

## Research Article

# Some Aspects of Biology of *Leucinodes Orbonalis* Guenee (Lepidoptera: Pyralidae), Feeding Behaviour of Larval Instars on Fresh *Solanum* Spp. Substrates (Solanaceae)

Elono Azang Pierre Stephan<sup>1,\*</sup> , Heumou Cyril Romeo<sup>2</sup>, Akama Pierre Dieudonne<sup>1</sup>, Alene Desiree Chantal<sup>3</sup>, Djieto-Lordon Champlain<sup>3</sup>

<sup>1</sup>Department of Biological Sciences, University of Yaounde I, Yaounde, Cameroon

<sup>2</sup>Department of Biology, University of Bamenda, Bamenda, Cameroon

<sup>3</sup>Department of Animal Biology and Physiology, University of Yaounde I, Yaounde, Cameroon

## Abstract

The fruits of *Solanum* spp. (Solanaceae) are attacked by several pests, including the species *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) which is the most dangerous agronomically, causing enormous damage of up to 70% in our country. Life history of *Leucinodes orbonalis* was studied on different species/varieties of *Solanum* spp. (*S. aethiopicum* var. zong, *S. aethiopicum* var. jakatu, *S. melongena* var. F1 African beauty and *S. tuberosum* var. local) at Laboratory of Zoology of the University of Yaounde I at  $28 \pm 1.44^\circ\text{C}$ ,  $48 \pm 10.07\%$  RH and  $929 \pm 3.27\text{mb/hPa}$ . Fresh fruits of different species/varieties were obtained in an experimental field set up at the Higher Teacher Training College. Data on development period of immature stage and growth larval parameters were collected. Development stages consist of an egg, five larval instars (from S1 to S5), pupa and adult on fresh fruits of *Solanum* spp. The average length, the average width and the average weight of the larvae after each stage did not vary significantly from one substrate to another ( $p \geq 0.05$ ). Thus, the respective average lengths, widths and weights of the body were 3.5mm, 0.5mm and 3.25mg at S1; 8.12mm, 1.4mm and 10.87mg at S2; 11.0mm, 1.76mm and 17.12mg at S3; 13.37mm, 2.22mm and 29.93mg at S4; 15.87mm, 2.71mm and 59.56mg at S5; 14.03mm, 5.62mm and 57.56mg at the cocoon stage. The average diameter of the head capsules of the larvae did not vary from one substrate to another for all the larval stages ( $p \geq 0.05$ ) with 0.42mm at S1, 0.76mm at S2 (with an increase of 0.34 from S1 to S2); 1.13mm at S3 (with increase of 0.37 from S2 to S3); 1.46 at S4 (with increase of 0.33 from S3 to S4) and 1.56mm at S5 (with increase of 0.19 from S4 to S5). Body length, abdomen width and wingspan in females did not vary between substrates ( $p \geq 0.05$ ) with mean values of 12.45mm, 2.95mm and 20.25mm respectively. For males, body length and wingspan showed significant variations depending on the substrates ( $F=10.87$ ;  $df=3$ ;  $p=0.003$  for length;  $F=6.03$ ;  $df=3$ ;  $p=0.01$  for the wingspan) with 11.08mm on the variety F1 african b and 9.61mm on the zong then 18.83mm on the F1 variety and 17.33mm on the zong. The average width (cumulative substrates) was 2.12mm. At cumulative substrates, Body length, abdomen width and wingspan respectively were higher in females compared to males (with 12.45mm, 2.95mm and 20.25mm for females and 10.23mm, 2.12mm and 18.12mm for males). The duration of development from one larval stage to another and from the cocoon stage to the adult stage did not vary from one substrate to another. The average duration of development from the egg stage to S1 was 4.51 days. That of S1 to S2, from S2 to S3, from S3 to S4, from S4 to S5, from S5 to the cocoon stage was respectively 1.00 days, 1.15 days, 1.44 days, 2.28 days, 3.33 days and 11.75 days. The average duration of larval development (from S1 to the cocoon stage) was 9.21 days and the total average duration of development from the egg stage to the adult stage was 25.47 days.

\*Correspondence: Elono Azang Pierre Stephan (elonoazangpierrestephan@gmail.com)

Received: 28 July 2026; Accepted: 8 August 2026; Published: 28 October 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

## Keywords

Leucinodes Orbonalis, Larval Stages, Biology, Substrates, Development Time

## 1. Introduction

Plants of the genus of *Solanum* spp. (*Solanum melongena*, *Solanum aethiopicum* and *Solanum tuberosum*) are a popular vegetables grown year round in Bangladesh, South-East Asia [10] and Africa [12]. Brinjal belongs to the family Solanaceae and is known under the botanical name *Solanum melongena* L. The family contains 75 genera and over 2000 species, out of which, about 150-200 are tuber bearing and belong to section Tuberarium. The fruits are subject to repeated attacks by *Leucinodes orbonalis*, the main pest.

*Leucinodes orbonalis* Guenee 1854 (Lepidoptera: Pyralidae), is the most serious damaging pest of fruits of *Solanum* spp. and other related vegetables which may cause 80% damage if no control measures are applied [21, 22].

As a result of its feeding inside fruit, the fruits become unmarketable and yield losses up to 90 percent [6]. *Leucinodes orbonalis* Guenee is practically monophagous, feeding principally on eggplant; however, other plants belonging to family Solanaceae are reported to be hosts of this pest [13]. In India it is believed the losses occurred were recorded up to 95% and this pest is believed to be cosmopolitan attacking other Solanaceous crops like potato and tomato [16]. Farmers of Bangladesh particularly of intensive brinjal growing areas like Jessore apply insecticides 84 to 140 times in a growing season [2-22]. Pesticide resistance is emerging as one of the key constraints to successful crop protection and public health problems worldwide [8, 22, 24]. Insecticides resistance in Brinjal Shoot and Fruit Borer specially to pyrethroids is now widespread in many brinjal-producing countries [22].

Information of the biology is required for effective management of the field pest [19]. Like other members of the order Lepidoptera, *L. orbonalis* goes through four growth stages: egg, larva, pupa and adult. The larval period is the longest, followed by pupal and incubation period [13]. In natural conditions adult female usually prefers an area on the host plant like leaf surface or foliage, where less exposure to direct sunlight and to the predators and Oviposition occurs mostly during night time with optimum temperature and low humidity increases the egg fecundity [7]. Oviposition takes place during the night and eggs are laid singly on the lower surface of the young leaves, green stems, flower buds, or calyces of the fruits and number of eggs laid by a female varies from 80 to 253 [13] and the eggs are laid in the early hours of the mornings singly or in the batches on the ventral surface of the leaves [13]. The egg takes incubation period of 3-5 days in summer and 7-8 days in winter and hatch into dark white larvae [13-21]. In natural conditions adult female usually prefers an area on the

host plant like leaf surface or foliage, where less exposure to direct sunlight and to the predators. Oviposition occurs mostly during night time with optimum temperature and low humidity increases the egg fecundity [4]. The larval period usually occurred for 12 to 15 days in the summer and up to 14 to 22 days in the winter [20]. Larvae pass through at least five instars [3] and there are reports of the existence of six larval instars [5-9]. The cocoon matches the soil color were found in a depth of 1-3 cm and lasted for 10-16 days being normal pupation period in all three different fruits selected [7]. The pupal period lasts 6 to 17 days depending upon temperature [1]. It is 7 - 10 days during summer, while it is 13 - 15 days during winter season [21]. The adults emerged from pupae are white in colour with brown triangle like patches with abdomen of female moth appeared pointed and in males it appeared as blunt abdomen along with its ornamented wings [7]. The endurance of normal adults in brinjal was 1.5 to 2.4 days in males and for females it is 2.0 to 3.9 days and normally under lab conditions adult emergence was during early morning hours [14]. The adult gains full maturity in 10 to 14 days. Longevity of adults lasts 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods range 1.2 to 2.1 and 1.4 to 2.9 days, respectively [14]. The adult male dies after mating and the female moth dies after laying eggs. The overall life cycle completes in 22 to 55 days [14].

The general objective of this work was: to show the influence of different types of food substrates of *Solanum* spp. on the development and growth of young larval stages of *Leucinodes orbonalis*. As specific objectives, we propose in this study: (i) to note the influence of the different substrates of *Solanum* spp. on the variation in size and weight of *Leucinodes orbonalis* larvae at each stage of development and on the variation in head capsule diameter between molts, (ii) to highlight the influence of the different substrates of *Solanum* spp. on the size of male and female adults of *Leucinodes orbonalis* at emergence, (iii) to highlight the duration of larval development of *Leucinodes orbonalis* on the different fresh substrates of *Solanum* spp.

## 2. Material and Methods

### 2.1. Study Sites

The study was carried out of the campus of Higher Teacher

Training College of the University of Yaounde I (lat. 3°51'35.5''N; long. 11°30'37.1''E; asl. 729m) for the harvest fresh fruits of *Solanum* spp. on field, and of the Laboratory of Zoology of the Faculty of Science of the University of Yaounde I (lat. 03°51'35,3''N; long. 11°30'00,6''E; asl. 770m) for breeding younger instars on fresh food substrates of *Solanum* spp. (Figure 1).

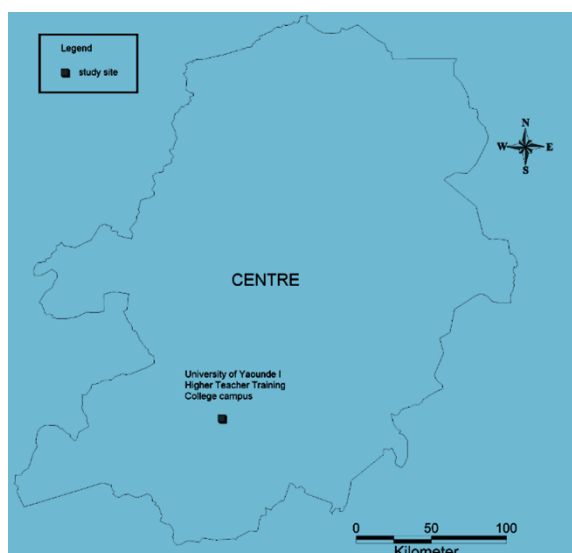


**Figure 1.** Study site for the experimental garden of *Solanum* spp. used for inoculation young larvae stages.

## 2.2. Study Material

The biological material on which the larvae were inoculated consisted of four fresh substrates of *Solanum* spp. of the Solanaceae family; the zong (Figure 2A) and jakatu (Figure 2D) varieties of the *Solanum aethiopicum* species; the F1 African beauty variety (Figure 2B) of the *Solanum melongena* species and the local potato variety (Figure 2C) of the *Solanum tuberosum* species.

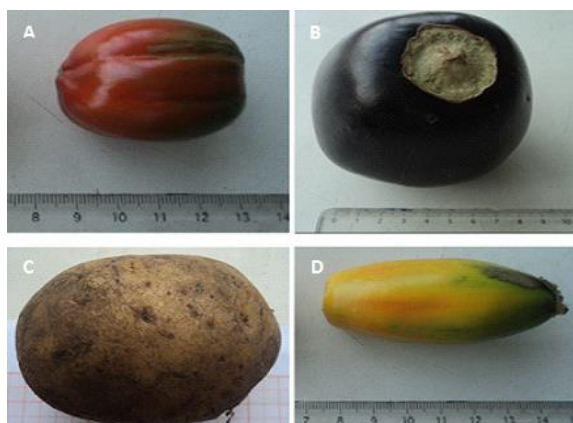


**Figure 2.** Fresh substrates of *Solanum* spp. A: *Solanum aethiopicum* var. zong, B: *Solanum melongena* var. F1 African beauty, C: *Solanum tuberosum* var. wild, and D: *Solanum aethiopicum* var. jakatu.

## 3. Sampling Method

### 3.1. Search For First Instar Larvae

The eggs were collected in the field (very early in the morning at 6 a.m. because the females lay at night) on the fresh leaves of *S. aethiopicum* var. zong (variety serving as control); they were counted using a "Leica" binocular magnifying glass, then incubated in the Laboratory in Petri dishes 1.5 cm high by 9 cm in diameter until the larvae hatched. The hatching rate was calculated from the ratio "number of stage 1 larvae obtained or number of eggs hatched after incubation on the total number of eggs collected" x 100 according to the formula:

$$HR (\%) = (TNHE / TNE) * 100$$

Where:

HR (%) = Hatching rate (%);

TNHE = Total number of 1st instar larvae obtained (or Total number of hatched eggs);

TNE = Total number of eggs.

### 3.2. Rearing of First Instar Larvae

In the Laboratory, young first instar larvae (stage 1) were inoculated into each fresh substrate of *Solanum* spp. Each larva was marked with a code number for better tracking until the emergence of the imago. On each substrate, observations and measurements of the larvae were made every day at the same time (4 p.m.) in order to note the variations in the size and weight of the body, cocoon and head capsule of each larva. The foods (fruits of *Solanum* spp.) were renewed at each check to refresh the diet and prevent the development of fungi. The factors of the environment on which the speed of development of the larvae depends (temperature and hygrometry) were recorded each time using a portable thermohygrometer brand "Auriol". The inoculation of the young larvae on each substrate was repeated four times and the breeding's were carried out in Petri dishes 15 cm in diameter by 2 cm in height under a hood available in the laboratory. It should be noted that the pupal stage of the larvae develops in a cocoon (silk envelope woven by the larva after its last stage and having the function of protecting the chrysalis).

### 3.3. Evaluation of Masses and Morphometric Parameters of Larvae, Head Capsules, Cocoons and Adults

After each larval moult, the diameter of the cephalic capsules, the length and the width of the body were measured using a binocular magnifying glass equipped with a "Leica" brand micrometer, as well as their weight using an ultra-sensitive electronic scale from the "Pioneer" brand. The cocoons containing the chrysalises were also measured and weighed then returned to rearing in Petri dishes which served at the

same time as a place of emergence for the adults. Each box was moistened with a cotton ball soaked in water. On adults, the following measurements were taken in both sexes: body length, width of mid-abdomen, and wing span. We were able to determine, from this study, the influence of each substrate of *Solanum* spp. on the development time of the larvae.

## 4. Statistical Analysis

The data after treatment were subjected to an analysis of variances (ANOVA) contained in the Generalized Linear Model (GLM) procedure, followed by a multiple comparison of the means 2 to 2 by a Tukey HSD test in case of significant difference; to highlight the comparisons between the size (length and width) and the weight of the different larvae, the diameter of the head capsule after each larval moult, on each

substrate and with cumulative substrates. The analyzes were carried out using the STATISTICA software version 8.0 (2007) and the results assessed at the significance level of 5%.

## 5. Results

### 5.1. Influence of the Substrate on the Size and Weight of *Leucinodes Orbonalis* Larvae at Each Development Stage at 28°C

#### 5.1.1. At the Egg Stage

Eggs obtained from *S. aethiopicum* var. zong (control), were on average  $91.75 \pm 13.05$  eggs sampled in the field (after 04 samples). The average hatching rate and the average incubation duration in the Laboratory are shown in (Table 1).

**Table 1.** Mean incubation time of *Leucinodes orbonalis* eggs collected from *S. aethiopicum* var. zong (control) at Yaounde at 28°C.

| Sample         | Total Number of eggs | Total Number of eggs hatched | Hatching rate (%) | Incubation (per Day)        |
|----------------|----------------------|------------------------------|-------------------|-----------------------------|
| P1             | 76                   | 19                           | 25.00             | $4.73 \pm 0.45$ [4.51-4.95] |
| P2             | 108                  | 34                           | 21.48             | $4.52 \pm 0.51$ [4.35-4.75] |
| P3             | 98                   | 27                           | 27.55             | $4.35 \pm 0.61$ [4.13-4.57] |
| P4             | 85                   | 31                           | 36.47             | $4.44 \pm 0.50$ [4.24-4.64] |
| Mean $\pm$ SD. | $91.75 \pm 13.05$    | $27.75 \pm 6.01$             | $30.12 \pm 4.62$  | $4.51 \pm 0.15$ [4.31-4.72] |

SD=Standard Deviation; P1 to P4= Samples (replication), Values in square brackets represent the minimum and maximum values of the mean.

#### 5.1.2. In Larval Stage 1

The average length, the average width and the average weight followed by the extreme dimensions (in square brackets), were on *S. aethiopicum* var. zong (control),  $3.5 \pm 0.95$  mm [1.90-5.09],  $0.50 \pm 0.08$  mm [0.37-0.62] and  $3.25 \pm 0.95$  mg [1.72-4.77] respectively (Table 2).

#### 5.1.3. In Larval Stage 2

At this stage, from the control substrate, the average length, width and weight were slightly higher on *S. aethiopicum* var. jakatu and on *S. melongena* var. F1 African beauty (Table 2). These parameters did not vary from a substrate of *Solanum* spp. to another ( $F=2.2$ ;  $df=3$ ;  $p=0.14$  /  $F=1.34$ ;  $df=3$ ;  $p=0.30$  /  $F=3.30$ ;  $df=3$ ;  $p=0.057$  respectively).

#### 5.1.4. In Larval Stage 3

At this stage, the average length was slightly higher on *S. melongena* var. F1 African beauty compared to control substrate, while slightly higher average width and weight on *S.*

*aethiopicum* var. jakatu (Table 2). These three larval parameters of *L. orbonalis* showed non-significant variations depending on the substrates ( $F=0.36$ ;  $df=3$ ;  $p=0.78$  /  $F=0.20$ ;  $df=3$ ;  $p=0.89$  /  $F=0.22$ ;  $df=3$ ;  $p=0.87$  respectively for the three parameters).

#### 5.1.5. In Larval Stage 4

At this stage, and in comparison to the control substrate, the average length of the larvae was slightly higher on *S. aethiopicum* var. jakatu while the average width and weight, clearly higher on *S. melongena* var. F1 African beauty (Table 2). The three parameters always presented non-significant variations from one substrate to another ( $F=2.71$ ;  $df=3$ ;  $p=0.09$  /  $F=2.77$ ;  $df=3$ ;  $p=0.086$  and  $F=2.98$ ;  $df=3$ ;  $p=0.07$  respectively).

#### 5.1.6. In Larval Stage 5

The larvae from *S. melongena* var. F1 African beauty presented a slightly higher average width (Table 2). The mean length and the mean weight of *L. orbonalis* larvae varied according to the four substrates of *Solanum* spp. ( $F=3.52$ ;  $df=3$ ;  $p=0.04$  and  $F=4.52$ ;  $df=3$ ;  $p=0.024$  respectively), while the

width at the same larval stage presented a non-significant variation depending on the different substrates ( $F=2.39$ ;  $df=3$ ;  $p=0.11$ ).

### 5.1.7. In Cocoon Stage

Cocoon weights on *S. aethiopicum* var. zong and on *S. aethiopicum* var. jakatu varied significantly ( $p=0.027$ ). The cocoons from *S. aethiopicum* var. jakatu were significantly larger in length and width. The weight of cocoons from *S. aethiopicum* var. jakatu was significantly higher (Table 2). At this stage, the length, width and average weight of the larvae showed a non-significant variation from one substrate to another ( $F=1.027$ ;  $df=3$ ;  $p=0.41$  /  $F=2.87$ ;  $df=3$ ;  $p=0.08$  /  $F=2.36$ ;

$df=3$ ;  $p=0.12$  respectively).

Overall, the larvae developed normally on the four substrates in which they were inoculated. The average length, width and weight of the different larval stages did not vary significantly from one substrate to another overall (Table 2).

On cumulative substrates, length, width and weight varied highly significantly from one larval stage to another ( $F=371.01$ ;  $df=4$ ;  $p<0.001$  /  $F=227.9$ ;  $df=4$ ;  $p<0.001$  and  $F=142.2$ ;  $df=4$ ;  $p<0.001$  respectively). The average length, width and weight of the larvae increase as the larva grows. On the other hand, at the cocoon stage, the length and the weight decrease while the width increases (Table 3).

**Table 2.** Measurements of development parameters on the larval stages of *L. orbonalis* on fresh substrates of *Solanum* spp. at 28°C.

| Parameters            | Fresh substrates | Larval stages and pupae (Mean±SD) |            |             |             |             |             |
|-----------------------|------------------|-----------------------------------|------------|-------------|-------------|-------------|-------------|
|                       |                  | 1st stage                         | 2nd stage  | 3rd stage   | 4th stage   | 5th stage   | pupa        |
| Mean body length (mm) | zong             | 3.50±0.95                         | 7.5±0.57a  | 10.75±0.5a  | 12.5±1.0a   | 15.0±0.81a  | 13.25±0.95a |
|                       | jakatu           | 3.50±0.95                         | 8.5±0.57a  | 11.0±0.1a   | 14.0±0.81a  | 16.75±0.5a  | 14.75±0.5a  |
|                       | F1 African b     | 3.50±0.95                         | 8.5±0.57a  | 11.25±0.5a  | 13.5±0.57a  | 16.5±0.57a  | 14.25±1.5a  |
|                       | potato           | 3.50±0.95                         | 8.0±0.81a  | 11.0±0.81a  | 13.5±0.57a  | 15.25±1.5a  | 14.0±1.63a  |
| Mean±SD               |                  | 3.50±0                            | 8.12±0.44  | 11.0±0.18   | 13.37±0.58  | 15.87±0.81  | 14.06±0.57  |
| Mean body width (mm)  | zong             | 0.50±0.08                         | 1.42±0.09a | 1.72±0.09a  | 2.05±0.31a  | 2.47±0.05a  | 4.62±0.94a  |
|                       | jakatu           | 0.50±0.08                         | 1.42±0.09a | 1.80±0.14a  | 2.22±0.22a  | 2.82±0.35a  | 6.37±0.47a  |
|                       | F1 African b     | 0.50±0.08                         | 1.45±0.05a | 1.75±0.12a  | 2.52±0.22a  | 3.07±0.29a  | 5.75±0.95a  |
|                       | potato           | 0.50±0.08                         | 1.37±0.09a | 1.77±0.18a  | 2.10±0.27a  | 2.50±0.57a  | 5.75±0.95a  |
| Mean±SD               |                  | 0.5±0                             | 1.41±0.03  | 1.76±0.031  | 2.22±0.19   | 2.71±0.26   | 5.62±0.67   |
| Mean body weight (mg) | zong             | 3.25±0.95                         | 9.50±1.29a | 16.5±2.38a  | 23.75±4.90a | 52.75±7.70a | 43.0±2.44a  |
|                       | jakatu           | 3.25±0.95                         | 11.5±0.57a | 17.5±1.29a  | 28.50±6.60a | 63.5±3.69b  | 67.7±6.55c  |
|                       | F1 African b     | 3.25±0.95                         | 11.5±1.29a | 17.25±2.21a | 36.75±3.16a | 68.0±2.16fb | 62.7±22.03c |
|                       | potato           | 3.25±0.95                         | 11.0±0.81a | 17.25±0.95a | 30.75±5.43a | 54.0±10.7a  | 56.7±15.52b |
| Mean±SD               |                  | 3.25±0                            | 10.87±0.88 | 17.12±0.40  | 29.94±4.99  | 59.56±6.84  | 57.52±9.88  |

SD=Standard deviation, Data in a column per each parameter followed by the same letter (s) do not differ significantly at  $p\geq 0.05$  (HSD Tukey test), and data in a column per each parameter followed by the different letter (s) differ significantly at  $p<0.05$  (using HSD Tukey test), zong, jakatu, eggplant and potato=Different varieties of *Solanum* spp.

**Table 3.** Measurements of development means parameters on the larval stages of *L. orbonalis* (fresh substrates of *Solanum* spp. cumulated) at 28°C.

| Larval stages and pupae | Mean parameters ± SD (cumulated <i>Solanum</i> spp. substrates) |                        |                        |
|-------------------------|-----------------------------------------------------------------|------------------------|------------------------|
|                         | Mean body length (mm)                                           | Mean body width (mm)   | Mean body weight (mg)  |
| 1st stage               | 3,50±0,89e [3,02-3,97]                                          | 0,50±0,07e [0,46-0,53] | 3,25±0,85e [2,79-3,70] |

| Larval stages and pupae | Mean parameters $\pm$ SD (cumulated <i>Solanum</i> spp. substrates) |                              |                                 |
|-------------------------|---------------------------------------------------------------------|------------------------------|---------------------------------|
|                         | Mean body length (mm)                                               | Mean body width (mm)         | Mean body weight (mg)           |
| 2nd stage               | 8,12 $\pm$ 0,71d [7,74-8,50]                                        | 1,40 $\pm$ 0,08d [1,35-1,44] | 10,87 $\pm$ 1,25d [10,20-11,54] |
| 3rd stage               | 11,00 $\pm$ 0,63c [10,66-11,33]                                     | 1,76 $\pm$ 0,13c [1,69-1,83] | 17,12 $\pm$ 1,66c [16,23-18,01] |
| 4th stage               | 13,37 $\pm$ 0,88b [12,90-13,84]                                     | 2,22 $\pm$ 0,29b [2,06-2,38] | 29,93 $\pm$ 7,38b [26,00-33,87] |
| 5th stage               | 15,87 $\pm$ 1,14a [15,26-16,48]                                     | 2,71 $\pm$ 0,41a [2,49-2,94] | 59,56 $\pm$ 9,07a [54,72-64,39] |
| pupa                    | 14,06 $\pm$ 1,23 [13,40-14,72]                                      | 5,62 $\pm$ 1,00 [5,08-6,16]  | 57,56 $\pm$ 15,7 [49,13-65,93]  |

Note. Data in a column per each parameter followed by the different letter (s) differ significantly using HSD Tukey test; SD=standard deviation.

## 5.2. Influence of Substrates on the Variation of Diameter of the Head Capsules of *Leucinodes Orbonalis* at 28°C

The Table 4 presents the variation of the mean diameter of the head capsule after each larval moult on the three species/varieties of *Solanum* spp.

### 5.2.1. At Stage 1

The mean head capsule diameter was 0.42  $\pm$  0.15 mm [0.18-0.66] in *S. aethiopicum* var. zong (control).

### 5.2.2. At Stage 2

The diameter was slightly higher on *S. melongena* var. F1 African beauty with an increase of 0.38 mm and on *S. aethiopicum* var. jakatu with an increase of 0.35 mm compared to the control (Table 4). The average head capsule diameter as a function of the substrates presented non-significant variations (F=0.57; df=3; p=0.63).

### 5.2.3. At Stage 3

The mean diameter was slightly higher on *S. melongena* var. F1 African beauty, on *S. aethiopicum* var. jakatu and on *S. tuberosum* var. local with an increase of 0.38 mm, 0.35 mm and 0.37 mm respectively, compared to the control (Table 4). The average head capsule diameter as a function of the substrates always presented non-significant variations (F=0.57; df=3;

p=0.64).

### 5.2.4. At Stage 4

The diameter was slightly higher on *S. melongena* var. F1 African beauty with an increase of 0.33 mm, on *S. aethiopicum* var. jakatu with an increase of 0.35 mm and on *S. tuberosum* with an increase of 0.35 mm compared to the control (Table 4). This average head capsule diameter as a function of the substrates presented non-significant variations (F=1.87; df=3; p=0.18).

### 5.2.5. At Stage 5

The diameter was slightly higher on *S. melongena* var. F1 African beauty with an increase of 0.16 mm and the other two *Solanum* spp. with an increase of 0.18 mm respectively compared to the control (Table 4). The average head capsule diameter showed non-significant variations depending on the substrates (F=0.36; df=3; p=0.78).

In general, the mean diameter of the head capsules did not vary from one substrate to another. All the substrates appear to be favorable to the development of *L. orbonalis*. The jakatu and F1 African beauty varieties were even more favorable.

It should be noted that with cumulative substrates, the mean diameter of the head capsules showed a significant variation from one larval stage to another (F=418.3; df=4; p<0.01); and that the increase in head capsule diameter from stage 1 to stage 2 and from stage 2 to stage 3 is higher and begins to decrease from stage 3 to stage 4 and finally from stage 4 to stage 5 (Table 5).

**Table 4.** Variation in mean head capsule diameter (in mm) after each larval molt of *Leucinodes orbonalis* on fresh substrates of *Solanum* spp.

| Larval stages         | var. zong  |              |               | var. jakatu |              |               | var. F1 African beauty |              |               | var. potato |              |               |
|-----------------------|------------|--------------|---------------|-------------|--------------|---------------|------------------------|--------------|---------------|-------------|--------------|---------------|
|                       | Range (mm) | Mean±SD (mm) | Increase (mm) | Range (mm)  | Mean±SD (mm) | Increase (mm) | Range (mm)             | Mean±SD (mm) | Increase (mm) | Range (mm)  | Mean±SD (mm) | Increase (mm) |
| 1 <sup>st</sup> stage | 0,18-0,66  | 0,42±0,15c   | -             | 0,18-0,66   | 0,42±0,15c   | -             | 0,18-0,66              | 0,42±0,15c   | -             | 0,18-0,66   | 0,42±0,15c   | -             |
| 2 <sup>nd</sup> stage | 0,65-0,84  | 0,75±0,05d   | 0,33          | 0,69-0,85   | 0,77±0,05d   | 0,35          | 0,67-0,92              | 0,80±0,08d   | 0,38          | 0,65-0,84   | 0,75±0,05d   | 0,33          |
| 3 <sup>rd</sup> stage | 0,86-1,26  | 1,06±0,12c   | 0,31          | 0,89-1,35   | 1,12±0,14c   | 0,35          | 0,98-1,38              | 1,18±0,12c   | 0,38          | 0,89-1,35   | 1,12±0,14c   | 0,37          |
| 4 <sup>th</sup> stage | 1,27-1,52  | 1,40±0,08b   | 0,34          | 1,39-1,55   | 1,47±0,05b   | 0,35          | 1,47-1,55              | 1,51±0,02b   | 0,33          | 1,32-1,62   | 1,47±0,09b   | 0,35          |
| 5 <sup>th</sup> stage | 1,54-1,70  | 1,62±0,05a   | 0,22          | 1,55-1,74   | 1,65±0,05a   | 0,18          | 1,52-1,82              | 1,67±0,09a   | 0,16          | 1,55-1,74   | 1,65±0,05a   | 0,18          |
| Mean±SD               | 0,90-1,19  | 1,05±0,45    | 0,30          | 0,94-1,23   | 1,08±0,47    | 0,31          | 0,97-1,26              | 1,12±0,48    | 0,31          | 0,91-1,24   | 1,08±0,48    | 0,31          |

Note. Data in a column followed by the different letter (s) differ significantly at  $p < 0.05$  (HSD Tukey test); Mean±SD=Mean±Standard deviation

**Table 5.** Variation in the diameter (mm) of the head capsules after each larval moult of *L. orbonalis* from stage 1 to stage 5 (*Solanum* spp. cumulated) at 28°C.

| Larval stages         | Mean diameter per larval stage (cumulative substrates) |            |               |
|-----------------------|--------------------------------------------------------|------------|---------------|
|                       | Mean±SD (mm)                                           | Range (mm) | Increase (mm) |
| 1st stage             | 0,42±0,13 e                                            | 0,36-0,49  | -             |
| 2 <sup>nd</sup> stage | 0,76±0,06 d                                            | 0,73-0,80  | 0,34          |
| 3rd stage             | 1,13±0,12 c                                            | 1,05-1,19  | 0,37          |
| 4th stage             | 1,46±0,07 b                                            | 1,42-1,50  | 0,33          |
| 5th stage             | 1,65±0,06 a                                            | 1,61-1,68  | 0,19          |
| Mean±SD               | 1,08±0,47                                              | 1,03-1,13  | -             |

Note. Data in a column followed by the different letter (s) differ significantly at  $p < 0.05$  (HSD Tukey test); SD=standard deviation.

### 5.3. Influence of Substrates on the Adult Males and Females of *Leucinodes Orbonalis* at 28°C

Length, abdomen width and wingspan in females did not vary between substrates ( $F=1.66$ ;  $df=3$ ;  $p=0.25$  for length;  $F=1.2$ ;  $DF=3$ ;  $p=0.38$  for the width and  $F=0.16$ ;  $df=3$ ;  $p=0.81$  for the wingspan). For males, body length and wingspan showed significant variations depending on the substrates

( $F=10.87$ ;  $df=3$ ;  $p=0.003$  for length;  $F=6.03$ ;  $df=3$ ;  $p=0.01$  for the wingspan) and a non-significant variation in the width of the abdomen according to the substrates ( $F=0.19$ ;  $df=3$ ;  $p=0.89$ ).

On *S. aethiopicum* var. jakatu and *S. tuberosum* var. locally, the body length of the males was not different compared to that of the control males. On the other hand, the length of males from *S. melongena* var. F1 African beauty was different from that of the control. On the wingspan of males, the results from *S. aethiopicum* var. jakatu and *S. melongena* var. F1 Af-

rican beauty were different from those of males from the control variety, unlike *S. tuberosum* var. local whose males

showed the same wingspans as those from *S. aethiopicum* var. zong (Table 6).

**Table 6.** Influence of fresh substrates of *Solanum* spp. on the length, width of the abdomen and wingspan of adult male and female of *Leucinodes orbonalis* at 28°C.

| Parameters              | Substrates   | Adult male and female and wingspan |             |             |             |
|-------------------------|--------------|------------------------------------|-------------|-------------|-------------|
|                         |              | female                             | Range       | male        | Range       |
| Mean body length (mm)   | zong         | 11.66±1.15a                        | 8.79-14.53  | 9.61±0.53a  | 8.27-10.95  |
|                         | jakatu       | 12.66±0.57a                        | 11.23-14.10 | 10.16±0.28a | 9.44-10.88  |
|                         | F1 African b | 12.83±0.28a                        | 12.11-13.55 | 11.08±0.14a | 10.72-11.44 |
|                         | potato       | 12.66±0.57a                        | 11.23-14.10 | 10.08±0.14a | 9.72-10.44  |
| Mean±SD                 |              | 12.45±0.78                         | 11.96-12.95 | 10.23±0.61  | 9.84-10.83  |
| Mean abdomen width (mm) | zong         | 2.83±0.28a                         | 2.11-3.55   | 2.08±0.14a  | 1.72-2.44   |
|                         | jakatu       | 3.08±0.14a                         | 2.72-3.44   | 2.16±0.14a  | 1.80-2.52   |
|                         | F1 African b | 3.08±0.14a                         | 2.72-3.44   | 2.16±0.28a  | 1.44-2.88   |
|                         | potato       | 2.83±0.28a                         | 2.11-3.55   | 2.08±0.14a  | 1.72-2.44   |
| Mean±SD                 |              | 2.95±0.23                          | 2.70-3.10   | 2.12±0.16   | 1.67-2.23   |
| Mean wingspan (mm)      | zong         | 20.00±1.00a                        | 17.51-22.48 | 17.33±0.57a | 15.89-18.76 |
|                         | jakatu       | 20.33±0.57a                        | 18.89-21.76 | 18.66±0.57b | 17.23-20.10 |
|                         | F1 African b | 20.33±0.57a                        | 18.89-21.76 | 18.83±0.28b | 18.11-19.55 |
|                         | potato       | 20.33±0.57a                        | 18.89-21.76 | 17.66±0.57a | 16.23-19.10 |
| Mean±SD                 |              | 20.25±0.62                         | 18.85-20.64 | 18.12±0.80  | 17.61-18.63 |

Note. Mean with the same letter in a column per parameters are not significantly different at  $P \geq 0.05$  (using HSD Tukey test) and Means with the different letter in a column per parameters are significantly different at  $P < 0.05$  (using HSD Tukey test).

#### 5.4. Biological Performance of Fresh Substrates Over the Duration of Larval Development of *Leucinodes Orbonalis* at 28°C

At 28 °C, the mean development duration from stage 1 to stage 2 was of  $1.00 \pm 0.00$  day for the four substrates.

The mean development duration of *L. orbonalis* larvae showed a non-significant variation according to the four substrates of *Solanum* spp. from stage 2 to stage 3 ( $F=0.96$ ;  $df=3$ ;  $p=0.44$ ), from stage 3 to stage 4 ( $F=1.74$ ;  $df=3$ ;  $p=0.21$ ), from stage 4 to stage 5 ( $F=0.65$ ;  $df=3$ ;  $p=0.59$ ) and from stage 5 to the cocoon stage ( $F=1.95$ ;  $df=3$ ;  $p=0.17$ ). From the cocoon stage to the adult stage (female and male combined), the duration of development also showed a non-significant variation

depending on the substrates ( $F=0.13$ ;  $df=3$ ;  $P=0.93$ ) (Table 7).

Thus, the average total duration of larval development from stage 1 to stage 5 and the average total duration of development from egg to adult for the four *Solanum* spp. are shown in Table 7.

At cumulative substrates, the average larval duration of *L. orbonalis* from the egg stage to stage 1, from stage 1 to 2, from stage 2 to 3, from stage 3 to 4, from stage 4 to 5, from stage 5 to cocoon stage and from the cocoon stage to the adult stage was respectively  $4.52 \pm 0.00$  days (4.52-4.52);  $1.00 \pm 0.00$  days (1.00-1.00);  $1.15 \pm 0.05$  days (1.12-1.17);  $1.44 \pm 0.08$  days (1.40-1.49);  $2.28 \pm 0.24$  days (2.15-2.41);  $3.33 \pm 0.20$  days (3.22-3.43) and  $11.75 \pm 1.00$  days (11.21-12.28). The total larval duration was therefore  $9.2 \pm 0.91$  days and that from egg to adult  $25.47 \pm 3.64$  days (Table 7).

**Table 7.** Developmental period (per days) of the life cycle of *Leucinodes orbonalis* on fresh *Solanum* spp. substrates.

| Instars larvae                             | Mean development period per days |           |             |            |                        |            |             |            | Mean±SD (cumuled) |             |
|--------------------------------------------|----------------------------------|-----------|-------------|------------|------------------------|------------|-------------|------------|-------------------|-------------|
|                                            | var. zong                        |           | var. jakatu |            | var. F1 African beauty |            | potato      |            |                   |             |
|                                            | Mean±SD                          | Range     | Mean±SD     | Range      | Mean±SD                | Range      | Mean±SD     | Range      | Mean±SD           | Range       |
| Egg to 1 <sup>st</sup> instar              | 4.52±0.51                        | 4.31-4.72 | 4.52±0.51   | 4.31-4.72  | 4.52±0.51              | 4.31-4.72  | 4.52±0.51   | 4.31-4.72  | 4.52±00           | 4.52-4.52   |
| 1 <sup>st</sup> instar to 2 <sup>nd</sup>  | 1.00±0.00f                       | 1.00-1.00 | 1.00±0.00f  | 1.00-1.00  | 1.00±0.00f             | 1.00-1.00  | 1.00±0.00f  | 1.00-1.00  | 1.00±00           | 1.00-1.00   |
| 2 <sup>nd</sup> in-star to 3 <sup>rd</sup> | 1.18±0.06e                       | 1.08-1.28 | 1.15±0.04e  | 1.08-1.21  | 1.14±0.04e             | 1.06-1.21  | 1.13±0.04e  | 1.05-1.20  | 1.15±0,05         | 1.12-1.17   |
| 3 <sup>rd</sup> instar to 4 <sup>th</sup>  | 1.52±0.09d                       | 1.37-1.66 | 1.44±0.05d  | 1.35-1.53  | 1.42±0.09d             | 1.27-1.57  | 1.40±0.04d  | 1.33-1.48  | 1.44±0.08         | 1.40-1.49   |
| 4 <sup>th</sup> instar to 5 <sup>th</sup>  | 2.40±0.21c                       | 2.05-2.74 | 2.27±0.26c  | 1.85-2.69  | 2.30±0.35c             | 1.73-2.86  | 2.15±0.12c  | 1.94-2.35  | 2.28±0.24         | 2.15-2.41   |
| 5 <sup>th</sup> instar to pupae            | 3.45±0.05b                       | 3.35-3.54 | 3.17±0.12b  | 2.97-3.37  | 3.27±0.09b             | 3.12-3.42  | 3.42±0.33b  | 2.89-3.95  | 3.33±0.20         | 3.22-3.44   |
| pupae to adult                             | 12.00±0.81a                      | 10.7-13.2 | 11.5±1.29a  | 9.44-13.55 | 11.75±1.25a            | 9.74-13.75 | 11.75±0.95a | 10.22-13.2 | 11.75±1.00        | 11.21-12.28 |
| LDP                                        | 9.55±0.95                        | -         | 9.03±0.85   | -          | 9.13±0.89              | -          | 9.10±0.94   | -          | 9.20±0.91         | -           |
| TDP                                        | 26.07±3.71                       | -         | 25.05±3.56  | -          | 25.4±3.65              | -          | 25.37±3.66  | -          | 25.47±3.64        | -           |

Note. Means with the different letters in a column per diet are significantly different using HSD Tukey test ( $p < 0.05$ ); LDP=larval development period; TDP=Total development period; var=*S. aethiopicum* and *S. melongena* varieties.

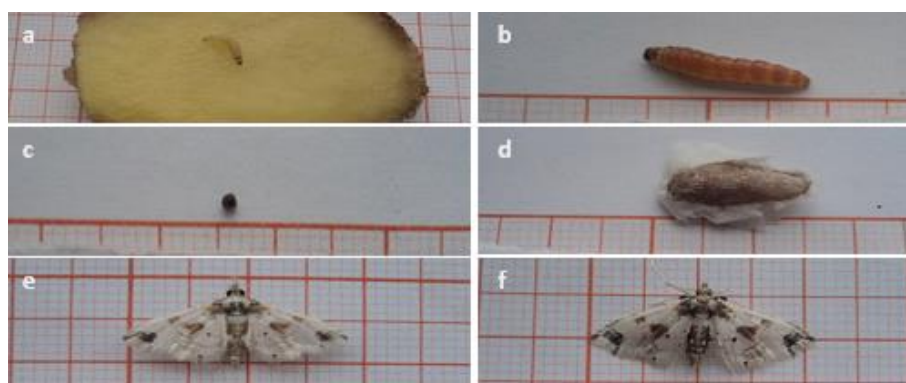


**Figure 3.** A) *Leucinodes orbonalis* larvae of 2nd instar on potato substrate (length=8 mm); b) larvae of 5th instar (length=17.5 mm); c) Head capsule of larvae of 4th instar (diameter=1.4 mm); d) pupae (length=15 mm); e) adult male (wingspan=18 mm); f) adult female (wingspan=21 mm).

## 6. Discussion

### 6.1. Influence of the Substrate on the Size and Weight of *Leucinodes Orbonalis* Larvae at Each Stage of Development at 28°C

Young *L. orbonalis* larvae were reared on fresh substrates

of *Solanum* spp. at ambient temperature and relative humidity. After the egg stage, we obtained on each substrate five larval stages, a cocoon stage and an adult stage. These results are similar to those obtained by [19] in Nigeria on varieties of *Solanum* spp. On the other hand, the results of [5] and those of the [9] show the existence of six larval stages of this same pest;

probably because of differences in climate between agro-ecological zones.

The average length, the average width and the average weight of the different larval stages did not vary significantly from one *Solanum* spp. substrate to another. Larvae also developed normally in eggplant and potato fruits. In a given agro-ecological environment and in the absence of eggplant fruits, the potato could constitute an alternative substrate for the development of *L. orbonalis* larvae [7-22]. These larvae are notably known by several authors as stem borers of this Solanaceae. [17] and [23] show that *L. orbonalis* could cause up to 41.87% damage to terminal shoots, reducing yield by 2.25 t per ha for apple cultivation of land in India.

Stage 2 larvae and cocoons averaged 8.5 mm and 14.25 mm respectively on *S. melongena* var. F1 African beauty, 8.0 mm and 14.0 mm on *S. tuberosum* var. local and cumulative substrates, 8.12 mm and 14.06 mm. [22] found a higher length of the same larval stage of 8.72 mm and 9.37 mm on potato and eggplant respectively and a cocoon length of 13.6 mm (lower) and 15.0 mm (higher) on apple and eggplant respectively. [19] find a lower value of 6.98 mm at stage 2 and 13.9 mm at cocoon stage in Nigeria on *Solanum* gilo.

With cumulative substrates, the average lengths of stages 1, 3, 4 and 5 (3.5, 11.0, 13.37, 15.87 mm) obtained were lower than those observed by [19] which were rather 4.19 mm, 11.10 mm, 16.58 mm and 18.44 mm respectively for the same larval stages. For the average widths obtained from stage 1 to the cocoon stage (0.5 mm, 1.4 mm, 1.76 mm, 2.22 mm, 2.71 mm and 5.62 mm), the results obtained by [19] were lower (i.e. 0.49 mm, 0.9 mm, 1.38 mm, 1.71 mm, 2.15 mm and 5.48 mm respectively for the same stages of development).

## 6.2. Influence of Substrates on the Variation in the Diameter of the Head Capsules of *Leucinodes Orbonalis* at 28°C

For each larval stage, the diameters of the head capsules did not vary from one substrate to another, but on cumulative substrates, this diameter varied significantly from one larval stage to another. The results obtained by [18] on the diameters of the head capsules from one larval stage to another were lower (0.2 mm, 0.36 mm, 0.64 mm, 0.95 mm and 1.46 mm from stage 1 to stage 5 respectively).

The head capsule increases from stage 1 to stage 2 and from stage 2 to stage 3; it begins to decrease from stage 3 to stage 4 and finally from stage 4 to stage 5. Almost similar results were also observed by [19] in Nigeria. This author showed that from stage 2 to stage 4, the increase in the head capsule was respectively 0.29 mm, 0.32 mm and 0.38 mm with a decrease in size from stage 4 to stage 5 (from 0.38mm to 0.29mm).

## 6.3. Influence of Substrates on the Adult Male and Female *Leucinodes Orbonalis* at 28°C

The work of Onekututu et al. (2013) in Nigeria are almost

similar on average body lengths of males and females (13.26 and 14.17 mm) and wingspan (21.59 and 24.33 mm respectively), but slightly higher than ours (10.23 mm and 12.45 mm) and (18.22 mm and 20.25 mm respectively).

## 6.4. Biological Performance of Fresh Substrates Over the Duration of Larval Development of *Leucinodes Orbonalis* at 28°C

The average development time of *L. orbonalis* (with cumulative substrates) from egg stage to stage 1, from stage 1 to 2, from stage 2 to 3, from stage 3 to 4, from stage 4 to 5, from stage 5 to stage cocoon and cocoon stage to adult stage was respectively 4.52 days, 1.00 day, 1.15 day, 1.45 day, 2.28 days, 3.33 days and 11.75 days with an average total day from egg to adult stage of 25.47 days (cumulative substrates). [19] recorded results almost similar but slightly higher than ours on the development time of the different development stages of *L. orbonalis* on the fruits of *Gilo raddi* in Nigeria (with 5.93 days, 1.00 days, 1.16 days, 1.48 days, 2.63 days, 4.46 days and 11.2 days). According to the same authors, the total duration of development of *L. orbonalis* on eggplant “gilo” was 28.17 days, a higher result than what we obtained.

The incubation period was instead shown to be 5.20 days, that of total larval development 10.73 days, and that of the cocoon 8.05 days, for an average total of 23.98 days, rather lower results than those obtained in our sites [15].

The slight differences in size would be due to differences in temperature, relative humidity, altitude and the seasons in which the larvae were subjected. Temperature and relative humidity are the most important factors affecting the development rates of larvae and pupae [11]. [18] also showed that climatic parameters play an important role in the development cycle of *Leucinodes orbonalis*.

## 7. Conclusion

The biology of *Leucinodes orbonalis* on substrates of *Solanum* spp. has been studied. Potato being its close relative in Solanaceae family needs to be studied widely as a supplementary diet source for *Leucinodes orbonalis*.

## Abbreviations

|      |                              |
|------|------------------------------|
| HR   | Hatching Rate                |
| LDP  | Larval Development Period    |
| TDP  | Total Development Period     |
| TNEH | Total Number of Hatched Eggs |
| TNE  | Total Number of Eggs         |

## Acknowledgments

Authors acknowledge the support of Director of Higher Teacher's Training College, University of Yaounde I, for their

material support and cooperation.

## Author Contributions

**Elono Azang Pierre Stephan:** Conceptualization, Formal Analysis, Methodology, Project administration, Resources, Software, Writing – original draft, Writing – review & editing

**Heumou Cyril Romeo:** Conceptualization, Methodology, Project administration, Resources, Writing – review & editing

**Akama Pierre Dieudonne:** Software, Writing – review & editing

**Alene Desiree Chantal:** Conceptualization, Methodology, Project administration, Writing – review & editing

**Djeto-Lordon Champlain:** Formal Analysis, Validation, Writing – review & editing

## Data Availability Statement

The data is available from the corresponding author upon reasonable request.

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] Alam S., N., Rashid M., A., Rouf F., M., A., Jhala R., C., Patel J., R., Satpathy S., Shivalingaswamy T., M., Rai S., Wahundeniya I., Cork A., Ammaranan C., and Talekar N., S. Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia. 2003. Technical Bulletin No. 28. AVRDC Publication No. 03-548. AVRDC-The World Vegetable Center, Shanhua, Taiwan. 56 p.
- [2] Anonymous. A farmer's guide to harmful and helpful insects in eggplant field. 2003a. Tech. Bull. No. 29, AVRDC-The World Vegetable Center, Shanhua, Taiwan. 24p.
- [3] Atwal A., S. Agricultural pests of India and Southeast Asia. 1976. Kalyani Publishers. New Delhi, India. 529 p.
- [4] AVRDC. Eggplant entomology. Control of eggplant fruit and shoot borer. Progress Report. 1994. Asian Vegetable Research and Development Center, (AVRDC), Shanhua, Taiwan. 88 p.
- [5] Baang L., A., and Corey F., M. Life history of an eggplant fruit and shoot borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Pyralidae). 1991. Chiang Mai University Journal of Science 4(1): 45-61.
- [6] Baral K., Roy B., C., Rahim K., M., B., Chatterjee H., Mondal P., Mondal D., Ghosh D and Talekar N., S. Socio-economic parameters of pesticide use and assessment of impact of an IPM strategy for the control of eggplant fruit and shoot borer in West Bengal, India. 2006. Technical Bulletin No. 37. AVRDC publication number 06-673. AVRDC - The World Vegetable Center, Shanhua, Taiwan. 36 p.
- [7] Boopal K., Arya V., V., Rami R., P., V., Hanur V., S. Potato a suitable alternative host for brinjal fruit shoot and fruit borer *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). 2013. International Journal of Agricultural Science and Research. (3): 179-184.
- [8] Dover M., J., Croft B., A. Getting tough: Public policy and the management of insecticide resistance. 1984. World resource institute. Stud. 1 Washington DC.
- [9] FAO. Eggplant integrated pest management an ecological guide. FAO inter-country programme for integrated pest management in vegetables in South and Southeast Asia. 2003. Bangkok, Thailand. 177 p.
- [10] Khorsheduzzaman A., K., M., Alam M., Z., Rahman M., M., Khaleque M., M., A., Ismail H., M., M. Biochemical basis of resistance in Eggplant (*Solanum melongena* L.) to *Leucinodes orbonalis* Guenee and their correlation with shoot and fruit infestation. 2010. Bangladesh Journal of Agricultural Research. 35(1): 149-155.
- [11] Kumar P., Johnsen S. Life cycle studies on fruit and shoot borer (*Leucinodes orbonalis*) and natural enemies of insect-pests on eggplant (*Solanum melongena*). 2000. Journal of Applied Biology. 10: 178-184.
- [12] Lester R., N., Daunay M., C. Diversity of African vegetable *Solanum* species and its implications for a better understanding of plant domestication. 2003. In: Knüpffer H. and Ochsmann J. (eds). Rudolf Mansfeld and plant genetic resources; Schriften zu Genetischen Ressourcen (Deutschland). 22: 137-152.
- [13] Mainali M., P. Biology and management of eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae): a review. 2014. Int J Appl Sci Biotechnol, Vol 2(1): 18-28.
- [14] Mehto D., N., Singh K., M., Singh R., N., and Prasad D. Biology of brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. 1983. Bulletin of Entomology. 24 (2), 112-115.
- [15] Mondal A., H., Quayam M., A., Faruki S., I. Development of the brinjal (*Solanum melongena*) shoot and fruit borer, *Leucinodes orbonalis* Guen. (Lepidoptera: Pyralidae). 2012. Development Compilation. 7(2): 41-47.
- [16] Naresh J., S., Malik V., S., Balan J., S., Khokhar K., S. A new record of *Trathala* sp., a larval endoparasite attacking brinjal fruit borer, *Leucinodes orbonalis* Guenee. 1986. Bulletin of Entomology, New Delhi. 27(1): 74.
- [17] Niranjana M., P., Nandihalli B., S. Crop loss estimation caused by *Leucinodes orbonalis* Guenee in potato. 2002. Pest Management Horticultural Ecosystem. 9: 59-62.
- [18] Onekutu A., Omoloye A., A. Planting date of garden egg *Solanum gilo* and egg fruit and shoot borer *Leucinodes orbonalis* infestation. 2012. Nigerian Journal of Horticultural Science. 17: 14-19.
- [19] Onekutu A., Omoloye A., A., Odebiyi J., A. Biology of the Egg fruit and Borer (EFSB), *Leucinodes orbonalis* Guenee (Crambidae) on the Garden Egg, *Solanum gilo* Raddi. 2013. Journal of Entomology.

- [20] Prabhat K., Johnsen S. Life cycle studies on fruit and shoot borer (*Leucinodes orbonalis*) and natural enemies of insect-pests of eggplant (*Solanum melongena*). 2000. *Journal of Applied Biology* 10 No. 2 pp. 178-184.
- [21] Rahman M., M. Vegetable IPM in Bangladesh. Department of Entomology. Bangabandhu Sheikh Mujibur Rahman 2006. Agricultural University Gazipur, Bangladesh (Available at: <http://ipmworld.umn.edu/chapters/rahman.htm> Retrieved on February 2, 2012).
- [22] Rahman M., M., Mahmud M., T., M., Hasan M., F., Habib S., H. and Kausar H. Study on the growth and development of brinjal shoot and fruit borer with different diets. 2011. *African Journal of Biotechnology* Vol. 10(57), pp. 12299-12302.
- [23] Rajneesh H., Nandihalli B., S. Evaluation of integrated pest management modules in the management of *Leucinodes orbonalis* L. in potato. 2009. *Karnataka Journal of Agricultural Sciences*, 22(3): 716-717.
- [24] Sundaramurthy V., T. The impacts of the transgenes on the modified crops, non-target soil and terrestrial organisms. 2010. *African Journal of Biotechnology*. 9 (54): 9163-9176.