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Biological parameters of *Leptoglossus membranaceus* Fabricius, 1781 (Heteroptera: Coreidae) Cucumber pest (Tokyo F1 and poinsett varieties) in the rainy season in Daloa (Côte d'Ivoire)

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Abstract
Leptoglossus membranaceus attacks the cucumber. Its control requires knowledge of biological parameters. The study was carried out in Daloa first by monitoring insects in cages in order to study their reproductive and survival potential. The results show that the female lays 180 ± 35 eggs. The average length of the laying period is 98.76 ± 13 days. The incubation of the eggs averages is 7, 33 ± 0, 58 days. The mean fertility rate is 91.97 ± 4.08%. Insect survival rate is 17.03%. The sex ratio is 0.77 in favour for the males. The lifespan 129.4 ± 28.23 days for males and 105.9 ± 21.37 for females. The development cycle is 33.41 ± 2.52 days. This insect causes many damage to the cucumber. A healthy plant produces 14.1± 2.26 fruits and an attacked plant produces 7.93±1.80 fruits. The work will allow the control of this insect through the control of the biological cycle.

Keywords: Biological parameters, cucumber, Coreidae, Daloa, insects, pest

1. Introduction

Cucumber (*Cucumis sativus*) is an annual, herbaceous, creeping, vegetable plant belonging to the Cucurbitaceae family. It used to grow naturally in the Himalayas and was domesticated for the first time in India at least 3,000 years ago.

Its production was estimated in 2013 at 71 365 573 tons and China is the world's largest producer with 76% [1]. During 2002, Africa produced only 507,000 tons from 25,000 ha, representing just less than 1.5% of world production. In Côte d'Ivoire the production is estimated at about 30 000 tons in 2009 [2]. This production remains low due to insect's attacks especially *Leptoglossus membranaceus*. The impact of adults and larvae of this insect are sucking biting insects. It feeds on sap of the plant, which considerably dehydrates it, and can cause stunted growth and even death. Their attacks can lead to slower growth and even die of plants. These stings also cause fruit malformation, reduced flowering and delayed development of new shoots [3]. The larvae of stages 2 to 5 and the adults of this insect feed by biting leaves, stems and fruits. Damage is then caused by feeding punctures on flower buds, which may lead to abortions on the young fruit, causing them to fall. These punctures on fruits, pods or seeds cause discoloration, changes in surface consistency and stains in the flesh [4]. Their feeding stings, sometimes accompanied by toxins, cause swellings and holes on stems, leaves and fruit as well as deformations and stunting of the apexes [5]. Unfortunately, few data exist on the biological parameters of this insect. Actually, however, knowledge of its biological parameters are important for the implementation of new reasonable and effective control methods against this insect. In order to contribute to the improvement of cucumber yield, this study was undertaken to determine the biological parameters of *L. membranaceus*, with the aim of successfully controlling this pest. Specifically, this study aims to:

- Determine female fertility, egg-laying period, sex ratio, adult longevity and identify the infective stages through the study of the reproductive cycle of *L. membranaceus*.
- To assess the impact of *L. membranaceus* attacks on cucumber production.

2. Materials and Methods

2.1 Study site

The survey was carried out in Daloa, (06° 52'38" N and 06° 27'00" W), a town located in the west of Côte d'Ivoire. This zone is characterized by a sub-equatorial, hot and humid climate with two seasons. The rainy season goes from February to October, and a dry season from November to January (ANADER, 2018). During the handling (April to September), the average temperature, rainfall and relative humidity of the region were respectively 27.57 °C; 25.66 mm and 68.5%. The average temperature during the year varied by 2.8 °C and the average annual rainfall was 1317 mm.

2.2 Methodology

2.2.1 Bioecology data

The study of bio-ecological parameters was carried out in semi-natural conditions in cages (70 cm wide and 160 cm high) containing a cucumber plants. The cage was covered with white muslin with a mesh size of 0.50 mm (Figure 1). These cages have an opening lined with adhesive strips to prevent the exit of insects reared on the cucumber plant. Cylindrical boxes 10 cm in diameter and 20 cm in height perforated were used to transfer insects from one cage to another.

Fig 1: Experimental plots

2.2.2. Determination of biological parameters

The biological parameters studied were adult lifespan, pre-copulation, pre-oviposition and oviposition periods. The number of eggs laid per female, egg incubation time, fertility rate, duration of larval stages, survival rate and sex ratio were also estimated.

2.2.2.1. Pre-copulation and pre-oviposition periods

Thirty (30) pairs of imago's of *L. membranaceus*, derived from the imago molt, were isolated. Each pair was immediately put in a cage containing a cucumber plants with fruit. The sumpling were made a long period in semi-natural conditions. Insects were followed until the first mating was observed. The mating date (Ja) was recorded and then the average pre-mating period was determined.

$$\text{Average pre-copulation period (days)} = \frac{\Sigma xini}{\Sigma ni}$$ xi =Ja-Jo; ni : number of couples ja= moulting date

The insects were observed until the first egg laying was seen in each cage. The date of first oviposition (Jpp) was recorded and then the mean preoviposition period was determined.

$$\text{Mean pre-oviposition period (days)} = \frac{\Sigma oifi}{\Sigma fi}$$ oi = Jpp - Ja; fi : number of females

2.2.2.2 Number of eggs laid per female, laying period and life span of adults

The pairs formed were monitored and as soon as the first oviposition was observed, each pair was removed and placed in a new cage to allow the insects to settle on the cucumber plants and fruits of the new diet. The number of eggs laying by the female on the undersides of the leaves and on the tendrils was recorded each day. The proving was continued until the females died. The date of the last egg laying (Ddp), the average laying period and the total of eggs laid per female were determined.

$$\text{Average egg laying period (days)} = \frac{\Sigma pifi}{\Sigma fi}$$

pi = Jdp - Jpp; fi: number of females; Jpp: the date of first oviposition

Finally, the lifespan is the time between the date of hatching of the eggs (Jo) and the date of death (Dm). The average life spans of the females and males making up the 30 pairs were calculated.

$$\text{Average life span (days)} = \frac{\Sigma divi}{\Sigma vi}$$ di =Jm - Jo; vi: number of males or females

2.2.2.3. Incubation period and egg fertility rate

The date of laying (Dp) of the eggs was noted. For each 30 females, the number of eggs hatched was recorded and the average fertility rate was calculated.

$$\text{Average fertility rate (\%)} = \frac{\Sigma tifi}{\Sigma fi} \text{ X } 100$$

$$ti = \frac{\textit{Number of eggs hatched}}{\textit{Number of eggs laid}}$$ fi : number of females

2.2.2.4. Larvae survival rate, development time and sex ratio

Observations on larvae survival, development time and sex ratio were made from the offspring of 30 pairs formed. First larvae hatched were isolated in a cage containing a cucumber plant. The cages were monitored daily. The dates of successive moults were recorded. The average survival rate was calculated for each larval stage.

$$\text{Average larval survival rate (\%)} = \frac{\Sigma sifi}{\Sigma fi} \text{ X } 100$$ fi: number of females

$$Si = \frac{\textit{Number of larvae in the next stage}}{\textit{Number of larvae in the previous stage}}$$

The transition from one larval stage to the next is marked by a moult followed by the rejection of an exuviate. The size of this exuvia is always larger than that of the last stage. The average duration of passage from one larval stage to the next was calculated and expressed in days. After the imaginary moult, the insects reaching adulthood were grouped by sex. The average total development time, which includes the egg incubation period (Pi), the length of the larval period (Dl) and the time from imago to adult (Dim), was calculated.

$$\text{Average total development time (days)} = \frac{\Sigma biki}{\Sigma ki} X\ 100$$

bi = Pi + DI + Dim ki: adult population size

Then the sex-ratio was calculated for the descendants of each female, according to the formula

$$\text{Sex ratio} = \frac{\text{Number of females}}{\text{Number of males}}$$

2.2.3. Impact of *L. membranaceus* attacks on cucumber production

To estimate the damage on cucumber production, 60 plants were randomly selected from the experimental plot and covered with muslin. Assisted pollination was carried out in order to obtain fruit. From the 60 plants, 30 were repeatedly attacked by *L. membranaceus* and the remaining 30 remained protected without attack. The number of fruits of each group of plants (attacked and healthy plants) was counted and weighed. Pi : Number of plants. fi: Number of fruits.

$$\text{Average number of fruits per plan} = \frac{\Sigma fi}{\Sigma\ Pi}$$

$$\text{Loss rate (\%)} = \frac{\Sigma fipia}{\Sigma fipis} X\ 100$$

Pia: Number of plants attacked by *L. membranaceus*

Pis: Number of per healthy plant

2.2.4. Statistical analysis and data processing

Analyzes were carried out with Excel version 2013 and the paleontological software Past 3. Two-factor have been analyzed and classified by the Newman Keuls system.

3. Results

3.1. Pre-copulation and pre-oviposition periods

The first matings were observed on the 6th, 7th and 8th days after the moulting. Therefore 7.85 ± 1.38 days as an average pre-copulation period. The first eggs were laid on the 8th; 9 and 10th days after mating. Therefore 9±0.66 days as an average pre-oviposition period (Figure 2).

3.2. Number of eggs laid per female, laying period and adult lifespan

The number of eggs lay varies from 4 to 28 with an average of about 13 eggs per strand or lay. The female lays between 94 and 249 eggs. Therefore 180 ± 35 eggs as an average. The laying frequency is 2 to 28 eggs each 2 thru 3 days. The average length of the laying period was 98.76 ± 13 days. The average lifespan of females was 105.9 ± 21.37 days and that of males 129.4 ± 28.23 days.

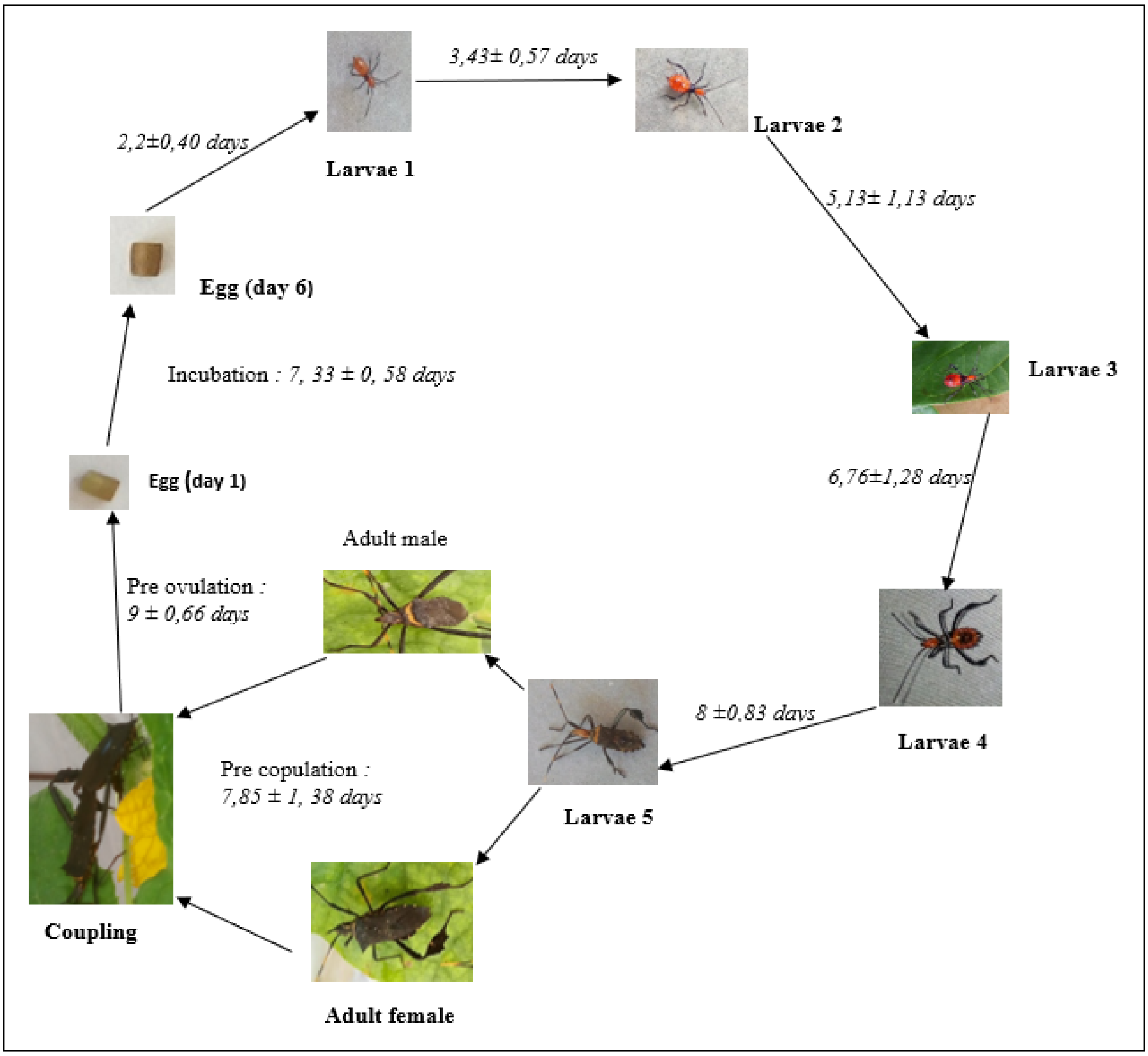


Fig 2: Development cycle of *Leptoglossus membranaceus*

3.3 Incubation period and egg fertility rate

The incubation of the eggs lasted 6 to 12 days. There 7.33 ± 0.58 days as an average period. The temperature of the cages varied from 26.5 to 32.1 °C with an average of 29.45 ± 0.9 °C. The comparison between the internal temperature of the cage and the duration of the incubation showed that these two parameters evolve in opposite directions: the number of days necessary for the hatching of the eggs decreases when the temperature increases. Out of a total of 249 ± 40 eggs laid by a female, 229 ± 25 eggs hatched, either an average fertility rate of 91.97 ± 4.08%.

3.4 Larval survival rate, development time and sex ratio of *L. membranaceus*

Five larval stages (L1, L2, L3, L4 and L5) were observed. The lengths of the larval stages varied from 2.2 ± 0.80 days (L1) to 8 ± 1.20 days (L5). That to say a tern of larva's period is 25.56 ± 2.67 days. Stage 1 larvae were obtained after the eggs hatched. Survival rates ranged from 44.54% (L1) to 97.50% for the L5 stage. The larva goes by from 2 ± 0.5 mm L1 to 13 ± 1.3 mm L5 (Table 1). To change the stage, moulting is necessary. The number to larvae decreases from stage L1 to stage L3 and then remains almost stable from L3 to L5 (Figure 3). The larvae are attacked by spiders (Arthropods) and several types of ants (Hymenoptera). In addition to these natural enemies, climatic hazards such as rain and wind prevail. The mortality rate is higher in young larvae, they are more vulnerable. Only 39 over 229 per female larvae reached the adult stage when climatic factors were propitions, whether 17, 03% of survival rate in general. The total development time for *L. membranaceus* (from egg to adult) is 33.41 ± 2.52 days. The adults obtained are divided into 22 males and 17 females, a sex ratio of 0.77 in favor of males. The duration of larval development (from L1 to adults) decreases with increasing temperature (Figure 4A). As for the relative humidity of the air, it does not influence the larval lifespan (Figure 4B).

Table 1: Period length and survival rate of larval stages of *L. membranaceus*

	Stage 1 larva	Stage 2 larva	Stage 3 larva	Stage 4 larva	Stage 5 larva
Duration of larval period (days)	2,2± 0,40	3,43± 0,57	5,13± 1,13	6,76± 1,28	8 ± 0,83
Average number of Strength	229± 25	102± 4,2	55± 2,7	46± 1,74	40± 0,8
Survival rate (%)	44, 54%	53,92	83, 63	86,95%	97, 50
Average length (mm)	2±0,5	4±0,6	8±0,4	10±0,8	13±1,3

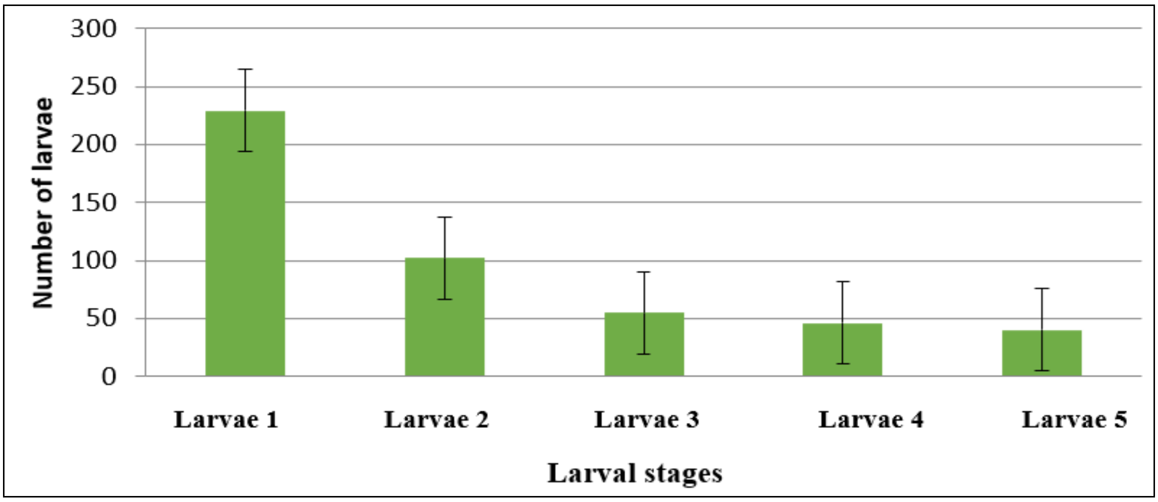
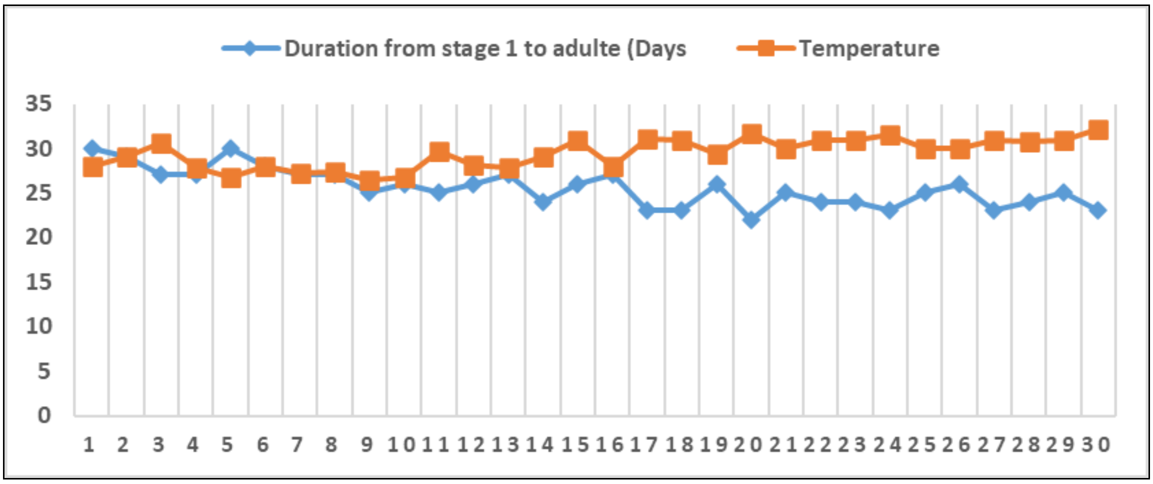
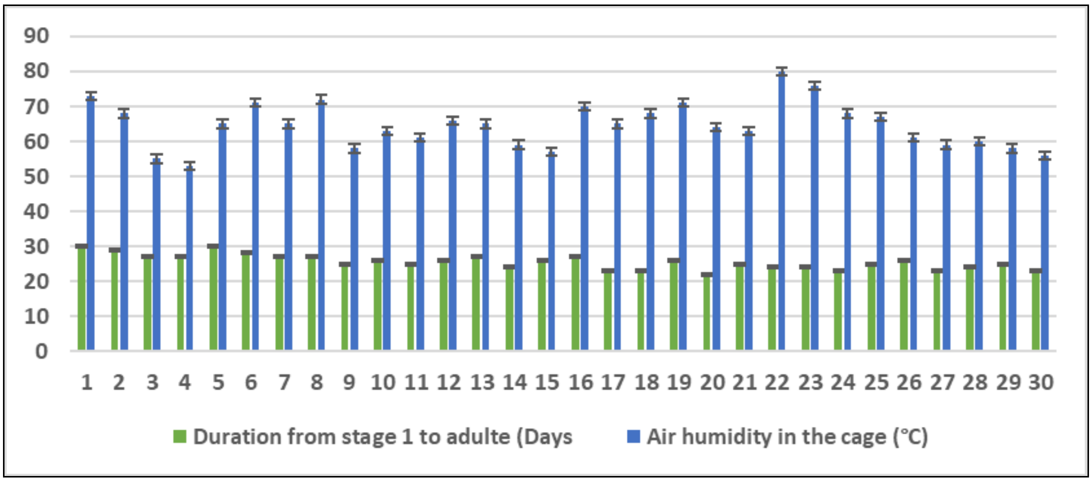


Fig 3: Variation in the number of larvae according to larval stages



A.



B

Fig 4: Duration of larval stages as a function of the temperature and relative humidity of the air inside the cages. **A:** Duration of larval stages as a function of internal cage temperature **B**: Duration of larval stages as a function of relative air humidity

3.5. Impact of *L. membranaceus* attacks on cucumber production

The number of fruits of healthy plants is higher than those of the attacked one. A healthy plant produces on average 14.1 ± 2.26 fruits compared to 7.93 ± 1.80 for a plant attacked by *L. membranaceus* in the rainy season (Figure 5). Analysis of variance (Kruskal-Wallis) showed that there is a significant difference between the number of fruits at the 5% threshold ($p < 0.05$) (p = 1.806. 10-09). The rate of loss in number of fruits due to repeated attacks by *L. membranaceus* is 59.34%. The average mass of a healthy fruit is 656.2 ± 26.22 g compared to 328.98 ± 15.12 g for a fruit attacked by *L. membranaceus,* i.e. 50.13% loss.

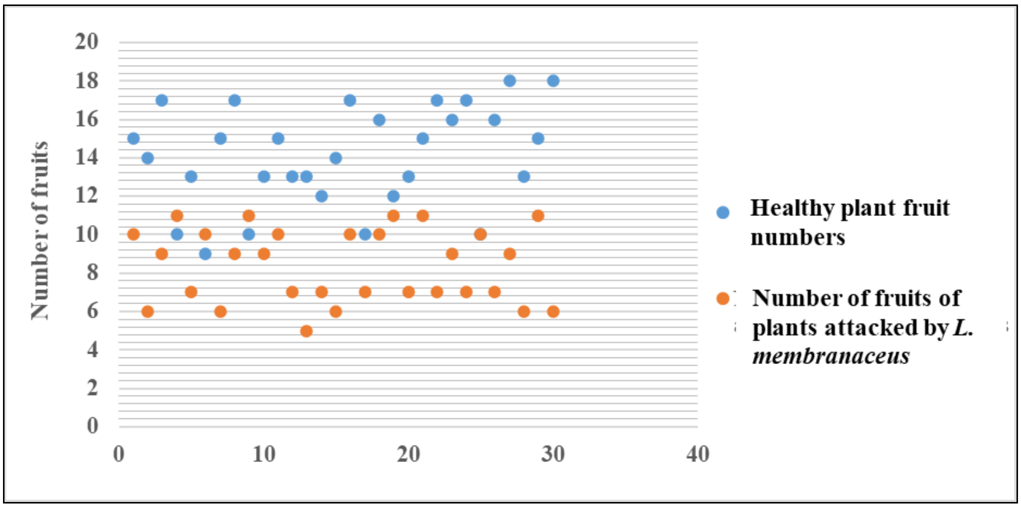


Fig 5: Number of fruits per healthy shoots and shoots attacked by *L. membranaceus*

4. Discussion

The pre-copulation and pre-oviposition periods are 7.85 ± 1.38 days and 9 ± 0.66 days, respectively. These periods observed in the study are different from those obtained by Tano et al (2011) [6] in *Pseudotheraptus devastans* (3.43±0.26 days for pre-copulation and 5.10 ± 0.60 days for pre-oviposition). They are also different from those observed by Dabiré (2001) [7] in another Coreidae: *Clavigralla tomentosicollis* Stäl. (3.34 days for pre-copulation and 4.10 days for pre-oviposition). The mean number of eggs laid by the female of *L. membranaceus* (180 ±35 eggs) is higher than that obtained by Way (1953) [8] in P. wayi (74 eggs). The egg-laying time (98.76±13 days) is diffent to that obtained by Tano 2012[9] in *C. lameensis* (107.56±18 days). Concerning the lifespan of adults of *L. membranaceus*, observations revealed that males live longer (129.4 ± 28.23 days) than females (105.9±21.37 days). These results are similar to those of Tano (2011)[6] and Way (1953)[8] who observed a longevity of 136.9 ± 22.84 days and 117.9 ± 18.42 days in males and females of *P. devastans*, respectively, 84 days and 73 days in males and females of *P. wayi*. The incubation period for eggs of *L. membranaceus* was 7.33 ± 0.58 days. Similar results were obtained in *P. wayi* (6-9 days) by Way (1953) [8] and in *Amblypelta cocophaga* (6-8 days) by Brown (1958) [10]. The mean egg fertility of *L. membranaceus* (91.97 ± 4.08%) is similar to that observed in the Coreidae species such as *Leptoglossus gonagra* (93.4%) (Amaral-Filho & Storti-Filho, 1976) [11] and *Veneza stigma* (91.66%) (Amaral-Filho & Cajueiro, 1977) [12]. Caldas et al (2000) [13] recorded a higher fertility rate in *Corecoris dentiventris* (99.63%). The lowest larval survival rates are observed in the 1st and 2nd instars. These results are similar with those obtained by Tano 2011[6] in *P. devastans*. According to Panizzi & Parra (1991) [14], survival of early instar larvae depends on the energy accumulated by the previous instar. For the same authors, high mortality could be explained by a low capacity to metabolize, for the first time, toxins or non-nutritive compounds contained in the tapped sap. Another raison of this mortality would be related to the large number of larvae of *L. membranaceus*, which would lead to intraspecific competition, following a limitation of trophic resources, as indicated by Sanon & Ouédraogo (1998) [15] in *Callosobruchus maculatus* and Aboua (2004) [16] in *Dinarmus basalis* and *Eupelmus vuilleti*. Concerning the life cycle, five larval stages were recorded in *L. membranaceus*. The length of the larval period ranged from 2.2 ± 0.80 days for the first instar to 8 ± 1.20 days for the fifth instar. the results are similar to those of Way (1953) [8], Dabiré (2001) [7] and Mille (2003) [17] who reported respectively that the development of *P. wayi*, *Clavigralla tomentosicollis* and *Amblypelta bilineata* includes 5 larval instars. In *L. membranaceus*, the duration of the 5th larval instar is longer than the 1st instar. This difference has been observed by Van Reenen (1973) [18] in the same species and other Coreidae species such as *Leptoglossus gonagra* (Amaral-Filho & Storti-Filho, 1976) [11], *Corinocerus sanctus* (Amaral- Filho, 1986) [19], *L. zonatus* (Panizzi, 1989) [20], *L. fulvicornis* (Wheeler & Miller, 1990) [21] and *C. tomentosicollis* (Dabiré, 2001) [7]. The total larval development time of *L. membranaceus* (from egg to adult) is 33.41 ± 2.52 days. It falls within the range defined by Way (1953) [8] in *P. wayi* (26-40 days). Concerning the incidence of *L. membranaceus* attacks on cucumber production, losses are greater than 50%. These results are similar to those of Gnanasekaran et al. 2005[22] obtained on sesame where *Asphondylia catalaunalis* caused losses ranging from 25 to 100% yield.

5. Conclusion

The study of biological parameters showed that *L. membranaceus* is a heterometabole with a development cycle consisting of 5 larval instars with low survival rates for the l, and 2. The total length of the development cycle of this pest is 33.41 ± 2.52 days and males live longer than females. Females of *L. membranaceus* lay an average of 180 ±35 eggs under semi-natural conditions. The study determined the duration of egg laying, adult longevity and that the developmental stages of the insect are all pests of cucumbers but stages 4 and 5 remain the most voracious as the adult. Thus, knowledge of the development cycle of *L. membranaceus* would enable appropriate control methods to be implemented.

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