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Authors: Soares de Matos, Sidnéia Terezinha, dos Santos-Cividanes, Terezinha Monteiro, Cividanes, Francisco Jorge, dos Santos, Laís da Conceição, Suguino, Eduardo, et al.

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First record of lepidopteran borers in macadamia nuts in Brazil

Sidnéia Terezinha Soares de Matos^{1,*}, Terezinha Monteiro dos Santos-Cividanes², Francisco Jorge Cividanes², Laís da Conceição dos Santos³, Eduardo Suguino⁴, and Alex Antônio Ribeiro¹

The macadamia nut tree, *Macadamia integrifolia* Maiden and Betche (Proteaceae), is native to Australia. Macadamia nuts have a refined taste and are very popular for consumption raw, roasted, or as an ingredient in chocolates. These nuts have beneficial properties for human health. For example, they have high nutritional quality and fatty-acid content, which can delay aging and protect the cardiovascular system (Pimentel 2007; Freitas & Naves 2010; Piza & Moriya 2014).

The wide dissemination of its nutritional qualities has increased the demand for the macadamia nut and its derivatives. Several countries cultivate macadamia nuts, most prominently Australia, the USA, South Africa, Kenya, Guatemala, Brazil, Malawi, Colombia, and China. Macadamia nut cultivation is currently expanding and attracting attention from the global agricultural trade (Piza & Moriya 2014).

Insect pests affect macadamia nut productivity and may cause significant losses to producers. Australia and the US are the world's largest producers of macadamia nuts, and the lepidopteran borers *Cryptophlebia ombrodelta* (Lower) (Tortricidae), *Dichocrocis punctiferalis* (Guenée) (Pyralidae), and *Assara seminivale* (Turner) (Pyralidae) have been reported as pests of the macadamia nut tree (Gallagher et al. 2003). In Brazil, there are no records to date of these species attacking the fruits of this plant.

This study reports the occurrence of lepidopteran borers in macadamia nut trees from the municipality of Jaboticabal, state of São Paulo, Brazil. The study was conducted in 2 orchards. One of them was located on the campus of the Paulista State University School of Agrarian and Veterinary Sciences, Jaboticabal Campus, and consisted of trees of cultivars 'IAC S-10' and 'IAC 8-17,' approximately 30 yr old. The second orchard was located on the "Fazendinha Belo Horizonte" farm, planted with 18-yr-old trees of cultivars 'HAES 660' and 'HAES 344.' The association of borers with the macadamia nut fruits was determined through sampling the bored fruits (Fig. 1). The material collected had circular holes caused by larvae. Sampling was performed biweekly on 10 randomly chosen plants from each orchard, from Aug 2011 through May 2012, and from Aug 2012 through May 2013.

The collected fruits were sent to the Insect Ecology Laboratory, Paulista State University School of Agrarian and Veterinary Sciences, Jaboticabal Campus, where they were placed in 500 mL transparent plastic cups with 5.0 cm of soil, and sealed with voile to keep the insects from escaping, but allowing fresh air into the container. Soil was

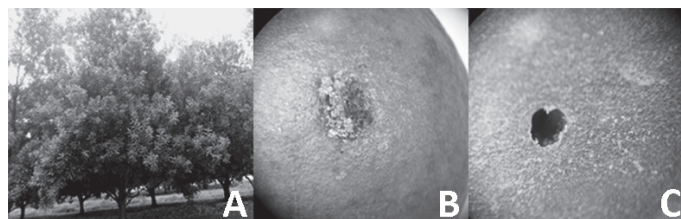


Fig. 1. (A) Macadamia nut trees; (B) bored fruit; and (C) fruit with a hole made by a lepidopteran borer.

used because some lepidopteran species pupate in the soil. The cups were kept in a climate-controlled room with $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$ temperature, $70\% \pm 10\%$ relative humidity, and a 12:12 h (L:D) photoperiod. After emergence, lepidopteran adults were collected and sent to Vitor Os-mar Becker (Uiracú Institute, Bahia State, Brazil) for identification.

The lepidopteran borer species associated with fruits of macadamia nut trees were identified as *Elaphria hypophaea* (Hampson) (Noctuidae), *Gymnandrosoma aurantianum* (Lima) (Tortricidae), and *Ectomyelois ceratoniae* (Zeller) (Pyralidae). The larvae of these species occurred in the stages of fruit formation and growth, ripe fruits, and dropped fruits, respectively (Fig. 2). *Gymnandrosoma aurantianum* and *E. ceratoniae* have been reported as important pests of macadamia nut fruits in Australia, Costa Rica, and Israel, directly attacking the fruits and causing significant losses (Wysoki 1986; Blanco-Metzler et al. 2013; Carvalho et al. 2015). In Brazil, *G. aurantianum* is a pest of *Citrus* (Rutaceae); the females lay eggs on the orange fruits, and the newly hatched larvae penetrate and feed inside the fruits (Garcia 1998). *Gymnandrosoma aurantianum* is one of the main pests of macadamia nuts in Costa Rica, and it causes damage to the nuts, and feeds on the kernel (Nakano & Soares 1995; Blanco-Metzler et al. 2013). These authors reported that its life cycle (egg to adult) lasts nearly 36 d, and the species may produce up to 10 generations per yr, depending on weather conditions and food availability.

This is the first record of *E. hypophaea* as a macadamia fruit borer worldwide. This is also the first report of *G. aurantianum* and *E. ceratoniae* as macadamia fruit borers in Brazil. These findings indicate that these lepidopteran pests are potentially damaging to macadamia nuts.

¹Departamento de Fitossanidade, Universidade Estadual Paulista, 14884-900, Jaboticabal, São Paulo, Brazil; E-mail: sidimatos@yahoo.com.br (S. T. S. M.), alexmudas@bol.com.br (A. A. R.)

²Laboratório de Parasitologia Vegetal, Instituto Biológico, 14030-670, Ribeirão Preto, São Paulo, Brazil; E-mail: terezinha@biologico.sp.gov.br (T. M. S. C.), fjcivida@gmail.com (F. J. C.)

³Faculdade Quirinópolis, 75860-000, Quirinópolis, Goiás, Brazil; E-mail: lais_santos@yahoo.com.br (L. C. S.)

⁴Instituto Agronômico, 14001-970, Ribeirão Preto, São Paulo, Brazil; E-mail: esuguino@apta.sp.gov.br (E. S.)

*Corresponding author; E-mail: sidimatos@yahoo.com.br

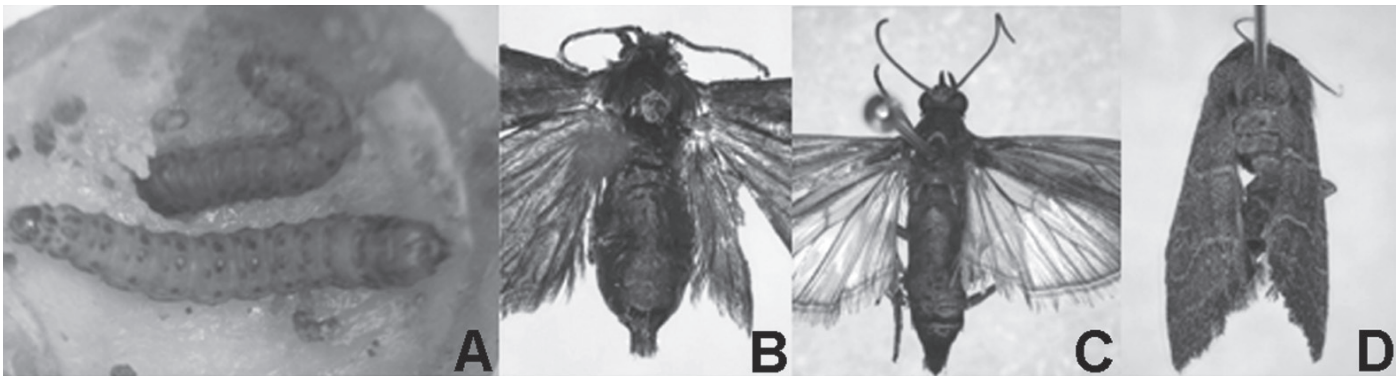


Fig. 2. (A) Larvae and (B) adult of *Gymnandrosoma aurantianum*; (C) *Ectomyelois ceratoniae*; and (D) *Elaphria hypophaea*.

Few studies have investigated the occurrence of insects associated with macadamia nuts in Brazil, because commercial production in this country is recent. Therefore, most of the available information on pests and control methods is derived from studies conducted in Australia and the US. This highlights the need for studies on pests and natural enemies associated with macadamia nut trees in producing countries, including Brazil, which ranks sixth largest among the world's macadamia nut exporting countries. Finally, identifying species associated with macadamia trees forms the basis for developing integrated pest management programs (Schneider et al. 2012).

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Summary

Brazil recently began commercial cultivation of macadamia nuts, making it necessary to identify the insect pests attacking them in order to develop a pest management program. This study reports the occurrence of lepidopteran borers in macadamia fruits of orchards from the municipality of Jaboticabal, state of São Paulo, Brazil. Sampling was performed biweekly by visually searching for attacked fruits. The nuts collected had circular holes caused by lepidopteran larvae. The borers identified were *Elaphria hypophaea* (Hampson) (Noctuidae), *Gymnandrosoma aurantianum* (Lima) (Tortricidae), and *Ectomyelois ceratoniae* (Zeller) (Pyralidae), which occurred in the stages of fruit formation and growth, ripe fruits, and dropped fruits, respectively. This is the first record of *E. hypophaea* as a macadamia fruit borer worldwide, and the first record of *G. aurantianum* and *E. ceratoniae* as macadamia fruit borers in Brazil.

Key Words: *Macadamia integrifolia*; insect pest; lepidopteran larva; damage; Proteaceae

Sumário

O Brasil recentemente começou a cultivar macadâmia comercialmente, e isso torna necessário identificar os insetos-praga que atacam as nozes de macadâmia, a fim de desenvolver um programa

de controle de pragas. Este estudo relata a ocorrência de brocas de lepidópteros em frutos de macadâmia de pomares do município de Jaboticabal, estado de São Paulo, Brasil. As amostragens foram realizadas quinzenalmente, procurando visualmente por frutos atacados. As castanhas coletadas tinham orifícios circulares causados por lagartas. As espécies de lepidópteros brocas identificados foram *Elaphria hypophaea* (Hampson) (Noctuidae), *Gymnandrosoma aurantianum* (Lima) (Tortricidae), e *Ectomyelois ceratoniae* (Zeller) (Pyralidae), que ocorreram nas fases de formação e crescimento dos frutos, frutos maduros e frutos em queda, respectivamente. Este é o primeiro registro mundial de *E. hypophaea* como broca de macadâmia e o primeiro registro de *G. aurantianum* e *E. ceratoniae* como broca de macadâmia no Brasil.

Palavras Chave: *Macadamia integrifolia*; inseto-praga; lagarta; dano; Proteaceae

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