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Development and reproduction of *Ceraeochrysa cubana* (Neuroptera: Chrysopidae) fed with *Aleurocanthus woglumi* (Hemiptera: Aleyrodidae)

Desenvolvimento e reprodução de *Ceraeochrysa cubana* (Neuroptera: Chrysopidae) alimentado com *Aleurocanthus woglumi* (Hemiptera: Aleyrodidae)

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Abstract

This study evaluated the development and reproduction of *Ceraeochrysa cubana* when fed the citrus blackfly *Aleurocanthus woglumi*. The study was carried out at the Laboratory of Entomology, Department of Plant and Environmental Sciences, Federal University of Paraíba – Areia/PB. It used a completely randomized design. The study was conducted in climate chambers, regulated to 26 ± 2°C and a relative humidity of 70 ± 10% with a 12 h photoperiod. The treatments were as follows: eggs, nymphs of only the 1st, 2nd, 3rd, or 4th instars, and nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*, with eggs of *Sitotroga cerealella* as a control. The 1st instar of *C. cubana* lasted 5.8 to 10.7 days, the 2nd instar lasted 6.0 to 13.3 days, and the 3rd instar lasted 8.2 to 18.5 days. The larvae of *C. cubana* did not survive when the food provided was only the eggs of *A. woglumi*, since the predator could not eat them. *C. cubana*, when provided nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of the citrus blackfly, had a shorter pre-pupal period and lower longevity than when consuming the eggs of *S. cerealella*, but the sex ratio and oviposition period were not affected. However, changes occurred in the pre-oviposition period, the total number of eggs, and the number of viable eggs.
Key words: Biological control, biology, citrus blackfly, lacewings

Resumo

Avaliou-se o desenvolvimento e reprodução de *Ceraeochrysa cubana* quando alimentado com a mosca-negra-dos-citros *Aleurocanthus woglumi.* O estudo foi conduzido no Laboratório de Entomologia do Departamento de Fitotecnia e Ciências Ambientais da Universidade Federal da Paraíba – Areia/PB. Utilizou-se o delineamento experimental inteiramente casualizado. A pesquisa foi realizada em câmaras climatizadas, reguladas à 26 ± 2ºC, umidade relativa de 70 ± 10% com fotofase de 12 horas. Os tratamentos foram constituídos pelos seguintes alimentos: ovos, ninfas de 1º, 2º, 3º, 4º instares e

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diferentes ninfas (1º, 2º, 3º e 4º instares), tendo como testemunha ovos de *Sitotroga cerealella*. A duração larval para o 1º ínstar de *C. cubana* foi de 5,8 a 10,7 dias; no 2º ínstar de 6,0 a 13,3 dias e no 3º ínstar de 8,2 a 18,5 dias. As larvas de *C. cubana* foram inviabilizados quando o alimento foi exclusivamente ovos de *A. woglumi*, considerando-se que não houve alimentação por parte do predador. A espécie *C. cubana* ao consumir diferentes ninfas (1º, 2º, 3º e 4º instares) da mosca-negra-dos-citros apresentou menor período de pré-pupa e longevidade quando comparado ao alimento ovos de *S. cerealella*, não afetando a razão sexual e o período de oviposição, contudo ocorrendo alterações no período de pré-oviposição, número total de ovos e número de ovos viáveis.

Palavras-chave: Biologia, controle biológico, crisopídeos, mosca-negra-dos-citros

Introduction

The citrus blackfly *Aleurocanthus woglumi* Ashby (Hemiptera: Aleyrodidae) is a native pest from Asia that has caused serious damage to citrus crops across Africa, America, and Oceania (EPPO, 2008). It has been found in Brazil since 2001 infesting cultivated and wild plants, and is of socioeconomic significance because of its damage to fruit trees, particularly citrus trees. It has been successfully controlled in several parts of the world using biological control methods (WHITE et al., 2005; NGUYEN, 2008).

Integrated pest management programs comprise a set of actions that aim particularly to reduce the use of synthetic products in the agricultural environment to improve several environmental aspects and reduce production costs (DE BORTOLI et al., 2005). Thus, natural processes for insect pests regulation should be studied, including biological control with lacewings, since these predators are present in several regions of agricultural interest and regulate a range of pest species (FREITAS, 2001; CARVALHO; SOUZA, 2009). They are efficient both for natural biological control and for rearing and release (RIDGWAY; MURPHY, 1984).

The proper food is essential for the development of lacewing larvae to ensure a high reproductive capacity. The food in the immature stage of predators affects their rate of growth, development time, weight, survival, behavior, and reproductive success (PARRA, 1991). Differences in these biological parameters of the predator from different prey has been found by Almeida et al. (2009) for *Ceraeochrysa claveri* Navás (Neuroptera: Chrysopidae), De Bortoli et al. (2009) for *Ceraeochrysa cincta* Schneider (Neuroptera: Chrysopidae), and De Bortoli and Murata (2011), for *Ceraeochrysa paraguaria* Navás (Neuroptera: Chrysopidae).

In citrus orchards, *Ceraeochrysa cubana* Hagen (Neuroptera: Chrysopidae) has been shown to be a promising candidate for the biological control of mealybugs, whiteflies, leafminers, and mites (SOUZA et al., 1996) and the citrus blackfly (SILVA, 2005). However, studies of species have found that different prey have different effects on its biology (SANTA-CECÍLIA et al., 1997) and for *Aphis gossypii* Glover (Hemiptera: Aphididae) at different temperatures (ALCANTRA et al., 2008). Information about the influence of the citrus blackfly on the biological development of this predator has been scarce. Hence, we aim to study the development and reproduction of *C. cubana* when fed the citrus blackfly *Aleurocanthus woglumi*.

Material and Methods

Rearing of C. cubana and A. woglumi

We used larvae of *C. cubana* from the F6 generation of the Entomology Laboratory of the Agricultural Sciences Center, Federal University of Paraíba (LEN/CCA/UFPB), Areia/PB, at a temperature of 26 ± 2°C and relative humidity of 70 ± 10% with a 12 h photoperiod. Approximately 20 mating pairs of *C. cubana* were kept in plastic cages (20.0 × 20.0 cm) internally coated with bond paper as a substrate for egg laying. The upper end of the cage was closed with a “nylon” cloth and a rubber band, and the bottom part had a zinc cap. The diet consisted of yeast extract and honey in a ratio of 1:1 supplied every two days. Leaves infested with nymphs of *A. woglumi* were collected daily from citrus hosts in an orchard from Manoel Joaquim in Areia/PB. Subsequently, nymphs were examined using stereoscopic magnifying glasses to verify the presence of undesirable arthropods and/or insects infected by microorganisms.

Period of development and survival of C. cubana

Larvae of *C. cubana* obtained from the mass rearing were individually placed in plastic pots (3.0 × 5.0 cm). A total of 140 individuals of *C. cubana* were divided into seven food treatments: eggs; nymphs of 1st, 2nd, 3rd, or 4th instars; and nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*, and, as a control, eggs of *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae). Food was provided in a quantity exceeding the daily requirement, as defined in preliminary tests. The change of instars was verified through exuvia and/or through the numbers of bristles on each tuber of *C. cubana.* The evaluated parameters were the duration and survival of the larval, pre-pupal, and pupal stages. There were 20 individuals per treatment.

Longevity and reproduction of C. cubana

The study used newly emerged adult *C. cubana* arising from larvae fed with eggs of *S. cerealella* or nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*, with five reproductive pairs per treatment in separate plastic cages (10.0 × 20.0 cm) internally coated with bond paper as a substrate for laying. The pairs of *C. cubana* were kept in the same conditions as described for rearing. The eggs were collected and transferred daily to microplates (10.0 × 7.0 cm) containing 96 holes. The stages of pre-oviposition and oviposition, number of eggs, number of viable eggs, longevity, and sex ratio were recorded.

Statistical analysis

The experimental design was completely randomized. The data were subjected to variance analysis, and the averages of treatments were compared using the Tukey test at 1% probability. The sex ratio was calculated using data analyzed by the equation: number of females / (number of females + number of males), proposed by Silveira Neto (1976). Data were analyzed by the program Assistat 7.7 (SILVA; AZEVEDO, 2002).

Results and Discussion

The average period of *C. cubana* larvae varied depending on the type of food consumed (Table 1). The period of 1st instar larvae of *C. cubana* increased when the food were nymphs of the 2nd instar and nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*. However, despite the larvae surviving for 6.1 days on eggs of *A. woglumi*, they did not molt to the next stage. This happens because the mouth parts of the predator do not fit the diameter of *A. woglumi* eggs, since the eggs are small, or because of the way the eggs are bonded to the leaf. The 2nd instar of the predator was longer when fed nymphs of 1st or 2nd instars of the citrus blackflies. The 3rd instar of *C. cubana* was longer when fed 2nd, 3rd, or 4th instar nymphs of *A. woglumi*. This can be explained by the prey's body structure, because the cuticle of the citrus blackfly becomes more rigid as it develops, resulting in handling difficulty. These differences in the larvae of *C. cubana* have also been found by researchers evaluating another species of lacewing, *Chrysoperla externa* Hagen (Neuroptera: Chrysopidae), fed lepidopterans and aphids Lira and Batista (2006), Ribeiro et al. (2007) and Costa et al. (2012).

Table 1. Average duration and survival (± SE) of larvae of *Ceraeochrysa cubana* fed eggs of *Sitotroga cerealella* and eggs and nymphs of *Aleurocanthus woglumi.*

Food	Duration (days)		
	1st instar	2nd instar	3rd instar
Eggs of *S. cerealella*	6.8 ± 0.10 b	6.2 ± 0.26 d	10.5 ± 0.23 b
Eggs of *A. woglumi*	6.1 ± 0.46 b	-	-
Nymphs of 1st instar of *A. woglumi*	5.8 ± 0.17 b	6.0 ± 0.19 d	8.6 ± 0.25 c
Nymphs of 2nd instar of *A. woglumi*	10.1 ± 0.23 a	12.6 ± 0.34 ab	17.6 ± 0.38 a
Nymphs of 3rd instar of *A. woglumi*	6.6 ± 0.33 b	13.3 ± 0.33 a	16.8 ± 0.37 a
Nymphs of 4th instar of *A. woglumi*	7.2 ± 0.39 b	11.7 ± 0.58 b	18.5 ± 0.74 a
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	10.7 ± 0.28 a	10.0 ± 0.25 c	8.2 ± 0.48 c
CV (%)	18.26	14.84	14.05
	Survival (%)		
Eggs of *S. cerealella*	100.0	100.0	100.0
Eggs of *A. woglumi*	00.0	00.0	00.0
Nymphs of 1st instar of *A. woglumi*	75.0	65.0	55.0
Nymphs of 2nd instar of *A. woglumi*	75.0	60.0	60.0
Nymphs of 3rd instar of *A. woglumi*	70.0	60.0	55.0
Nymphs of 4th instar of *A. woglumi*	75.0	70.0	70.0
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	100.0	95.0	85.0

*Averages followed by the same letter in the column do not differ statistically by a Tukey test, at 1% probability. (± SE) Standard error of mean.

C. cubana larvae in the three instar had higher survival when fed nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi* or *S. cerealella* eggs (Table 1). With other food, the 1st, 2nd, and 3rd instars had lower survival, with ranges of 70.0 to 75.0%, 60.0 to 70.0%, and 55.0 to 70.0%, respectively. Research on lacewings fed with *S. cerealella* eggs have found high rates of viability, indicated that they can be used for mass production of this predator in the laboratory, a fact highlighted by Fonseca et al. (2001), De Bortoli and Murata (2007), and De Bortoli et al. (2009). However, the fact that *C. cubana* has a high survival rate when consuming citrus blackflies, except when the food is in the egg stage, shows the potential of this prey to be used as the diet of this predator.

The shortest period of the pre-pupal stage of the biological agent occurred when consuming nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*. The reduction in this phase probably occurred because of the diversity of food offered during the larval stage and the higher intake of sugary substances excreted by the prey, allowing for the rapid accumulation of sufficient nutrients to make a "cocoon." The duration of the pupal stage of the predator was reduced when consuming nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi* and eggs of *S. cerealella*; however, it did not differ from the rate when fed the 3rd instar nymphs of the citrus blackfly (Table 2). Santa-Cecília et al. (1997) evaluated the performance of the lacewing *C. cubana* on different prey and found that the quality of food eaten by the larvae affects their biological development. Pessoa et al. (2004) found that *C. externa* that were fed with the aphid *A. gossypii* raised in cotton 'Auburn SM 310' had a 3.5 day pre-pupal stage and 6.8 day pupal stage. Costa et al. (2012), observed durations of 3.2 and 6.4 days for the pre-pupal and pupal stages, respectively, when *C. externa* was fed with *Neotoxoptera formosana* Takahashi (Hemiptera: Aphididae).

Table 2. Average duration and survival (± SE) of the pre-pupal and pupal stages of *Ceraeochrysa cubana* arising from larvae fed eggs of *Sitotroga cerealella* and nymphs of *Aleurocanthus woglumi*.

Food	Duration (days)	
	Pre-pupae	Pupae
Eggs of *S. cerealella*	1.8 ± 0.51 ab	15.4 ± 0.15 c
Nymphs of 1st instar of *A. woglumi*	2.2 ± 0.18 a	19.4 ± 1.15 a
Nymphs of 2nd instar of *A. woglumi*	1.7 ± 0.16 ab	19.5 ± 0.59 a
Nymphs of 3rd instar of *A. woglumi*	2.2 ± 0.18 a	16.6 ± 0.42 bc
Nymphs of 4th instar of *A. woglumi*	1.5 ± 0.17 b	18.5 ± 0.68 ab
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	1.0 ± 0.00 c	15.6 ± 0.41c
CV (%)	26.35	9.33
	Survival (%)	
Eggs of *S. cerealella*	100.0	100.0
Nymphs of 1st instar of *A. woglumi*	66.6	42.8
Nymphs of 2nd instar of *A. woglumi*	66.6	50.0
Nymphs of 3rd instar of *A. woglumi*	63.6	71.4
Nymphs of 4th instar of *A. woglumi*	64.2	55.5
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	88.2	100.0

*Averages followed by the same letter in the column do not differ statistically by a Tukey test, at 1% probability. (± SE) Standard error of mean. The treatment with eggs of *A. woglumi* is not shown because *C. cubana* larvae did not consume the eggs.

The pre-pupal and pupal stages of *C. cubana* had 88.2% and 100.0% of survival, respectively, when fed on nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi* (Table 2). For other food sources, except for the eggs of *S. cerealella,* there was a reduction in survival in the pre-pupal to pupal stages, except when fed on 3rd instar nymphs of the insect pest.

It was found that the lacewing nymphs of food from the 1st, 2nd, 3rd, and 4th instars of *A. woglumi* died after its hatch, before making couples. Such behavior can be attributed to the need of a food supplementation to the species of the present study. Canard and Principi (1984) say that the quality of food of lacewings during their larval period interferes in the pre-imaginal development, body weight gain, and viability.

Female *C. cubana* originating from larvae fed nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) had a longer pre-oviposition period of 16.8 days and reduced total number of eggs (54.2) when compared to females fed eggs of *S. cerealella* (Table 3). No significant difference in the length of the oviposition period was observed among treatments. The number of viable eggs and the longevity *C. cubana* when fed nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) were reduced to 49.2 and 60.4 days, respectively. The low production of eggs in *C. cubana* reflects the diet in the immature stage of this biological control agent, since the adult reproductive performance is influenced by the nutritional quality of the prey. According to Rousset (1984), a deficient diet for larvae significantly affects adulthood, because pre-vitellogenesis occurs during the pupal stage using the reserves accumulated in the growth of the ovaries. De Bortoli et al. (2009), when studying the biological aspects of *C. cincta*, found that the prey provided during the immature stage of the predator does not influence the reproductive parameters except for the number of viable eggs and the longevity of females.

Table 3. Pre-oviposition period, oviposition period, total number of eggs, number of viable eggs, longevity, and sex ratio (± SE) of *Ceraeochrysa cubana* arising from larvae fed eggs of *Sitotroga cerealella* and nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *Aleurocanthus woglumi*.

Food	Pre-oviposition (days)	Oviposition (days)	Total number of eggs
Eggs of *S. cerealella*	8.0 ± 0.31 b	47.2 ± 3.10 a	476.2 ± 3.21 a
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	16.8 ± 0.73 a	38.8 ± 2.45 a	54.2 ± 12.88 b
CV (%)	10.20	14.56	7.91
	Number of viable eggs	Longevity (days)	Sex ratio
Eggs of *S. cerealella*	476.2 ± 3.21a	77.2 ± 2.53 a	0.60
Nymphs of 1st, 2nd, 3rd, and 4th instars of *A. woglumi*	49.2 ± 9.74 b	60.4 ± 0.24 b	0.53
CV (%)	6.17	5.85	

*Averages followed by the same letter in the same column do not differ statistically by a Tukey test, at 1% probability. (± SE) Standard error of mean. When the food was *A. woglumi* nymphs of the 1st, 2nd, 3rd, or 4th instars, all individuals of *C. cubana* died in the pre-pupal or emergence phase.

Conclusion

The predator *Ceraeochrysa cubana* does not consume eggs of *Aleurocanthus woglumi*.

The best biological development of *C. cubana* is when it consumes nymphs of multiple instars (1st, 2nd, 3rd, and 4th instars) of *A. woglumi*.

The prey *A. woglumi* affects the egg production of its predator *C. cubana.*

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