Establishment in the field of *Cleruchoides noackae* (Hymenoptera: Mymaridae), an exotic egg parasitoid of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae)

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Abstract

Efficient strategies to control the bronze bug *Thaumastocoris peregrinus* Carpintero and Dellapé (Hemiptera: Thaumastocoridae) are unavailable, but *Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae) parasitizes eggs of this pest. The parasitism and number of parasitoids that emerged from the eggs of *T. peregrinus* were evaluated in the laboratory and from eggs of this pest collected in the field in an area of approximately 2 ha. Collections were done 1 yr after the first release of *C. noackae* to check for field establishment of this parasitoid in eucalyptus plantations in Minas Gerais State, Brazil. The emergence of *C. noackae* was 53 and 52% from eggs parasitized in the laboratory and in the field, respectively. This natural enemy was recorded for all sampling points from the field collections, which were up to 10 km from the place it had been released. The *C. noackae* establishment in the field, and the potential for biological control of *T. peregrinus* by this parasitoid were confirmed.

Key Words: biological control; bronze bug; *Eucalyptus*; parasitoid

Resumen

Estratégias eficientes para controlar o percevejo bronzeado *Thaumastocoris peregrinus* Carpintero e Dellapé (Hemiptera: Thaumastocoridae) não estão disponíveis, mas *Cleruchoides noackae* Lin e Huber (Hymenoptera: Mymaridae) parasita ovos desta praga. O parasitismo e o número de parasitoides emergidos por ovo de *T. peregrinus* foram avaliados em laboratório e em ovos desta praga coletados em campo em uma área de, aproximadamente, 2 hectares, 1 ano após a liberação de *C. noackae* para verificar o estabelecimento desse parasitoide em plantações de eucalipto, em Minas Gerais, Brasil. A taxa de emergência de *C. noackae*, de ovos parasitados em laboratório e campo, foi de 53% e 52%, respectivamente. Este inimigo natural foi registrado em todos os dez pontos de amostragem em campo; até dez quilômetros do local em que foi liberado pela primeira vez. O estabelecimento em campo e o potencial de utilização de *C. noackae* no controle biológico de *T. peregrinus* foram confirmados.

Palavras Chave: controle biológico; *Eucalyptus*; parasitoide; percevejo bronzeado

Eucalyptus species (Myrtales: Myrtaceae) (eucalyptus) are widely cultivated in more than 50 countries and thus represent the most commercially important timber in the world (Iglesias-Trabado & Wilstermann 2008; Shi et al. 2012). *Thaumastocoris peregrinus* Carpintero and Dellapé (Hemiptera: Thaumastocoridae), known as the bronze bug, damages eucalyptus plants worldwide. This pest is a native Australian hemipteran that feeds on the leaves of a wide variety of eucalyptus species and hybrids (Carpintero & Dellapé 2006; Noack et al. 2011; Soliman et al. 2012; Mutitu et al. 2013), causing silvering, tanning, and leaf drying. The efficiency of pesticides usage in forest crops is reduced because of the extensive nature of forest plantations, the height of eucalyptus trees, and the behavior of this insect pest (Zanuncio et al. 2010; Mewes et al. 2015).

Thaumastocoris peregrinus has been found in more than 10 countries across Europe, Africa, South America, and Oceania with a very fast spreading rate (Saavedra et al. 2015). Special attention should be paid to the regions of southern USA, Central America, and southern China and nearby countries, where environmental conditions are highly suitable for *T. peregrinus* population development (Montemayor et al. 2015).

Biological control is one of the strategies for the management of insect pests in forest plantations (Bragança et al. 1998; Pereira et al. 2008b; Garnas et al. 2012; Dias et al. 2014). *Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae), an egg parasitoid, the lacewings *Hemerobius bolivari* Banks (Neuroptera: Hemerobiidae) and

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Chrysoperla externa (Hagen) (Neuroptera: Chrysopidae), and predatory bugs have been reported as the main natural enemies of the bronze bug (Nadel & Noack 2012; Souza et al. 2012; Garcia et al. 2013). Parasitism of *T. peregrinus* by *C. noackae* was 25% in the field and 21% in the laboratory in Australia and 32% in the laboratory in South Africa (Mutitu et al. 2013).

The introduction and successful establishment of natural enemies are important to regulate pest populations (Gerard et al. 2011; Thompson & Reddy 2016). For establishment, the parasitoid should be able to find its host at both long and short distances (Cronin & Reeve 2014) and to adapt to environmental variability (Vercken et al. 2016). The objective of this study was to evaluate the parasitism of *C. noackae* on *T. peregrinus* under laboratory conditions and on eucalyptus plantations in Brazil.

Materials and Methods

Thaumastocoris peregrinus was reared in the laboratory at 24 ± 2 °C, 60 ± 10% RH, and a photoperiod of 12:12 h L:D on bouquets of *Eucalyptus benthamii* Maiden & Cambage (Myrtales: Myrtaceae) branches; the branches were fixed in a piece of foam to prevent drowning in a 500 mL glass flask filled with water (Barbosa et al. 2016).

Ten 0- to 24-h-old *T. peregrinus* eggs per paper towel strip obtained from a laboratory mass rearing facility (Laboratory of Forest Entomology of the EMBRAPA, Colombo, Brazil) were placed in a polystyrene vial (7.0 cm long and 3.0 cm in diameter) with a central hole and a plastic top sealed with "voile" fabric for airing. The eggs were exposed to *C. noackae* parasitism for 24 h with 23 replications. The parasitoid adults were obtained from Laboratory of Forest Entomology of the EMBRAPA, Colombo, Brazil). They were fed with 50% honey solution on filter paper strips (0.5 × 5 cm). These vials were kept in chambers at the following conditions: temperature of 23 ± 2 °C, relative humidity of 60 ± 10%, and a photoperiod of 12:12 h L:D.

Observations in the field were performed in Oct 2013 on eucalyptus plantations (growing clone VM01 of the hybrid *Eucalyptus urophylla* S. T. Blake × *Eucalyptus camaldulensis* Denhardt; Myrtales: Myrtaceae) of Vallourec Florestal in Minas Gerais State, Brazil (19.2511°S, 44.4683°W; 750 m altitude). Eucalyptus leaves with *T. peregrinus* eggs were collected from 22 points in an area of approximately 2 ha 1 yr after the first release of *C. noackae*. A sample of 30 viable *T. peregrinus* eggs (without signs of nymph hatching) was removed from the middle portion of the tree canopy per collection point, stored in polystyrene vials as described earlier for the parasitism experiment, and kept at a temperature of 23 °C and relative humidity of 60%. Other samples of *T. peregrinus* eggs were collected at random points of the plantation to evaluate *C. noackae* dispersion in the field.

The emergence of parasitoids was observed under a stereomicroscope, and they were sexed based on their external morphology. The number of adults emerged per d, the percentage of emergence, and the sex ratio (SR = number of ♀ / number of ♂+♀) of *C. noackae* from *T. peregrinus* eggs in the laboratory experiment and from samples collected in the field were calculated for 20 d.

Results and Discussion

In total, 230 and 660 *T. peregrinus* eggs were evaluated from those of the laboratory experiment and the field collection, respectively; the percentage of emergence of *C. noackae* from these eggs was 53% and 52%, respectively (Table 1). The similar parasitism rates on *T. peregrinus* in the laboratory and the field suggest high efficacy of *C. noackae* in Brazil, and the rates were higher than those reported in the laboratory (25%) and the field (21%) in Sydney, Australia, and in the laboratory (34%) in Pretoria, South Africa (Mutitu et al. 2013). These results may be due to different strains of this parasitoid as found for *Trichogramma* species (Hymenoptera: Trichogrammatidae) (Pak et al. 1986; Oliveira et al. 2000) or due to environmental conditions (Grevstad 1999; Vercken et al. 2015).

Table 1. Total number of eggs and adults, percentage of emergence, and sex ratio (mean ± SE) of *Cleruchoides noackae* (Hymenoptera: Mymaridae) from *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) eggs per d.

Site	Eggs (n)	Adults (n)	Emergence (%)	Sex ratio
Laboratory	230	123	53 ± 3	0.69 ± 0.02
Field[a]	660	342	52 ± 3	0.65 ± 0.02

[a]Paraopeba, Minas Gerais State, Brazil.

The parasitism rate of 1-d-old *T. peregrinus* eggs by *C. noackae* in the laboratory was higher than that reported on *Eucalyptus grandis* W. Hill ex Maiden (Myrtales: Myrtaceae) clone Tag 5 in South Africa, which was 34.1 and 16.6% in 0- to 1-d-old and 4- to 5-d-old eggs, respectively, of this host (Mutitu et al. 2013). Hosts in the initial development stages may be more appropriate than those in the late stages for hymenopteran parasitoids (Lytle et al. 2012; Peñaflor et al. 2012; Tavares et al. 2013) as shown for *C. noackae* (Mutitu et al. 2013), *Gonatocerus ashmeadi* Girault, *Gonatocerus triguttatus* Girault, and *Gonatocerus fasciatus* Girault (Hymenoptera: Mymaridae) (Irvin & Hoddle 2005), *Trichogramma* species (Vianna et al. 2009; Soares et al. 2012), and Eulophidae species (Pereira et al. 2008a,b).

The sex ratio of *C. noackae* in the laboratory and field was similar, 69 and 65% females, respectively. This result indicates favorable conditions for mass rearing (Heimpel & Lundgren 2000) with a greater female production than that found in the laboratory in Pretoria, South Africa, where the sex ratio was 50% (Mutitu et al. 2013). A high male production could be the result of poor host quality (Pereira et al. 2009; Zanuncio et al. 2010), high parasitoid/host ratio, or inbreeding (Tavares et al. 2009; Vianna et al. 2009).

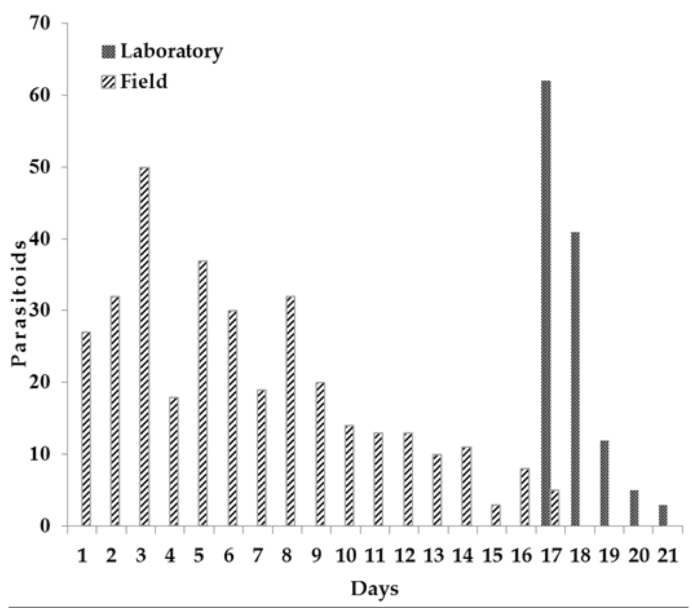

Fig. 1. Total number of *Cleruchoides noackae* (Hymenoptera: Mymaridae) adults emerged from *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) eggs per d that were parasitized in the laboratory (23 ± 2 °C, 60 ± 10% RH, and 12:12 h L:D photoperiod) and from eggs of this pest collected in the field.

The emergence of *C. noackae* in the laboratory was highest on day 17 and decreased until day 21 with an average development period of 17.9 d from oviposition to emergence (Fig. 1). The parasitoid can parasitize and complete its development from oviposition to adult emergence in 15.7 d in host eggs (Mutitu et al. 2013).

The information generated in this study is an important step to developing an integrated pest management program that includes releases of the egg parasitoid *C. noackae* as a biological control agent of *T. peregrinus* on eucalyptus plantation in Brazil. The recovery of *C. noackae* from *T. peregrinus* eggs collected in the field shows that this parasitoid reproduced and dispersed to a distance of over 10 km from its initial release point after 1 yr. This is the first record of the successful establishment and efficiency of *C. noackae* in the biological control of *T. peregrinus* in Brazil.

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