Discovery of the first Aximopsis (Hymenoptera: Eurytomidae) Parasitoid of Lepidoptera in Brazil and Notes on Its Biology

Authors: Tavares, Wagner de Souza, Wilcken, Carlos Frederico, Ramalho, Francisco de Sousa, Soares, Marcus Alvarenga, Fernandes, Flávio Lemes, et al.

Source: Florida Entomologist, 98(4) : 1077-1080

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.098.0411

Discovery of the first *Aximopsis* (Hymenoptera: Eurytomidae) parasitoid of Lepidoptera in Brazil and notes on its biology

Wagner de Souza Tavares[1], Carlos Frederico Wilcken[2], Francisco de Sousa Ramalho[3], Marcus Alvarenga Soares[4], Flávio Lemes Fernandes[5], José Eduardo Serrão[6], and José Cola Zanuncio[7,]*

Abstract

Eucalyptus cloeziana F. Muell. (Myrtales: Myrtaceae) and the tropical almond *Terminalia catappa* L. (Myrtales: Combretaceae) are widely cultivated in urban and forest areas of many countries where biological control is the most-preferred method to control insects. *Aximopsis* sp. (Hymenoptera: Eurytomidae) is reported for the first time in Brazil in a new group of lepidopteran hosts. Individuals of this species emerged from the pupae of *Thyrinteina arnobia arnobia* Stoll (Lepidoptera: Geometridae) and *Thagona tibialis* Walker (Lepidoptera: Lymantriidae) that developed from larvae defoliating *E. cloeziana* and *T. catappa* plants on the campus of the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais, Brazil. *Aximopsis* sp. was identified by comparing it with species of this group as described for the Neotropical region. Voucher specimens were deposited in the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France. Twenty new pupae each of *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae) and *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) were held individually in test tubes with a drop of honey as food and 3 mated *Aximopsis* sp. females for 2 d. *Aximopsis* sp. parasitized 20% of the *T. molitor* pupae but none of the *A. gemmatalis* pupae. The duration of the life cycle (egg to adult), parasitism and emergence rates, total individuals emerged from each pupa, sex ratio, length of the body and width of the head capsule, and the longevities of *Aximopsis* sp. males and females that emerged from parasitized *T. molitor* pupae were evaluated. The duration of the life cycle of *Aximopsis* sp. was 14 ± 2 d. An average of 62 ± 5 *Aximopsis* sp. individuals emerged from each *T. molitor* pupa, and their sex ratio was 0.96 ± 0.02. The total number of parasitoids that emerged was 248 individuals. Measurements of characters of progeny *Aximopsis* sp. females (n = 10) and males (n = 5), respectively, were as follows: body length: 3.50 mm (2.40–3.80 mm) and 1.99 mm (1.97–2.02 mm); head capsule width: 0.63 mm (0.58–0.72 mm) and 0.48 mm (0.46–0.51 mm), and longevity: 6 ± 1 d and 4 ± 1 d. These results open prospects for investigations of biological control of pests with this natural enemy.

Key Words: Chalcidoidea; Combretaceae; Myrtaceae; urban area

Resumo

Eucalyptus cloeziana F. Muell. (Myrtales: Myrtaceae) e amendoeira-da-praia, *Terminalia catappa* L. (Myrtales: Combretaceae), são cultivados em áreas urbanas e florestais de muitos países onde o controle biológico é o método preferido para controlar insetos. *Aximopsis* sp. (Hymenoptera: Eurytomidae) é relatado pela primeira vez no Brasil em um novo grupo de Lepidoptera hospedeiros. Indivíduos desta espécie emergiram de pupas de *Thyrinteina arnobia arnobia* Stoll (Lepidoptera: Geometridae) e *Thagona tibialis* Walker (Lepidoptera: Lymantriidae) que se desenvolveram de lagartas desfolhando plantas de *E. cloeziana* e *T. catappa* no campus da Universidade Federal de Viçosa (UFV) em Viçosa, Minas Gerais, Brasil. *Aximopsis* sp. foi identificado por comparação com espécies desse grupo descritas para a região Neotropical. Espécimes desse inseto foram depositados no Centre de Coopération Internationale en Recherche pour le Développement Agronômica (CIRAD), França. Vinte pupas de *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae) e vinte de *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) foram individualizadas em tubos de ensaio com uma gota de mel como alimento e 3 fêmeas de *Aximopsis* sp. por 2 dias. *Aximopsis* sp. parasitou 20% das pupas de *T. molitor*, mas nenhuma de *A. gemmatalis*. A duração do ciclo de vida (ovo a adulto), taxas de parasitismo e emergência, total de indivíduos emergidos por pupa, razão sexual, comprimento do corpo e a largura da cápsula cefálica e longevidades de machos e fêmeas de *Aximopsis* sp. que emergiram de pupas parasitadas de *T. molitor* foram avaliados. A duração do ciclo de vida de *Aximopsis* sp. foi de 14 ± 2 dias. Uma média de 62 ± 5 indivíduos de *Aximopsis* sp. emergiu por pupa de *T. molitor* com razão sexual de 0,96 ± 0,02. O número total de parasitoides emergidos foi de 248. Medidas da progênie de *Aximopsis* sp. fêmeas (n =

[1] Departamento de Fitotecnia, Universidade Federal de Viçosa, 36570-900, Viçosa, Minas Gerais, Brasil. Current address: Bahia Specialty Cellulose/Copener Florestal Ltda., rua Dr. José Tiago Correa, s/n, bairro Alagoinhas Velha, 48030-480, Alagoinhas, Bahia, Brasil
[2] Departamento de Produção Vegetal, Universidade Estadual Paulista "Júlio de Mesquita Filho", 18603-970, Botucatu, São Paulo, Brasil
[3] Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Algodão, Unidade de Controle Biológico, rua Oswaldo Cruz, nº 1143, bairro Centenário, 58107-720, Campina Grande, Paraíba, Brasil
[4] Departamento de Agronomia, Universidade Federal dos Vales do Jequitinhonha e Mucuri, 39100-000, Diamantina, Minas Gerais, Brasil
[5] Campus de Rio Paranaíba, Universidade Federal de Viçosa, 38810-000, Viçosa, Minas Gerais, Brasil
[6] Departamento de Biologia Geral, Universidade Federal de Viçosa, 36570-900, Viçosa, Minas Gerais, Brasil
[7] Departamento de Entomologia, Universidade Federal de Viçosa, 36570-900, Viçosa, Minas Gerais, Brasil
*Corresponding author; E-mail: zanuncio@ufv.br

10) e machos (*n* = 5) foram, respectivamente, de: comprimento do corpo: 3,50 mm (2,40–3,80 mm) e 1,99 mm (1,97–2,02 mm), largura da cápsula cefálica: 0,63 mm (0,58–0,72 mm) e 0,48 mm (0,46–0,51 mm) e longevidade: 6 ± 1 e 4 ± 1 dias. Estes resultados abrem perspectivas para investigações de controle biológico de pragas com este inimigo natural.

Palavras Chave: Chalcidoidea; Combretaceae; Myrtaceae; área urbana

Eucalyptus cloeziana F. Muell. (Myrtales: Myrtaceae) is cultivated in urban and forest areas to supply raw material for blacksmithing, props, structures, sleepers, and, especially, poles (Dall'Oglio et al. 2013). However, this plant does not thrive in regions with frost, soils with low fertility, altitudes above 1,600 m, fires, and severe water deficits, and it has reduced sprouting (Marques et al. 1996; Okino et al. 2004). *Eucalyptus cloeziana* can be infested by *Ctenarytaina spatulata* Taylor (Hemiptera: Aphalaridae), although other species of eucalyptus and other Myrtaceae are preferred by this aphalarid for feeding and oviposition (Queiroz et al. 2010). Furthermore, *E. cloeziana* is susceptible to defoliation by *Hylesia paulex* Dognin (Pereira et al. 2009) and *Dirphia moderata* Bouvier (Lepidoptera: Saturniidae) (Zanuncio et al. 1998; Pereira et al. 2008a) and suffers extensive damage from *Thyrinteina arnobia arnobia* Stoll and *Thyrinteina leucoceraea* Rindge (Lepidoptera: Geometridae) (Lemos et al. 1999; Pereira et al. 2008b).

Lepidopteran defoliators of *Eucalyptus* species can be controlled with chemical insecticides (Elek et al. 2003; Mansfield et al. 2006), but biological control with pupal parasitoids can reduce applications of these expensive and sometimes problematic products (Tavares et al. 2014a). The identification of natural enemies is the first step to develop biological control techniques in integrated management of a forest pest (Dall'Oglio et al. 2013). Thus, it is significant that *Palmistichus elaeisis* Delvare & LaSalle and *Trichospilus diatraeae* Cherian & Margabandhu (Hymenoptera: Eulophidae) were found to parasitize *T. arnobia arnobia* pupae on *E. cloeziana* plants (Pereira et al. 2008b,c), and the development and reproduction of *P. elaeisis* in *T. arnobia arnobia* pupae were studied in the laboratory (Pereira et al. 2010).

The number of natural enemies associated with *T. arnobia arnobia* may be great than currently is known, because *Paropsis atomaria* Olivier (Coleoptera: Chrysomelidae), the main pest of *E. cloeziana* in Australia, has a large number of egg and larval parasitoids and hyperparasitoids (Nahrung et al. 2008). The main natural enemy of this pest is *Neopolycystus* sp. (Hymenoptera: Pteromalidae), which was found to parasitize 45% of this beetle's eggs (Duffy et al. 2008). The aim of this study was to identify parasitoids of *T. arnobia arnobia* pupae on *E. cloeziana* plants in an urban area of Brazil and determine their parasitism rate on alternative hosts in order to develop mass production methods for use in biological control programs.

Materials and Methods

EXPERIMENTAL SITE

Thyrinteina arnobia arnobia pupae of various ages were collected on *E. cloeziana* plants at the campus of the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais, Brazil (20°44'S, 42°50'W; 650 m asl) in 2007. In 2011, *Thagona tibialis* Walker (Lepidoptera: Lymantriidae) pupae of various ages were obtained from larvae defoliating *Terminalia catappa* L. (Myrtales: Combretaceae) trees, which are cultivated in urban areas and on the campus of UFV (20°45'S, 42°51'W, 651 m asl). These pupae were brought to the Laboratory of Biological Control of Insects (LCBI) of UFV and kept in a room at 25 ± 1 °C, a 12:12 h L:D photoperiod, and 70 ± 10% RH. Each pupa was placed in a test tube (14.0 cm long × 2.2 cm diameter), which was sealed with a cotton swab until emergence of the lepidopteran or parasitoids. The collection areas were subjected to human impact and presented a flat terrain near a fragment of secondary forest with a diversified flora and fauna (Pereira et al. 2009; Tavares et al. 2011b, 2012c).

IDENTIFICATION OF INSECTS

Seventy-three individuals of an undescribed gregarious endoparasitoid species belonging to the genus *Aximopsis* (Hymenoptera: Eurytomidae), emerged from 1 *T. arnobia arnobia* pupa collected in Nov 2007 on *E. cloeziana* plants. In addition, 73 and 79 *Aximopsis* individuals emerged from 2 *T. tibialis* pupae sampled on a *T. catappa* tree in May and Jun 2011, respectively. This parasitoid was identified by Gerard Delvare of the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France, from initial comparison with the types of Neotropical Eurytomidae housed in the U.S. National Museum of Natural History, Washington D.C., USA, and the Natural History Museum, London, United Kingdom. Individuals of this species were deposited in the CIRAD and in the Regional Museum of Entomology of the Department of Entomology at UFV.

BIOLOGICAL PROCEDURES

Twenty recent *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae) (271.7 ± 6.8 mg) and *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) (118.0 ± 5.6 mg) pupae were obtained from cultures of these species reared at UFV (Zanuncio et al. 2008; Pereira et al. 2010). Larvae of *A. gemmatalis* had been fed with a solid artificial diet composed of 125.0 g bean grains, 62.4 g yeast, 100.0 g wheat germs, 100.0 g soy protein, 50.0 g casein, 35.0 g agar, 5.0 g Nipagin®, 6.0 g ascorbic acid, 3.0 g sorbic acid, 6.0 mL formaldehyde at 40.0%, and 10.0 mL vitamin solution (Pereira et al. 2010). Larvae of *T. molitor* had been fed ad libitum with wheat bran (12% protein, 2% lipids, 75% carbohydrates, and 11% minerals/sugar) and pieces of *Saccharum officinarum* L. (Poales: Poaceae) and *Sechium edule* (Jacq.) Swartz (Cucurbitales: Cucurbitaceae). Sheets of paper were placed on top of the substrate to reduce the intensity of the light on the insects (Zanuncio et al. 2008).

Each pupa was individualized in a test tube with a drop of honey and 3 mated *Aximopsis* sp. females that had emerged from *T. tibialis* pupae. These insects remained in the test tubes for 2 d according to the method proposed for parasitism of *A. gemmatalis* and *T. molitor* pupae by *P. elaeisis* in the laboratory (Zanuncio et al. 2008; Pereira et al. 2010). Parasitism and emergence rates of parasitoids emerged from *A. gemmatalis* and *T. molitor* pupae were evaluated according to the number of parasitized pupae presenting caramel color. Unviable pupae became black, hollow, and died, whereas adult lepidopterans or coleopterans emerged from the non-parasitized ones (Zanuncio et al. 2008; Pereira et al. 2010).

EXPERIMENTAL DESIGN

The design was completely randomized with 2 treatments represented by *A. gemmatalis* and *T. molitor* pupae. Each treatment had 20 replications (1 pupa each). The duration of the life cycle (egg to adult, in d), parasitism and emergence rates (%), number of emerged individuals from each pupa, sex ratio, length of the body and width of the head capsule, and the longevity of *Aximopsis* sp. females and males that emerged from host pupae were determined according to

the method proposed for parasitism of *Heraclides anchisiades capys* Hübner (Lepidoptera: Papilionidae) pupae by *P. elaeisis* in the laboratory (Tavares et al. 2013c).

Results

Aximopsis sp. did not parasitize *A. gemmatalis* pupae, but it parasitized *T. molitor* pupae, which resulted in parasitism and emergence rates of 20% and 62 ± 5 individuals per pupa of this latter host (Table 1). The duration of the life cycle (egg to adult) of *Aximopsis* sp. was 14 ± 2 d. The sex ratio was 0.96 ± 0.02. The total number of parasitoids that emerged was 248 individuals. The longevity of *Aximopsis* sp. females was 6 ± 1 d and that of males was 4 ± 1 d. The body length and the width of the head capsule of *Aximopsis* sp. progeny were 3.50 mm (2.40–3.80 mm) and 0.63 mm (0.58–0.72 mm), respectively, in females (n = 10) and 1.99 mm (1.97–2.02 mm) and 0.48 mm (0.46–0.51 mm), respectively, in males (n = 5).

This is the first report of an *Aximopsis* sp. parasitizing lepidopteran pupae, i.e., *T. arnobia arnobia* and *T. tibialis*. Individuals of *Aximopsis* sp. that emerged from pupae of these 2 hosts in Brazil differed in their morphology from other species of this genus. Prior to this report, *Aximopsis* was known to parasitize only hymenopteran hosts. Thus, *Aximopsis* sp. that emerged from *T. arnobia arnobia* and *T. tibialis* pupae appear to be representatives of a new group that specializes on lepidopteran host species.

Discussion

The identification of *Aximopsis* sp. parasitizing *T. arnobia arnobia* pupae is important, because the pupal stage has no defense, whereas the larvae can reduce the impact of natural enemies by camouflage, by attacking natural enemies with their jaws, and by hanging from silk threads (Soares et al. 2009).

The number of individuals of *Aximopsis* sp. that emerged per *T. molitor* pupa (62 ± 5) was smaller than the numbers of *P. elaeisis* obtained in the following cases: (i) 4 *P. elaeisis* females per *T. molitor* pupae resulted in 100% parasitism, 90.8% emergence, and 70 ± 3 individuals per pupa (Zanuncio et al. 2008), (ii) 6 *P. elaeisis* females per *A. gemmatalis* pupa resulted in 100% parasitism,100% emergence, and 110 ± 19 individuals per pupa (Pereira et al. 2010), (iii) 10 *P. elaeisis* females per *H. anchisiades capys* pupa resulted in 40% parasitism, 40% emergence, and 323 ± 38 individuals per pupa (Tavares et al. 2013c), and (iv) 10 *Trichospilus pupivorus* Ferrière (Hymenoptera: Eulophidae) females per *A. gemmatalis* pupa resulted in 35% parasitism, 35% emergence, and 242 ± 12 individuals per pupa (Tavares et al. 2011a).

Table 1. Parameters (mean ± SD, or range) of *Aximopsis* sp. that parasitized pupae of *Tenebrio molitor* in the laboratory.

Parameter	Value
Duration of the life cycle (egg to adult) (d)	14 ± 2
Parasitism rate (%)	20
Emergence rate (%)	20
Number of emerged individuals from each pupa	62 ± 5
Total number of parasitoids that emerged	248
Sex ratio	0.96 ± 0.02
Length of the body (female) (mm) (n = 10)	3.50 (2.40–3.80)
Length of the body (male) (mm) (n = 5)	1.99 (1.97–2.02)
Width of the head capsule (female) (mm) (n = 10)	0.63 (0.58–0.72)
Width of the head capsule (male) (mm) (n = 5)	0.48 (0.46–0.51)
Longevity (female) (d)	6 ± 1
Longevity (male) (d)	4 ± 1

This lower number of individuals of *Aximopsis* sp. that emerged per *T. molitor* pupa compared with other cases may be because of the greater body length and the greater width of the head capsule of *Aximopsis* sp. female and male progeny than those of *P. elaeisis* (2.00 ± 0.03 mm and 0.58 ± 0.01 mm, respectively, in females and 1.34 ± 0.02 mm and 0.45 ± 0.01 mm, respectively, in males) that emerged from *T. molitor* pupae (Zanuncio et al. 2008) and the width of the head capsule of female and male *T. diatraeae* (0.71 ± 0.01 mm and 0.55 ± 0.02 mm, respectively) that emerged from *T. arnobia arnobia* pupae (Pastori et al. 2012).

This first report of *Aximopsis* sp. parasitizing pupae of *T. arnobia arnobia* and *T. tibialis* in Brazil opens possibilities for biological control of these pests in *Eucalyptus* plantations and on *T. catappa* plants in urban and forest areas by producing and releasing this natural enemy. The initial infestation of *T. tibialis* (population peak in May) on *T. catappa* plants (Tavares et al. 2013b, 2014b) near *E. cloeziana* plantations may have contributed to the dispersion, parasitism, and occurrence of *Aximopsis* sp. in Nov in *T. arnobia arnobia* pupae. *Terminalia catappa* is cultivated along the Atlantic coast of Brazil and in municipalities of Amapá, Pará, and Roraima States, which border French Guiana, Guyana, and Suriname (Tavares et al. 2011a, 2012a). This area may be the region of entrance and distribution of *Aximopsis* sp. to central Brazil. *Terminalia catappa* plants are grown near *Eucalyptus* crops, and those plants can be a refuge for natural enemies of forest pests, just as has been reported for agricultural crops where *Crotalaria juncea* L. (Fabales: Fabaceae) shelters natural enemies of pests of *Zea mays* L. (Poales: Poaceae) (Tavares et al. 2011c). *Thagona tibialis* pupae are also hosts of the eulophid parasitoids *P. elaeisis* and *T. pupivorus*, which are promising biological control agents of agricultural pests such as *A. gemmatalis*, a major defoliator of *Glycine max* (L.) Merr. (Fabales: Fabaceae) (Tavares et al. 2011a, 2012a,b, 2013a).

This newly discovered Brazilian species of *Aximopsis* is most similar to one that parasitizes *Sibine* sp. (Lepidoptera: Limacodidae) pupae in the Neotropical region, and which is deposited in the collection of CIRAD (G. Delvare, pers. com.). Probably, the Brazilian species is native to South America, although the Australasia fauna of this genus is largely unknown. The phylogenetic position of the genus *Aximopsis* Ashmead in the Eurytominae has been redefined (Gates et al. 2006). Additional phylogenetic studies of the species of this genus are needed, because it is extremely diverse in the Neotropical region. The DNA of some Eurytominae species was sequenced in order to verify a phylogenetic analysis based on morphological characters (Lotfalizadeh et al. 2007).

The *Aximopsis* sp. that emerged from *T. arnobia arnobia* and *T. tibialis* pupae appears to be representative of a new group of *Aximopsis* that specializes on host species differing from those parasitized by *Aximopsis masneri* Gates (Hymenoptera: Eurytomidae). The latter species parasitizes *Euglossa variabilis* Friese and *Euglossa cybelia* Moure (Hymenoptera: Apidae) in nests of these wasps in the Neotropical region (Gates 2009).

This is the first report of a species of the genus *Aximopsis* in Brazil. In addition, *Aximopsis* sp. parasitized Lepidoptera pupae of forest pests of the families Geometridae and Lymantriidae, which constitute a host group not previously known to be parasitized by species of *Aximopsis*. *Tenebrio molitor*, an adequate alternative host for some forest parasitoids in Brazil, has the potential to be used for mass rearing *Aximopsis* sp. in the laboratory. This study opens prospects for programs of biological control of pests with this natural enemy in urban and forest plantation areas of *E. cloeziana* and *T. catappa*.

Acknowledgments

We extend heartfelt thanks to Olaf Hermann Hendrik Mielke (Universidade Federal do Paraná, Departamento de Zoologia in Curitiba, Paraná, Brazil) for confirming the scientific name of *Thyrinteina arnobia arnobia* Stoll (Lepidoptera: Geometridae). We acknowledge Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), and Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) for financial support. Global Edico Services of India rewrote and edited the English of the submitted version of this manuscript.

References Cited

Dall'Oglio OT, Zanuncio TV, Tavares WS, Serrão JE, Wilcken CF, Zanuncio JC. 2013. Atlantic Rainforest remnant harbors greater biotic diversity but reduced lepidopteran populations compared to a *Eucalyptus* plantation. Florida Entomologist 96: 887-896.

Duffy MP, Nahrung HF, Lawson SA, Clarke AR. 2008. Direct and indirect effects of egg parasitism by *Neopolycystus* sp. Girault (Hymenoptera: Pteromalidae) on *Paropsis atomaria* Olivier (Coleoptera: Chrysomelidae). Australian Journal of Entomology 47: 195-202.

Elek JA, Steinbauer MJ, Beveridge N, Ebner P. 2003. The efficacy of high and low volume spray applications of Mimic® (tebufenozide) for managing autumn gum moth larvae *Mnesampela privata* (Lepidoptera: Geometridae) in eucalypt plantations. Agricultural and Forest Entomology 5: 325-332.

Gates MW. 2009. A new species of *Aximopsis* sensu lato Ashmead (Hymenoptera, Chalcidoidea, Eurytomidae) parasitic on *Euglossa* spp. (Hymenoptera, Apidae). ZooKeys 20: 165-174.

Gates MW, Metz MA, Schauff ME. 2006. The circumscription of the generic concept of *Aximopsis* Ashmead (Hymenoptera: Chalcidoidea: Eurytomidae) with the description of seven new species. Zootaxa 1273: 9-54.

Lemos RNS, Crocomo WB, Forti LC, Wilcken CF. 1999. Feeding selectivity and influence of leaf age of *Eucalyptus* spp. for *Thyrinteina arnobia* (Lepidoptera: Geometridae). Pesquisa Agropecuária Brasileira 34: 7-10.

Lotfalizadeh H, Delvare G, Rasplus JY. 2007. Phylogenetic analysis of Eurytominae (Chalcidoidea: Eurytomidae) based on morphological characters. Zoological Journal of the Linnean Society 151: 441-510.

Mansfield S, Withers TM, Gous SF, Potter KJB, Kriticos DJ, Watson MC, Kimberley MO. 2006. Potential of selective insecticides for managing *Uraba lugens* (Lepidoptera: Nolidae) on eucalypts. Journal of Economic Entomology 99: 780-789.

Marques OG, Andrade HB, Ramalho MAP. 1996. Assessment of the early selection efficiency in *Eucalyptus cloeziana* F. Muell. in the northwest of Minas Gerais State (Brazil). Silvae Genetica 45: 359-361.

Nahrung HF, Duffy MP, Lawson SA, Clarke AR. 2008. Natural enemies of *Paropsis atomaria* Olivier (Coleoptera: Chrysomelidae) in south-eastern Queensland eucalypt plantations. Australian Journal of Entomology 47: 188-194.

Okino EYA, Souza MR, Santana MAE, Alves MVD, Sousa ME, Teixeira DE. 2004. Cement-bonded wood particleboard with a mixture of eucalypt and rubberwood. Cement and Concrete Composites Journal 26: 729-734.

Pastori PL, Pereira FF, Andrade GS, Silva RO, Zanuncio JC, Pereira AIA. 2012. Reproduction of *Trichospilus diatraeae* (Hymenoptera: Eulophidae) in pupae of two lepidopterans defoliators of eucalypt. Revista Colombiana de Entomología 38: 90-93.

Pereira FF, Zanuncio AJV, Felipe JPD, Lorenzon AS, Canevari GD. 2008a. Development and reproduction of *Dirphia moderata* (Lepidoptera: Saturniidae) on *Eucalyptus cloeziana* or *Psidium guajava* leaves under laboratory conditions. Revista Árvore 32: 1119-1124.

Pereira FF, Zanuncio TV, Zanuncio JC, Pratissoli D, Tavares MT. 2008b. Species of Lepidoptera defoliators of *Eucalyptus* as new host for the parasitoid *Palmistichus elaeisis* (Hymenoptera: Eulophidae). Brazilian Archives of Biology and Technology 51: 259-262.

Pereira FF, Zanuncio JC, Tavares MT, Pastori PL, Jacques GC, Vilela EF. 2008c. New record of *Trichospilus diatraeae* as a parasitoid of the eucalypt defoliator *Thyrinteina arnobia* in Brazil. Phytoparasitica 36: 304-306.

Pereira AIA, Curvelo CRD, Guerra AMNM, Andrade GS, Zanuncio JC. 2009. *Eucalyptus cloeziana* as a new host to *Hylesia paulex* (Lepidoptera: Saturniidae) in southeast Brazil. Revista Caatinga 22: 1-5.

Pereira FF, Zanuncio JC, Pastori PL, Chichera RA, Andrade GS, Serrão JE. 2010. Reproductive biology of *Palmistichus elaeisis* (Hymenoptera: Eulophidae) with alternative and natural hosts. Zoologia 27: 887-891.

Queiroz DL, Zanol KMR, Oliveira EB, Anjos N, Majer J. 2010. Feeding and oviposition preferences of *Ctenarytaina spatulata* Taylor (Hemiptera, Psyllidae) for *Eucalyptus* spp. and other Myrtaceae in Brazil. Revista Brasileira de Entomologia 54: 149-153.

Soares MA, Zanuncio JC, Leite GLD, Wermelinger ED, Serrão JE. 2009. Does *Thyrinteina arnobia* (Lepidoptera: Geometridae) use different defense behaviours against predators? Journal of Plant Diseases and Protection 116: 33-33.

Tavares WS, Hansson C, Serrão JE, Zanuncio JC. 2011a. First report of *Trichospilus pupivorus* (Hymenoptera: Eulophidae) parasitizing pupae of *Anticarsia gemmatalis* (Lepidoptera: Noctuidae). Entomologia Generalis 33: 281-282.

Tavares WS, Serrão JE, Barbosa RA, Zanuncio JC. 2011b. *Lagerstroemia speciosa* (L.) Pers. (Lythraceae), a new host for the defoliator *Oiketicus kirbyi* Guilding, [1827] (Lepidoptera: Psychidae). Tropical Lepidoptera Research 21: 100-104.

Tavares WS, Cruz I, Silva RB, Figueiredo MLC, Ramalho FS, Serrão JE, Zanuncio JC. 2011c. Soil organisms associated to the weed suppressant *Crotalaria juncea* (Fabaceae) and its importance as a refuge for natural enemies. Planta Daninha 29: 473-479.

Tavares WS, Zanuncio TV, Hansson C, Serrão JE, Zanuncio JC. 2012a. Emergence of *Palmistichus elaeisis* (Hymenoptera: Eulophidae) from pupae of *Thagona tibialis* (Lepidoptera: Lymantriidae) collected in the medicinal plant *Terminalia catappa* (Combretaceae). Entomological News 122: 250-256.

Tavares WS, Mielke OHH, Wilcken CF, Simon L, Serrão JE, Zanuncio JC. 2012b. *Palmistichus elaeisis* (Hymenoptera: Eulophidae) parasitizing pupae of *Citioica anthonilis* (Lepidoptera: Saturniidae) collected on *Piptadenia gonoacantha* (Fabaceae). Journal of the Lepidopterists' Society 66: 216-220.

Tavares WS, Salgado-Neto G, Legaspi JC, Ramalho FS, Serrão JE, Zanuncio JC. 2012c. Biological and ecological consequences of *Diolcogaster* sp. (Hymenoptera: Braconidae) parasitizing *Agaraea minuta* (Lepidoptera: Arctiidae) and the effects on two *Costus* (Costaceae) plant species in Brazil. Florida Entomologist 95: 966-970.

Tavares WS, Hansson C, Mielke OHH, Serrão JE, Zanuncio JC. 2013a. Parasitism of *Palmistichus elaeisis* Delvare & LaSalle, 1993 on pupae of *Methona themisto* (Hübner, [1818]) reared on two hosts (Lepidoptera: Nymphalidae; Hymenoptera: Eulophidae). Shilap-Revista de Lepidopterologia 41(161): 43-48.

Tavares WS, Legaspi JC, Tavares MT, Nunez E, Pinto R, Zanuncio JC. 2013b. *Brachymeria koehleri* (Hymenoptera: Chalcididae) as a hyperparasitoid of *Lespesia melloi* (Diptera: Tachinidae) pupae in *Thagona tibialis* (Lepidoptera: Lymantriidae) caterpillars in Brazil. Florida Entomologist 96: 1635-1638.

Tavares WS, Soares MA, Mielke OHH, Poderoso JCM, Serrão JE, Zanuncio JC. 2013c. Emergence of *Palmistichus elaeisis* Delvare & LaSalle, 1993 (Hymenoptera: Eulophidae) from pupae of *Heraclides anchisiades capys* (Hübner, [1809]) (Lepidoptera: Papilionidae) in the laboratory. Folia Biologica (Krakow) 61: 233-237.

Tavares WS, Nunez E, Serrão JE, Soares MA, Wilcken CF, Zanuncio JC. 2014a. *Belvosia* sp. (Diptera: Tachinidae) parasitizing *Halysidota* sp. (Lepidoptera: Arctiidae) caterpillars on *Ficus benjamina* (Moraceae) in Brazil. Florida Entomologist 97: 272-276.

Tavares WS, Wilcken CF, Ramalho FS, Leite GLD, Serrão JE, Zanuncio JC. 2014b. Defoliation of *Terminalia catappa* by larvae of *Thagona tibialis* (Lepidoptera: Erebidae) in Viçosa, Brazil. Journal of Agricultural and Urban Entomology 30: 1-11.

Zanuncio JC, Mezzomo JA, Guedes RNC, Oliveira AC. 1998. Influence of strips of native vegetation on Lepidoptera associated with *Eucalyptus cloeziana* in Brazil. Forest Ecology and Management 108: 85-90.

Zanuncio JC, Pereira FF, Jacques GC, Tavares MT, Serrão JE. 2008. *Tenebrio molitor* Linnaeus (Coleoptera: Tenebrionidae), a new alternative host to rear the pupae parasitoid *Palmistichus elaeisis* Delvare & LaSalle (Hymenoptera: Eulophidae). Coleopterists Bulletin 62: 64-66.