid substances that result from consumption of animal protein and other food. Cucurbits constitute a major protein of vegetable source and are grown in different regions of Sudan (Ahmed, 2000). The Sudan' bank (2011) reported that annual production of cucurbits Sudan increased from 607000 tones (863000 acres) in 2003, to 616000 tones (88000 acres) in 2009. The cucurbits grown in Sudan include: snake cucumber (*Cucumis melo var flexuosus*), squash (*Cucurbita pepo* L), pumpkin (*Cucurbita maxima*), sweet melon (*Cucumis melo var cantalouppnesis*), water melon (*Citrullus lanatus*) and tibish (*Cucumis melo var tibish*). Many insect pests and diseases attack cucurbits and affect both productivity and quality and may even destroy whole plant.

The melon worm, *Diaphania hyalinata* Linnaeus (Lepidoptera: Pyralidae) was a minor pest but became a major pest in last few years. The *Diaphania* species are serious pests of Cucurbitaceae (Capinera, 2001; Panthi et

al., 2017; McKinlay, 1992). In Sudan it prefers snake cucumber and heavy attack had been reported from many parts of the country (Ali, 2009). The melon worm had been recorded earlier in the country (Medani, (1923; Gorier, 1932). However, during the growing season of 2005/ 2006 it was encountered as a serious pest on snake cucumber, cantaloupe, squash, and Pumpkin in the Gezira state (Mohamed and Ali, 2006). The melon worm moths deposit eggs as small clusters (2 - 6 eggs). On buds, stems, and underside of leaves during the nights. Covering the plants with a fine mesh screen can prevent melon worm adults from laying eggs on foliage (Webb and Linda, 1992). Eggs hatch in 2-4 d, and young larvae initially feed close to where they hatch (Canerday and Dilbeck, 1968; Fulton, 1947). The larva has five instars and total larval development time is about 14 days (Capinera, 2005). Larvae feed on lower surface of the leaves and later move and penetrate fruits and make them unmarketable (Ali 2006). The larvae can feed on the surface of the fruit, or even burrow into the fruit (Mohamed, 2012; Mohaned et al., 2013). However, melon worm under laboratory conditions completed its life cycle in 21-30 days at a range of temperature 18- 40 °C and RH 10-26 % (Capinera, 2005). The melon worm is also a serious pest of cucurbits through the southern



United States (Valles and Capinera, 1992). Due to the lack of scientific researches and data about this pest in Sudan, this study aimed to determine the biology (life cycle) of the insect on six cucurbit species: snake cucumber (*Cucumis melo var flexuosus*), squash (*Cucurbita pepo* L), pumpkin (*Cucurbita maxima*), sweet melon (*Cucumis melo var cantaloupensis*), watermelon (*Citrullus lanatus*), and tibish (*Cucumis melo var tibish*), and to reveal host preference of egg laying by females.

2. Materials and Methods

2.1. Identification Studies

The melon worm larvae were collected from infested fruits and brought to laboratory of the biology of the Crop Protection Department in the Faculty of Agricultural Sciences for rearing until adult emergence. The adults have been sent to the insect collection unit (ARC) for identification, also some pupae were sent to prof Dominique Bordat, CIRAD, Montpellier, France for confirmation the identification, with some adult photos.

2.2. Laboratory Studies

The biological studies were carried out under laboratory conditions to determine the life cycle of the insect at room temperature 28.3 ± 1.2 and RH 20-25%. Melon worm, small larvae were collected from snake cucumber in the field and brought to the laboratory, they were reared singly in cups (8cm diameter and 12cm length) and fed on leaves of the same cultivars with collection site. The leaves were replaced daily by new fresh leaves of snake cucumber until pupal stage. The morphological differences between male and female were observed and the sex was identified. The emerged adults were separated and each pair (male and female) were put together in a cage (50 × 50 × 50 cm), made of plastic and covered with muslin cloth. Leaves of snake cucumber brought from the field were washed by water to remove any eggs on them, and then were kept inside the cage for oviposition. A piece of cotton wool wetted with sucrose solution (10g sugar /100 L water) was used as food for adults and they were replaced daily with new ones. The leaves inside the cage were examined daily to observe the biological stages.

2.2.1. Eggs

The leaves with newly laid eggs were transferred to Petri-dishes lined with moist filter paper. The number of eggs in each Petri-dish was recorded. The eggs were daily inspected until hatching; incubation period and percentage of hatching were also recorded.

2.2.2. Larvae

After hatching, the newly emerged larvae (20 larvae) were reared on snake cucumber leaves. The larvae were confined in 20 plastic cups (8cm diameter and 12cm length). A single larva was placed in each cup with fresh leaves every day, until pupation. Duration of larvae from egg hatching until pupation period was recorded.

2.2.3. Pupae

The duration from pupation until adult emergence was recorded as pupal period.

2.2.4. Adults

The average of total life cycle and sex ratio for the melon worm were recorded. Ten pairs of newly emerged adults (male and female) were confined each into an oviposition cage, made of plastic and covered with muslin cloth. A piece of cotton wetted with 10 % sugar solution was provided every day for adult nourishment. The experiment was designed to study and evaluate the pattern of egg lying, pre-oviposition, oviposition and post-oviposition period in each cage and data were recorded on daily basis. The number of eggs laid by a single female per day and the adult longevity were also recorded.

2.3. Effect of Type of Food on Larval, Pupal Periods and Life Cycle

This study was carried out under laboratory conditions (temperature 28.3 ± 1.2 °C and RH 20-25%). One hundred and eighty newly hatched larvae were obtained from the laboratory and transferred to one hundred and eighty rearing cups. The larvae were divided into two groups: The first group, consisted of ninety larvae divided into six groups of fifteen replicates. Leaves of snake cucumber, squash, pumpkin, sweet melon, water melon or tibish. The second group, composed of ninety larvae, was also divided into six groups of fifteen replicates. The larvae of each group were confined to feed on one diet fruits of snake cucumber, squash, pumpkin, sweet melon, water melon or tibish. The diet (leaves or fruits) in each cup was replaced daily until the larvae reached the pupal stage. The differences in larval periods and pupal periods according to the different foods were recorded.

2.4. Host-Plants Preference

This experiment was designed to study the impact of 6 different host plants on the oviposition preference of *Diaphania hyalinata* females. The host plants tested were 15- day- old seedlings of the following crops: snake cucumber, squash, pumpkin, sweet melon, water melon and tibish. The host seedlings were grown in cups in the glass house before being transferred to the oviposition cage. The six cups were placed in rows in cage, each row constituted a replicate, four replicates were made. The cups in each row were randomly arranged. 4 females and 4 males were placed together in the same cage. The cups were carefully removed from the cage, next morning and test plants were thoroughly inspected for egg laying. The mean number of eggs laid /4 seedlings was calculated for each host separately.

2.5. Statistical Analysis

The cages inside greenhouse were arranged randomly through a completely randomized design (CRD) with three replication. The data were subjected to appropriate transformation when necessary, and analyzed using (ANOVA) for significant differences between treatments and Duncan's Multiple Range Test (DMRT) was used for means separation.

3. Results

3.1. Identification Studies

The adults of the melon worm sent to the insect collection unit (ARC) were identified as *Diaphania hyalinata* (Lepidoptera, Pyralidae); this result was confirmed by Dominique Bordat CIRAD, France.

3.2. Life Cycle of the Melon Worm

3.2.1. The eggs

Eggs were usually laid singly during the night, although some egg masses were observed. They were mainly deposited on the lower surface of the fresh leaves. They were also observed on stems. The eggs were glued to the lower surface of the leaves by a sticky secretion. Initially the newly laid eggs were white or greenish, but later they turn into yellow before hatching (Figure 1).



a) The eggs



b) The larvae



c) The female



d) The male

Figure 1. Different developmental stages of the melon worm, *Diaphania hyalinata*, showing the eggs (a), the larvae (b), the female (c) and the male (d).

The eggs incubation period

The eggs incubation period was 1-4 days with an average of 2.5 ± 0.25 days. Hatching occurred early in the morning and the mean percentage of hatching was $73.6\% \pm 3.63$ (Table 1).

3.2.2. The larvae

Hatching of eggs took place on the lower surface of the leaves. The newly hatching larvae were colorless. They moved to the upper surface of the leaves and immediately began to feed on the tender leaves and later on stems, buds, flowers and fruits. The two sub dorsal white stripes extending along the length of the body are considered the most distinctive characteristic of the larvae (Figure 1).

Table 1. Mean egg incubation period, percent hatching, developmental stages and adult ovipositional period of the melon worm, *Diaphani hyalinata*

Stage	Duration (days)
Incubation period of egg	2.5 ± 0.25
% hatching	73.6 ± 3.63
Larva	11.4 ± 0.13
Pupa	7.0 ± 0.15
Pre- oviposition	1.6 ± 0.22
Oviposition	5.6 ± 0.37
Post- oviposition	3.1 ± 0.37

Under laboratory conditions, the larval stage was completed in a period ranging from 11-13 days, with an average of 11.4 ± 0.13 days (Table 1).

3.2.3. The pupae

In the laboratory, pupation took place on cup covers, rearing cages and also observed on the leaves. However, under field conditions the larvae pupated on the leaves, but no pupation was observed in the soil. The pupal period ranged from 6-8 days with an average of 7.0 ± 0.15 days (Figure 1, Table 1).

3.2.4. The Adults

Adults mostly emerged during the night. There is a tuft of light brown "hairs" on the tip of the abdomen, vestigial in the male but well-developed in the female. The wings pearly are white centrally, but are edged with broad band. Moths mainly display brushy hair pencils at the tip of the abdomen when at rest position (Figure 1). The average total life cycle of the insect (from egg laying to adult emergence) was 21.37 ± 0.22 days and sex ratio male to female was 1: 0.8.

3.3. Oviposition, Fecundity and Longevity

The pre-oviposition period ranged between 1-3 days with an average of 1.6 ± 0.22 days. Whereas, the oviposition period ranged between 4-8 days with an average of 5.6 ± 0.37 days. The oviposition pattern was indicated in Figure 2. That pattern reached a peak in the third day after egg laying had started, and then declined sharply on the eighth day. The post-oviposition period ranged between 1-5 days with an average of 3.1 ± 0.37 days (Table 1). The mean number of eggs laid by a single female was 90.4 ± 7.60 with a range of 63-131 egg/female (Table 2). The longevity of males ranged from 7-10 days with an average of 8.2 ± 0.35 days. Male caged with female for mating generally died earlier. The longevity of adult females ranged from 7-12 days with an average of 10.3 ± 0.47 days (Table 2).

Table 2. Fecundity and longevity of adult male and female of melon worm, *Diaphania hyalinata*

Fecundity	90.4 ± 7.60
Male longevity (days)	8.2 ± 0.35
Female longevity (days)	10.3 ± 0.47

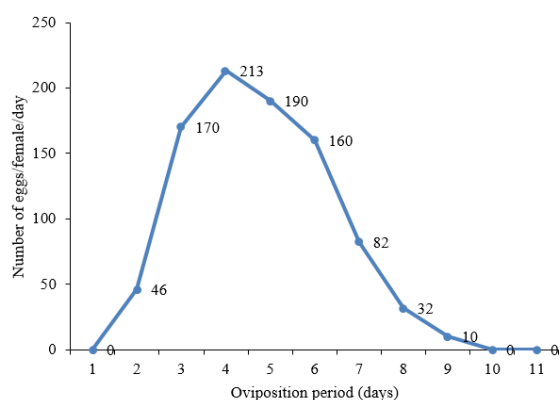


Figure 2. Oviposition pattern of the melon worm, *Diaphania hyalinata*, on snake cucumber.

3.4. Effect of Six Cucurbits Leaves on Larval, Pupal Periods and Life Cycle

The results of testing the different food types including leaves of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish on larval and pupal development, are presented in Table 3. Table 3 shows that the mean larval periods were 11.26 ± 0.45 , 11.46 ± 0.63 , 12.13 ± 0.16 , 11.80 ± 0.17 , 12.50 ± 0.20 and 13.25 ± 0.27 , when the larvae were reared on leaves of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish, respectively. The larvae fed on tibish leaves showed the longest developmental period followed by those fed on water melon and pumpkin, respectively. Whereas, those fed on snake cucumber leaves showed the shortest developmental period followed by those fed on squash and sweet melon leaves, respectively.

The mean pupal duration was 7.07 ± 0.23 , 7.46 ± 0.21 , 7.54 ± 0.27 , 7.64 ± 0.24 , 8 ± 0.30 and 7.62 ± 0.26 days for the larvae fed on snake cucumber, squash, pumpkin, sweet melon, water melon and tibish, respectively. The pupae developed from larvae fed on snake cucumber leaves emerged earlier in 7.07 ± 0.23 days. On the other hand those of water melon showed relatively longer pupation period of 8.0 ± 0.30 days. The pupae developed from larvae fed on leaves of sweet melon, tibish, pumpkin and squash reflected no significant differences in pupation period, which averaged 7.64 ± 0.24 , 7.62 ± 0.26 , 7.54 ± 0.27 and 7.46 ± 0.21 days, respectively, (Table 3). The average life cycle (from egg to adult emergence) was 20.38 ± 0.22 , 20.84 ± 0.33 , 21.54 ± 0.36 , 21.42 ± 0.20 , 22.33 ± 0.32 and 22.87 ± 0.39 days on snake cucumber, squash, pumpkin, sweet melon, water melon and tibish leaves, respectively. The average life cycle was shorter for those reared on snake cucumber leaves (20.38 ± 0.22) followed by squash leaves (20.84 ± 0.33) and longer for those on tibish leaves (22.87 ± 0.39) followed by water melon leaves (22.33 ± 0.32). Significant differences were found in the average life cycle of the insects raised on pumpkin and sweet melon (21.54 ± 0.36) and (21.42 ± 0.20) days respectively (Table 3).

The percentage of pupated larvae were 100, 100, 100, 100, 93.4, and 80 for snake cucumber, squash, pumpkin, sweet melon, water melon and tibish, respectively. The percentages of emerged adults were 86.7, 86.7, 73.4, 93.4, 85.7 and 66.7, respectively (Table 3).

3.5. Effect of Six Cucurbits Fruits on Larval, Pupal Periods and Life Cycle of the Melon Worm

The results of testing the different six fruits of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish on larval and pupal development, were presented in Table 4 which shows that the mean larval periods were 13.50 ± 0.20 , 13.35 ± 0.13 , 13.35 ± 0.21 , 13.28 ± 0.12 , 14.33 ± 0.14 and 14.09 ± 0.25 days for the larvae reared on fruits of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish, respectively.

Table 3. Effect of six cucurbits leaves on larval, pupal periods and life cycle of the melon worm, *Diaphania hyalinata*

Host plant	Means				
	Larval period (days)	Pupal period (days)	Total life cycle (days)	% Pupation	% Emergence
Snake cucumber	11.26±0.45 ^f	7.07±0.23 ^b	20.38±0.22 ^f	100	86.7
Squash	11.46±0.63 ^e	7.46±0.21 ^{ab}	20.84±0.33 ^e	100	86.7
Pumpkin	12.13±0.16 ^c	7.54±0.27 ^{ab}	21.54±0.36 ^c	100	73.4
Sweet melon	11.80±0.17 ^d	7.64±0.24 ^{ab}	21.42±0.20 ^d	100	93.4
Water melon	12.50±0.20 ^b	8.00±0.30 ^a	22.33±0.32 ^b	93.4	85.7
Tibish	13.25±0.27 ^a	7.62±0.26 ^{ab}	22.87±0.39 ^a	80	66.7
Mean	12.07±314	7.56±252	21.56±0.30	95.6	82.1
CV%	0.50	5.40	0.25		
LSD	0.12	0.73	0.11		

^{a,b,c,d,e,f} Means containing different letters are significantly different. P>0.05

Table 4. Effect of six cucurbit fruits on larval, pupal periods and life cycle of the melon worm, *Diaphania hyalinata*

Host plant	Means				
	Larval period (days)	Pupal period (days)	Total life cycle (days)	% Pupation	% Emergence
Snake cucumber	13.50±0.20 ^{bc}	7.83±0.20 ^d	23.25±0.25 ^e	93.4	85.8
Squash	13.35±0.13 ^c	8.08±0.19 ^c	23.50±0.19 ^d	93.4	85.8
Pumpkin	13.35±0.21 ^c	8.00±0.36 ^c	23.60±0.49 ^d	80.0	83.4
Sweet melon	13.28±0.12 ^c	8.72±0.14 ^a	23.90±0.16 ^c	93.4	78.6
Water melon	14.33±0.14 ^a	8.00±0.01 ^c	24.50±0.18 ^a	80.0	66.7
Tibish	14.09±0.25 ^{ab}	8.28±0.18 ^b	24.28±0.52 ^b	74.4	63.7
Mean	13.65±0.18	8.15±0.18	23.84±0.30	85.8	77.3
CV%	2.35	1.05	0.38		
LSD	0.58	0.15	0.17		

^{a,b,c,d,e} Means containing different letters are significantly different. P>0.05

The larvae fed on water melon and tibish fruits showed the longest developmental periods, respectively. While those fed on sweet melon squash, pumpkin, and snake cucumber fruits showed the shortest developmental periods, respectively. The mean pupal duration was 7.83±0.20, 8.08±0.19, 8±0.36, 8.72±0.14, 8, 8.28±0.18 days for the larvae fed on fruits of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish, respectively. The pupae developed from larvae fed on snake cucumber leaves emerged earlier in 7.83±0.20 days. While those of developed from sweet melon, tibish, squash, pumpkin and water melon had relatively longer pupation periods of 8.72±0.14, 8.28±0.18, 8.08±0.19, 8±0.36 and 8 days, respectively (Table 4).

The average life cycle (from egg to adult emergence) was 23.25±0.25, 23.50±0.19, 23.60±0.49, 23.90±0.16, 24.50±0.18 and 24.28±0.52 days for insects derived from snake cucumber, squash, pumpkin, sweet melon, water melon and tibish fruits, respectively. The average life cycle was shorter for those reared on snake cucumber, squash, pumpkin and sweet melon 23.25±0.25, 23.50±0.19, 23.60±0.49 and 23.90±0.16, respectively. While it was longer for those reared on water melon and tibish 24.50±0.18 and 24.28±0.52 days, respectively (Table 4).

The percentage pupated larvae were 93.4, 93.4, 80, 93.4, 80, and 74.4 for the groups fed on snake cucumber,

squash, pumpkin, sweet melon, water melon and tibish, respectively. The percents emerged adults were 85.8, 85.8, 83.4, 78.6, 66.7 and 63.7, respectively (Table 4).

3.6. Host Preference

The results of the cage experiment conducted in the laboratory for the determination of the host preference. The selectivity of the female for egg deposition on different hosts expressed as number of eggs/4 plants was the parameter used for assessment of host preference. Observations have shown that in the caged plants the eggs were either laid singly or in batches, mostly on the lower surfaces of the leaves and occasionally on the stems of the plants. Of the 6 types of cucurbits tested, snake cucumber and sweet melon were the most preferred with mean no. of eggs of 22.25 and 22.00 eggs /4 plants, respectively followed by squash, Pumpkin and water melon 21, 18.5 and 15.75 eggs/4 plants, respectively. Whereas tibish was the least preferred with a mean of 12.00 eggs/4 plants, and none of the six cultivars was immune to infestation (Table 5).

Table 5. Mean number of eggs deposited by four females on six different host plants in caged experiments

Treatments	Mean number of eggs/ 4 plants
Snake cucumber	22.25 ^a
Sweet melon	22 ^a
Squash	21 ^{ab}
Pumpkin	18.5 ^{ab}
Water melon	15.75 ^{ab}
Tibish	12 ^b
C.V	20
SE±	3.5

^{a,b} Means containing different letters are significantly different. P>0.05

4. Discussion

Laboratory studies on different developmental stages revealed that, the egg incubation period varied from 1 to 4 days (Mean 2.5±0.25). Capinera (2005) stated that egg hatching occurred after 3 to 4 days which agreed with this study. The larval period of *Diaphania hyalinata* varied from 10 to 13 days (Mean 11.4±0.4 days). Mohamed and Ali, (2006) reported larval period under temperature 18–40 and RH 10–26% was 14 to 18 days which was slightly longer than that observed in this study. The pupal stage duration varied between 6 to 8 days with an average of 7.1±0.7 days. The present study agreed with Mohamed and Ali, (2006) who reported that pupal period varied between 4 to 8 days and which was slightly shorter than Capinera (2005) results.

For the melon worm life cycle in this study, it was 20 to 23 days. Mohamed and Ali, (2006) reported life cycle of 21 to 30. The effect of six different food types, leaves and fruits of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish on the larval and pupal stages was studied in the laboratory. The results have shown some differences between the six crops, leaves of snake cucumber were found to be the most suitable for larval and pupal rearing. Thus, the larvae raised on it completed their life cycle (from egg to adult emergence) in a shorter period. While leave of tibish and water melon were found to be least suitable for larval and pupal rearing, respectively. The larvae reared on them completed their life cycle in a longer period, relatively. However, fruits of squash, pumpkin and snake cucumber were found to be the most suitable for larval and pupal rearing respectively. Similarly, the same results were obtained Linares-Ramírez (2007) by who reported that resistance to *Diaphania hyalinata* was observed in *Cucurbita moschata* under laboratory conditions. In general, larvae, pupae and life cycle took more time when reared on fruits compared to the leaves that could return to high moisture content inside the fruits. On the other hand, the larvae reared on squash, pumpkin and snake cucumber completed their life cycle in a shorter period. While fruits of water melon and sweet melon were found to be least suitable for larval and pupal rearing, respectively. The larvae rearing on them completed their life cycle in

relatively longer period. Other study conducted by Guillaume and Boissot (2001) also shown that *Cucumis metuliferus* Meyer and *Cucumis Pustulatus* Naudin (wild cucumis) were resistant to *Diaphania hyalinata*.

In the present study, the host preference by female among the six types of cucurbits was studied in a cage experiment. Snake cucumber and sweet melon were the most preferred, and squash, pumpkin, water melon and tibish were the least preferred. None of the test plants was immune. This could be probably due to less number of hairs on snake cucumber and sweet melon compared to other cucurbits.

5. Conclusion

In this research, the biology of the melon worm, *Diaphania hyalinata* L. were studied on laboratory in order to determine and identify life cycle of insect on six species of cucurbits, including snake cucumber, squash, pumpkin, sweet melon, water melon and tibish. The following conclusion and suggestions are drawn out:

1. *Diaphania hyalinata* females laid their eggs singly or in batches, mostly on the lower surfaces of the leaves and occasionally on the stems of the plant.
2. Eggs hatched after 1-4 days. The larvae have five larval instars. The larval development was completed in 11-13day. Pupation period was 6-8days. Pre oviposition, oviposition, and post oviposition periods were found to be 1-3, 4-8 and 1-5 days, respectively. The life cycle was completed in 20-23 days, when the insect was fed on snake cucumber.
3. The larval and pupal periods and life cycle of melon worm were slightly longer when fed on fruits of snake cucumber, squash, pumpkin, sweet melon, water melon and tibish than when fed on leaves of the same cucurbits.
4. Under laboratory conditions leaves of snake cucumber and sweet melon were the most attractive for female eggs lying.

Author Contributions

All tasks have been done by the single author.

Conflict of Interest

The author declared that there is no conflict of interest.

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