Biological Aspects and Predation of *Pygidicrana v-nigrum* (Dermaptera: Pygidicranidae) Against the Mediterranean Fly

ABSTRACT

The biological development and quantification of *Pygidicrana v-nigrum* consumption was evaluated taking as prey the immature stages of *Ceratitis capitata*. The dermapterous insect, when ingesting *C. capitata* larvae, reached its nymphal period, on average, at 228 days. The lowest nymphal viability of *P. v-nigrum* occurred in its 1st instar when fed with larvae, reaching a value of 85,0%. The food provided did not influence the size of this predator in terms of sex; however, food predation by larvae provided more females. The survival of the *P. v-nigrum* female is greater than that of the male regardless of the food consumed. The number of eggs per oviposition of *P. v-nigrum* was higher when feeding on pupae. The predatory consumption of *P. v-nigrum* increased when fed with *C. capitata* larvae and pupae regardless of the nymphal and adult phases. In view of the results, it can be concluded that the biological development of the predator is not affected when provided with the larval and pupal stages of *C. capitata*.

Keywords: Fruticulture, Ceratitis capitata, *Dermapterous, biological control*

1. INTRODUCTION

Dermapterous insects are terrestrial insects of nocturnal habits, with about 1800 species distributed in the tropical and subtropical regions [1], including several species with predatory habits. In this way, studies have investigated the behavior and the biological

development of the genera *Euborellia* and *Doru*, with numerous agricultural pests in the egg stages and young forms in Coleoptera, Lepidoptera, and Hemiptera [2, 3, 4, 5, 6, 7], and Lepidoptera [8, 9], respectively. These are commonly known as in Brazil as “tesourinhas” (“earwig”), because they have two tweezer-like structures at the end of the abdomen.

In this context, the tephritids are considered the main pests of the world fruticulture, whose direct damage affect production, including costs related to monitoring and control or eradication; while indirect damages are caused by the restriction imposed by certain importing countries [10]. The species of major importance belong to the genera *Ceratitis* and *Anastrepha*. Among the species, we highlight Ceratitis capitata Wiedemann (Diptera: Tephritidae), commonly known as the Mediterranean fly, found only in Brazil.

There is prominence for species *Pygidicrana v-nigrum* Serville, of the family Pygidicranidae, whose dermapterous insects seek shelter in jackfruit and banana trees. [11] studied this dermapterous insect with eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Crambidae) and found an average nymphal period of 237.20 days, with nine instars, showing proper development. Thus, it is necessary to study the biology and ethology of this dermapterous species [12] on significant pests such as *C. capitata*. The knowledge of the biological aspects of this dermapterous insect regarding its feeding is essential due to the influence on its biological cycle, being found in different environments playing an important role of arthropod pests. The research aimed to analyze the development of biological characteristics and the ability of *P. v-nigrum* predation when fed with immature stages of *C. capitata*.

2. MATERIAL AND METHODS

The research was carried out in the Laboratory of Entomology (LEN), Campus II of the Federal University of Paraíba (UFPB), Areia, Paraíba State, Brazil. The experiment was performed under laboratory conditions with 25 ± 2 ºC temperature, 70,0 ± 10,0% R.H. and 12 h photophase.

2.1 Rearing of *Pygidicrana v-nigrum* and the Mediterranean fly *Ceratitis capitata*

The nymphs and adults were kept in transparent plastic containers (6,0×8,0 cm) containing moistened absorbent paper and an artificial diet consisting of the following ingredients: milk powder (130 g), beer yeast (220 g), initial ration for meat chicken (350 g), wheat bran (260 g), and nipagin (40 g). The eggs were laid and fixed anywhere in the container by the female, who protects them from oviposition until hatching of the nymphs. Food exchange was carried out weekly, where there was also an exchange of the absorbent paper, leaving only the lid of the container, where 70,0% alcohol was applied to avoid the emergence of microorganisms.

The Mediterranean fly was established in the LEN/CCA in the abiotic conditions already mentioned above. Their larvae were fed an artificial diet composed of beer yeast (120 g), raw carrot (600 g), and nipagin (5 g). The adults were kept in cages and fed daily with a solution of 10,0% honey in distilled water, provided in cotton placed on the cage (50×50×60 cm) during the oviposition period.

2.2 Biological Development of Earwig *Pygidicrana v-nigrum* on *Ceratitis capitata*

The bioassays were organized in a completely randomized design with two treatments containing 20 nymphs of *P. v-nigrum*, one individual per replicate, in each treatment. The feed (prey) used for experimentation were 3rd instar larvae and pupae of *C. capitata* <24 h old and unviable at low temperatures, leading them to death. These were supplied in enough quantity according to the development of the earwig, as defined in preliminary tests. To evaluate the biological characteristics, the following parameters were assessed: nymphal duration and viability, adult insect size, sex ratio, adult survival, and egg production.

2.3 Predation Capacity of Earwig on *Ceratitis capitata*

We used 190 specimens of earwig, 110 and 80 individuals for the food of 3rd instar larvae and pupae of *C. capitata*, respectively. The nymphs and adults of the predator were individualized in Petri dishes (9.0×1.5 cm), and fed with 3rd instar larvae or pupae of *C. capitata*. Food was supplied in a quantity higher than that which each instar or stage of the predator consumed daily, so that the number of 3rd instar larvae and pupae consumed could be counted, evaluating the predation capacity per day of consumption. This number of 3rd instar larvae and supplied eggs was observed daily in preliminary trials.

2.4 Statistical Analysis

The experiments were arranged in a completely randomized design (CRD). In research I, biological aspects of the predator, the repetition consisted of larvae or pupae of the Mediterranean fly, having 20 replicates per food. The sex ratio was calculated by dividing the number of females by the total number of individuals (females + males) according to [13]; the adult survival probability was analyzed from non-parametric test and estimated by the Kaplan-Meier survival test (Log-Rank test), using the MedCalc® software; and the means of the analysis of variance of the other characteristics were compared by the F test at 5,0% probability level. The data were analyzed by the Assistat 7.7 program [14]. In research II, predation capacity, the repetition consisted of 3rd instar larvae or pupae of Mediterranean fly, with 15 repetitions per food. Predator consumption was measured using regression analysis.

3. RESULTS AND DISCUSSION

Biological Development of *P. v-nigrum* Fed with *C. capitata*

The number of instars of *P. v-nigrum* corresponded to nine during their nymphal period, although some individuals presented seven and eight stages regardless of food (Table 1). This behavior is related to the adequacy of food, which can result in the lengthening or reduction of the number of instars, since the development of insects undergoes great

variations caused by biotic and/or abiotic factors. In [12], it was found that species *Tagalina papua* Bormans (Dermaptera: Pygidicranidae) presented six instars, belonging to the same family of the species in question.

Table 1. Duration (days) and viability (%) of the stages of *Pygidicrana v-nigrum* fed with larvae and pupae of *Ceratitis capitata*

Duration (days)									
Food	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Larvae	21.46	22.40	24.40	27.06a	25.60a	26.40a	34.40a	35.27a	38.50a
Pupae				22.66b	23.20a	28.06a	32.93a	40.33a	31.50a
CV (%)				22.13	21.32	24.85	20.72	28.64	8.72
Viability (%)									
Larvae	85.0	88.2	93.3	100.0	100.0	100.0	100.0	100.0	100.0
Pupae	00.0	00.0	00.0	95.0	94.7	100.0	100.0	100.0	100.0

Means followed by the same letter in the column do not differ statistically.

Table 1 shows that 1st to 3rd instar nymphs of the predator did not consume pupae, differently when supplied with larvae of this tephritid (Table 1). The non-consumption by early nymphs is due to the fragility of their oral apparatus in contrast to the stiffness of the integument of the pupa, making it impossible to break it for ingestion. According to [15], for an insect to feed, several characteristics of the food should be analyzed, among these are the color, shape, size, temperature, sound, texture, and hardness. In the 4th instar there was statistical difference. Nymphs that consumed pupae had a shorter period (22.66 dayson average). This reduction of *P. v-nigrum* instar may have occurred due to ingestion of the previous food (standard diet), as it provides the necessary nutrients for proper development.

The mean nymphal viability of the dermapterous species varied from 85,0% to 100,0% for the larvae food and between 94.7% and 100,0% for pupae, inferring high viability regardless

of the food consumed. Understanding the failure of the nymphs (1st, 2nd and 3rd instars) regarding the pupae food, mentioned above, which resulted in 00.0% viability, the natural alternative of this predator would correspond to the search for prey with soft tegument; in addition, dermapterous species are omnivore. In this context, the results of this research confirm that the prey is a suitable nutritional source for *P. v-nigrum* development.

There was no statistical difference for the size of the predator, in its adult stage, regardless of feeding with pupae and larvae of *C. capitata* (Table 2). The females reached a range of 3.0 to 4.2 cm and 3.3 to 4.2 cm when fed with larvae and pupae, respectively; while males presented a range of 3.2 to 3.9 cm in both foods. This result of individuals larger than 4.0 cm exceeds what has already been reported in the literature for said order Dermaptera. Researchers [12], working with species *T. papua*, found a length of 2.9 to 3.6 cm. The *P. v-nigrum* sex ratio regarding food is within the expected and suitable values for laboratory breeding, with the ratio of one male per female (1:1) being sufficient for reproductive success.

Table 2. Size (cm) and sex ratio of *Pygidicrana v-nigrum* when fed with larvae and pupae of *Ceratitis capitata*

Food	Size		Sex Ratio
	Female	Male	
Larvae	3.48 a	3.47 a	0.60
Pupae	3.73 a	3.61 a	0.46
CV (%)	9.81	7.21	

Means followed by the same letter in the column do not differ statistically.

The survival time of the dermapterous when feeding on stages of *C. capitata* was higher for adult females than for male insects (Fig. 1). In female insects, at 50 days, approximately 70,0% of the individuals was alive; at 80 days, there were only 40,0% of the initial amount; and reaching 115 days, there were 20,0% adult females. At the end of longevity, *P. v-nigrum*

females averaged 160 and 163 days when consuming larvae and pupae, respectively. Regarding male survival, it was found that at 50 days, there were approximately 70,0% of the individuals; at 80 days, there was only 40,0% of the initial amount; and at 115 days, this value was 20,0%.

Males showed a change in survival behavior around 60 days between feeding with pupae and larvae, the latter causing prolongation in survival, but still, this variation being very low. The longevity found for the species in question was found in the literature for the species *Doru luteipes* Scudder (Dermaptera: Forficulidae), *Euborellia peregrine* Mjöberg, *Euborellia annulipes* Lucas (Dermaptera: Carcinophoridae), when coming from insect-pests.

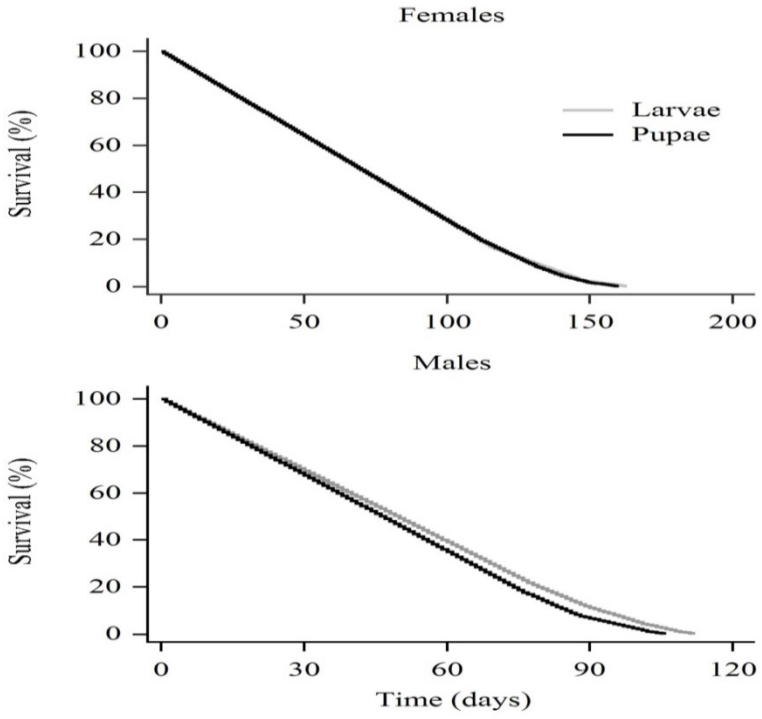

Fig. 1. Probability of adult survival for *Pygidicrana v-nigrum* fed with larvae and pupae of *Ceratitis capitata*

As for the number of eggs per oviposition for species *P. v-nigrum* fed with larvae and pupae of the Mediterranean fly, there was statistical difference (Table 3). Females fed with larvae produced, on average, 49.25 eggs while those that ingested pupae produced, on average, 101.75 eggs. Egg production is related to the accumulation of energy and nutrients, the quantity and quality of the food ingested, explaining the reproductive behavior of the insect. According to [16], in the production of eggs or progeny, there is involvement of energy and nutrient accumulation, this production also being affected by both biotic and abiotic factors.

Table 3. Number of eggs per oviposition of *P. v-nigrum* fed with different stages of *C. capitata*

Food	Number of eggs per oviposition
Larvae	49.25b
Pupae	101.75a
CV (%)	44.23

Means followed by the same letter in the column do not differ statistically.

The occurrence of a gradual oviposition of *P. v-nigrum* females was observed for days, during which time they were fed with pupae, occurring in the interval of 4 to 11 days, and with larvae, in the interval of 4 to 5 days. There was maternal care of the *P. v-nigrum* female on the oviposition, where it remained always above or beside the egg, also licking the eggs. [12] believe that in the act of licking them, the mother releases secretions that at the same time that humidify also disinfect the eggs.

During the incubation time, another observed characteristic was that with the occurrence of disturbances, the *P. v-nigrum* female can consume all its eggs, regardless of its time of incubation. This behavior possibly occurred due to the handling of cleaning, humidification, and exchange of food in the breeding containers [9]., working with *D. luteipes*, noticed a

decrease in viability when the male was left in contact with the female after intercourse, attributing to the male-caused disturbance the female's consumption of her eggs.

Predation of *P. v-nigrum* on *C. capitata*

The predator consumption was increasing when fed with larvae and pupae of *C. capitata* (Fig. 2). Early instar (1st, 2nd and 3rd) *P. v-nigrum* consumed only larvae, as these were not successful with the pupae food. It was verified that 4th and 5th instar nymphs had greater consumption of larvae than pupae at 35 days. 6th instar nymphs consumed more pupae at the end of their stage. It was verified that the predation of the 7th and 9th instar stages was higher for larvae, but there was no significant difference. 8th instar nymphs had similar predatory behavior. Regarding male and female adult consumption, there was higher larvae consumption in *P. v-nigrum* females, while male insects maintained close consumption, although they consumed more larvae.

The behavior of this dermapterous species in the present study makes it a possible potentiator in the consumption of the stages of this world pest. Its increasing consumption regardless of the stage shows its voracity in constant search to meet its nutritional needs; in addition, it consumed more than necessary, that is, there was accumulation of reserves to aid in its nymphal development, ecdysis and reproductive processes.

During the experiment, the daily consumption behavior by the predator was inconsistent, reaching peaks of daily high consumption, but interspersed with days of low and even lack of consumption due to its food satiation. The same behavior of consumption was found by [17] with the species *E. annulipes* when fed with eggs and caterpillars of *Spodoptera frugiperda* Smith, 1797.

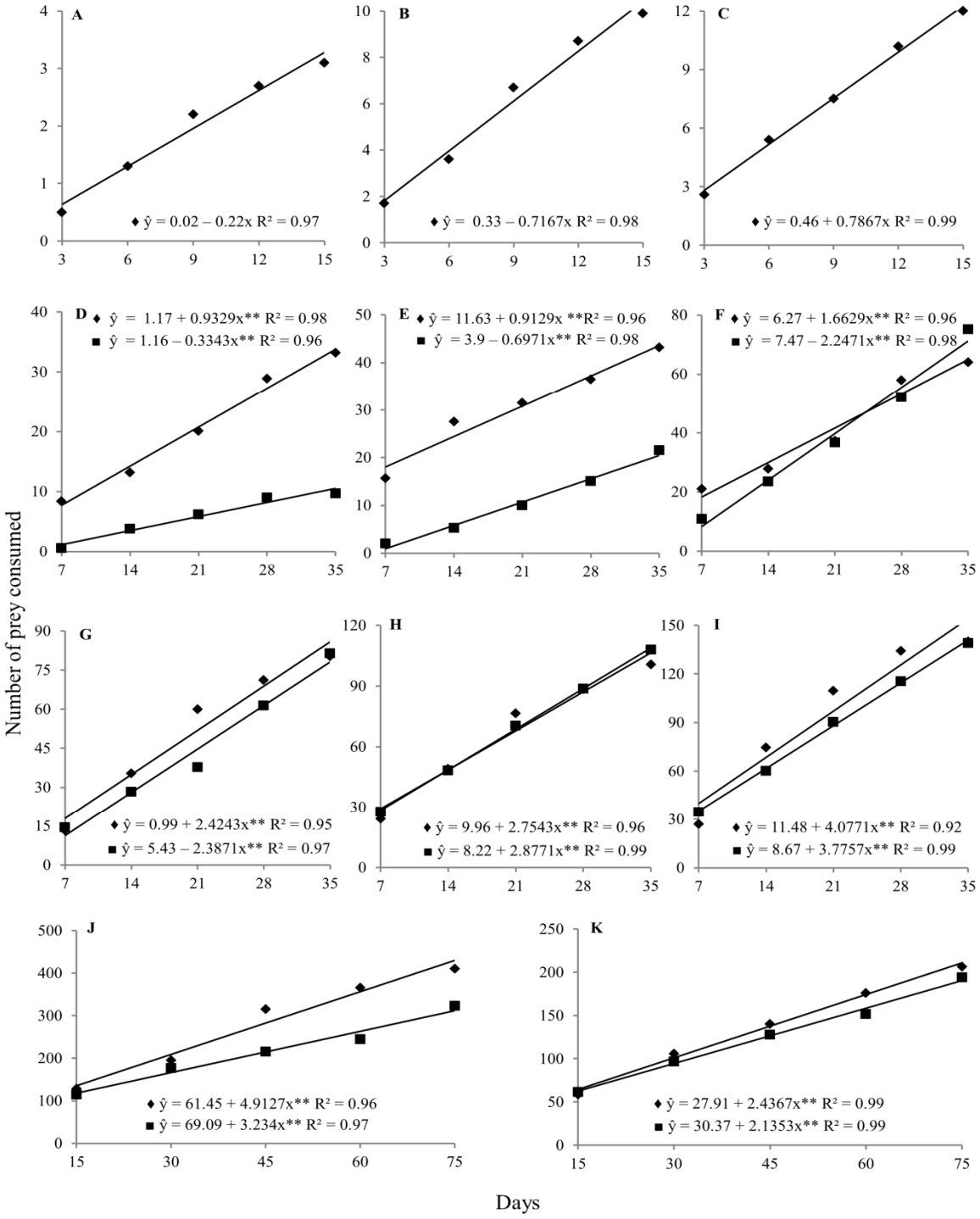

Fig. 2. Predatory consumption of nymphs in their 1st (A), 2nd (B), 3rd (C), 4th (D), 5th (E), 6th (F), 7th (G), 8th (H), 9th (I) instars, and of female (J) and male (K) adults of *Pygidicrana v-nigrum* when fed with larvae and pupae of *Ceratitis capitata*. (♦) corresponds to the 3rd instar larvae and (■) to the pupae food.

P. v-nigrum consumption of larvae and pupae of *C. capitata*, throughout the juvenile stage,was also similar to the adult stage of the predator *P. v-nigrum* (Fig. 2), with the exception of 1st to 3rd instars when fed with pupae, where there was no consumption (Fig. 2A,B,C). There was a predominance in larvae consumption in relation to pupae consumption of prey, both in their juvenile stage and when adults (Fig. 2); only in the 6th and 8th instars there was a higher consumption of pupae in relation to larvae (Fig. 2F,H), but this only occurred in the interval between 20 and 25 days after the ecdyses. Larger larvae consumption may be of nutritional origin, the predator having the need of greater consumption to meet its requirements. According to [16], physical characteristics such as hardness, shape, surface pilosity, in addition to allelochemicals and nutritional elements, as already mentioned, influence the consumption and digestion of food.

4. CONCLUSIONS

The 1st, 2nd and 3rd instar nymphs of the predator *Pygidicrana v-nigrum* do not consume pupae of the prey *Ceratitis capitata*. The dermapterous species *P. v-nigrum* had proper development regardless of the supplied phase of *C. capitata*. Further studies on species *P. v-nigrum* are required to determine its potential as a *C. capitata* regulator and its use in biological control programs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Buzzi, ZJ. Didactic Entomology: 5th ed. Publisher UFPR, Curitiba: 2010.

2. Ramalho FS, Wanderley PA. Ecology and management of the boll wevillin South America cotton. American Entomology. 1996; 42 (1): 41-47.

3. Silva AB, Batista JL, Brito CH. Predatory capacity of Euborellia annulipes (Lucas, 1847) on Spodoptera frugiperda. Acta Scientiarum Agronomy. 2009a; 31 (1): 7-11.

4. Silva AB, Batista JL, Brito CH. Biological aspects of Euborellia annulipes on Spodoptera frugiperda eggs. Environmental engineering. 2009b; 6 (3): 482-495.

5. Silva AB, Batista JL, Brito CH. Biological aspects of Euborellia annulipes (Dermaptera: Anisolabididae) fed with the aphid Hyadaphis foeniculi (Hemiptera: Aphididae). Caatinga Magazine. 2010a; 23 (1): 21-27.

6. Silva AB, Batista JL, Brito CH. Predatory capacity of Euborellia annulipes (Dermaptera: Anisolabididae) on Hyadaphis foeniculi (Hemiptera: Aphididae). Journal of Biology and Earth Sciences. 2010b; 10 (1): 44-51.

7. Oliveira R, Barbosa VO, Vieira DL, Oliveira FQ, Batista JL, Brito CH. Development and reproduction of Ceraeochrysa cubana (Neuroptera: Chrysopidae) fed with Aleurocanthus woglumi (Hemiptera: Aleyrodidae). Semina: Agrarian Science. 2016; 37 (26): 17-24.

8. Reis LL, Oliveira LJ, Cruz I. Biology and potential of Doru luteipes in the control of Spodoptera frugiperda. Pesquisa Agropecuária Brasileira. 1998; 23 (4): 333-342.

9. Cruz I, Alvarenga CD, Figueiredo PEF. Biology of Doru luteipes (Scudder) and its predatory capacity of Helicoverpa zea (Boddie) eggs. Annals of the Entomological Society of Brazil. 1995; 24 (2): 273-278.

10. Raga A (2005). Incidence, monitoring and control of fruit flies in the citrus industry in São Paulo. Orange. 2005; 26 (2): 307-322.

11. Oliveira R, Alves PRR, Costa WJD, Batista JL. Predatory capacity of Cuban Ceraeochrysa on Aleurocanthus woglumi. Caatinga Magazine. 2014; 27 (3): 177-182.

12. Matzke D, Klass KD. Reproductive biology and nymphal development in basal earwig Tagalina papua (Insecta: Dermaptera: Pygidicranidae), with a comparison ofbrood care in dermaptera and embiota. Entomologische Abhandlungen. 2005; 62 (2): 99-116.

13. Silveira Neto S, Nakano O, Barbin D, Villa Nova NA. Manual of ecology of insects. 1st ed. Agronomic Ceres, São Paulo; 1976.

14. Silva FAS, Azevedo CAV. Version of the assistat computer program for windows operating system. Brazilian Journal of Agroindustrial Products. 2002; 4 (1): 71-78.

15. Beck SD, Schoonhoven LM. Insect behavior and plant resistance. In: Maxwell FG, Jennings PR. (Eds). Breeding plants resistant to insects. New York: John Wiley & Sons, 1980. p. 116-135.

16. Panizzi AR, Parra JRP. Bioecology and insect nutrition: basis for integrated pest management. Brasília: Embrapa Information Technology, 2009.

17. Silva AB. Biological aspects and toxicity of products of plant origin to Euborellia annulipes on Spodoptera frugiperda. Doctoral thesis. Federal University of Paraiba. 2009; 138.