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Longevity of *Cleruchoides noackae* (Hymenoptera: Mymaridae), an egg parasitoid of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae), with various honey concentrations and at several temperatures

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Abstract

Thaumastocoris peregrinus Carpintero and Dellapé (Hemiptera: Thaumastocoridae), damages eucalyptus plants by sucking their sap. This pest can be controlled by releases of the egg parasitoid *Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae). Increasing the survival of this parasitoid is critically important for its mass rearing in order to release large numbers in integrated programs to manage *T. peregrinus*. The aim of this study was to evaluate the longevity of *C. noackae* adults fed various honey concentrations at 6 constant temperatures. The longevity of *C. noackae* was studied by keeping adults in a 1st experiment with 100, 50, or 10% honey solution, with distilled water, or without water and food in climate-controlled chambers at 25 ± 2 °C, $70 \pm 10\%$ RH, and a 12:12 h L:D photoperiod and—in a 2nd experiment—with 100% honey at constant temperatures of 15, 18, 21, 25, 28, or 31 °C in a climatic chamber at $70 \pm 10\%$ RH and a 12:12 h L:D photoperiod. Each adult parasitoid was held individually in a glass tube capped with plastic wrap under the conditions described, and the survival of adults was recorded daily. The longevity of *C. noackae* varied with food and temperature such that longevity was enhanced by all honey concentrations and temperatures of 25 °C and below. When fed honey, this parasitoid lived 2 to 3 fold longer when kept at 15, 18, 21, and 25 °C than at 28 and 31 °C. Thus, the parasitoid *C. noackae* should be mass reared with honey at temperatures from 15 to 25 °C for subsequent distribution of parasitoid adults in eucalyptus plantations for suppressing *T. peregrinus*.

Key Words: biological control; laboratory rearing; *Eucalyptus*

Resumen

Thaumastocoris peregrinus Carpintero y Dellapé (Hemiptera: Thaumastocoridae) causa daños a plantas de eucalypto succionando su savia. Este insecto plaga se puede ser controlado mediante liberaciones del parasitoide de huevos *Cleruchoides noackae* Lin y Huber (Hymenoptera: Mymaridae). El aumento de la supervivencia es esencial para producir y utilizar el parasitoide en programas integrado para manejo de *T. peregrinus*. El objetivo de este estudio fue evaluar la longevidad de adultos de *C. noackae* alimentados a diferentes concentraciones de miel en seis temperaturas constantes. La longevidad de *C. noackae* fue estudiada en un experimento por la alimentación con soluciones de miel de 100, 50, y 10%, agua destilada y sin comida, en cámara climatizada a 25 ± 2 °C, $70 \pm 10\%$ de humedad relativa y 12:12 h L: D de fotoperíodo y—en un segundo experimento—con el 100% de miel a temperaturas constantes de 15, 18, 21, 25, 28 y 31 °C en cámaras climatizadas con $70 \pm 10\%$ de humedad relativa y 12 h de fotoperíodo. Los adultos del parasitoide fueron individualizados en tubos de vidrio cubiertos con una envoltura de plástico en las condiciones descritas y su supervivencia se registró diariamente. La longevidad de *C. noackae* varió con el alimento y la temperatura, por lo que la longevidad fue realizada por todas las concentraciones de miel y temperaturas de 25 °C e inferior. El parasitoide alimentado con miel vivió 2-3 veces por más tiempo cuando se mantiene a 15, 18, 21 y 25 °C que a 28 y 31 °C. Por lo tanto, el parasitoide *C. noackae* debe ser criado con miel a temperaturas de 15 a 25 °C para la posterior distribución de parasitoides adultos en las plantaciones de eucalypto para la supresión de *T. peregrinus*.

Palabras Clave: control biológico; cría en laboratorio; *Eucalyptus*

Thaumastocoris peregrinus Carpintero and Dellapé (Hemiptera: Thaumastocoridae) is a pest of various *Eucalyptus* species and hybrids (Myrtales: Myrtaceae) in Argentina, Australia, Brazil, Chile, Kenya, South Africa, Uruguay, and Zimbabwe (Carpintero & Dellapé 2006; Nadel et

al. 2010; Noack et al. 2011; Laudonia & Sasso 2012). The spread of *T. peregrinus*, outside its origin in the Southern Hemisphere, includes South Africa (Jacobs & Nesar 2005; Nadel et al. 2010), Zimbabwe, Malawi, and Kenya (Noack et al. 2011). In South America, this pest has

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been detected in Argentina (Noack & Coviella 2006), Chile, Uruguay (Martínez & Bianchi 2010; Ide et al. 2011), and Brazil (Wilcken et al. 2010; Soliman et al. 2012). Furthermore, *T. peregrinus* was observed in Italy (Laudonia & Sasso 2012), Portugal (Garcia et al. 2013), and New Zealand (Sopow et al. 2012). *Thaumastocoris peregrinus* causes silvering, tanning, and drying of eucalyptus leaves. These symptoms result from the insect’s feeding habits of piercing leaves and branches to suck sap, leading to chlorosis and reduction of tree growth and productivity (Soliman et al. 2012). Owing to the extension of plantations, the height of the eucalyptus trees, and the behavior of this insect pest, the efficiency of pesticide use in forest crops is reduced (Zanuncio et al. 2010).

Biological control is one of the strategies for the management of insect pests in forest plantations (Pereira et al. 2008; Garnas et al. 2012). The endoparasitoid *Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae), the main biological control agent of *T. peregrinus* (Nadel & Noack 2012), was found in the eggs of *T. peregrinus* on *Eucalyptus scoparia* Maiden in Australia (Lin et al. 2007; Nadel et al. 2012).

Successful introduction of a biological control agent such as *C. noackae* requires knowledge of its lifecycle and interactions with the host *T. peregrinus* (Mutitu et al. 2013). Programs of biological control with egg parasitoids depend on producing large numbers of these natural enemies in the mass rearing facilities and releasing them when this insect pest is present in the eucalyptus plantation (de Carvalho Spínola-Filho et al. 2014).

Mass rearing of *C. noackae* requires analysis of its feeding habits, because in nature, insects seek different nutritional sources such as sugars and other carbohydrates (Harvey et al. 2012) than in the laboratory, where they depend on the food provided. Generally, the feeding of parasitoids in the laboratory positively affects their longevity and fecundity as demonstrated for *Aphytis melinus* DeBach (Hymenoptera: Aphelinidae) (Heimpel et al. 1997), *Cotesia glomerata* (L.) (Hymenoptera: Braconidae) (Wäckers 2001), *Pseudacteon tricuspis* Borgmeier (Diptera: Phoridae) (Chen et al. 2005), and *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae) (Jamont et al. 2013). Consumption of food, especially sugars, provides energy to maintain metabolism, longevity, fecundity, and flight activity of insects (Tenhumberg et al. 2006; Winkler et al. 2009).

The complexity of the interaction between various factors can affect the success of classical biological control programs (Vorsino et al. 2012). Temperature is one of the most important abiotic factors affecting survival, behavior, distribution and colonization (Pratissoli et al. 2004, 2005; Colinet & Boivin 2011), duration of development and parasitism (Zago et al. 2007; Soares et al. 2012), reproduction and sex ratio (Frazer & McGregor 1992), and longevity (Burgi & Mills 2013) of natural enemies. Enhanced longevity of parasitoids allows them to search for longer periods and therefore increases the probability of parasitism (Evans et al. 2010; Vollhardt et al. 2010).

Suboptimal temperatures can negatively affect the biological characteristics of adult insects, which must be evaluated for parasitoids (Lessard & Boivin 2013). Low temperatures can cause physiological dysfunctions (Colinet & Boivin 2011), reduce fertility (Pandey & Johnson 2005), and decrease the parasitoid’s mobility (Tezze & Botto 2004; Ayvaz et al. 2008). Thus, knowledge on development and longevity is important for maintaining and releasing the parasitoid *C. noackae* in integrated pest management programs against *T. peregrinus*. The objective of this study was to evaluate the longevity of *C. noackae* fed with several honey concentrations and reared at 6 constant temperatures.

Materials and Methods

The experiments were conducted in the laboratory of Biological Control of Forest Pests of the Faculty of Agricultural Sciences, São Paulo

State University (UNESP) in Botucatu, São Paulo State, Brazil. Individuals of *C. noackae* were obtained from a rearing facility of Embrapa Forestry (Brazilian Agricultural Research Corporation) in Colombo, Parana State, Brazil, with *T. peregrinus* as the host. These parasitoids were obtained from *T. peregrinus* eggs originally collected in urban trees of *Eucalyptus camaldulensis* Dehnh. and *E. scoparia* in Sydney, New South Wales, Australia. The newly emerged adults of this parasitoid were held individually in glass tubes (8.5 cm high × 2.5 cm wide) capped with plastic film.

The longevity of *C. noackae* adults was evaluated in the following treatments: T1, 100% honey; T2, 50% honey; T3, 10% honey; T4, distilled water; and T5, without honey or water in chambers conditioned at 25 ± 2 °C, 70 ± 10% RH, and a 12:12 h L:D photoperiod. The honey concentrations were obtained by diluting the honey with distilled water. These foods were provided on paper towel every 24 h to *C. noackae* adults during the evaluation of their survival.

In the 2nd experiment, the longevity of *C. noackae* adults was evaluated at 15 °C (T1), 18 °C (T2), 21 °C (T3), 25 °C (T4), 28 °C (T5), and 31 °C (T6) in a climatic chamber at 70 ± 10% RH and a 12:12 h L:D photoperiod, and adults were fed 100% honey. The longevity of these parasitoids was determined every 24 h until all adults died.

The data of *C. noackae* longevity were subjected to the Shapiro–Wilk normality residues test and analysis of variance. The means were compared by using the nonparametric Kruskal–Wallis test.

Results

Cleruchoides noackae adults lived 3.4, 3.3, and 3.7 d (Table 1) when fed 100, 50, and 10% honey, respectively, and these 3 values were not significantly different. However, these longevitys were significantly longer than those of adults fed only distilled water or nothing. The latter 2 longevitys were 1.7 and 1.2 d, respectively, and they did not differ significantly from one another (Table 1).

At temperatures of 15, 18, and 25 °C, *C. noackae* adults showed the greatest longevitys, which were 2.9, 3.3, and 3.5 d, respectively (Table 2). However, these 3 longevitys did not differ significantly from the longevity of 2.2 d at 21 °C. At 28 and 31 °C, the longevitys were 1.1 and 1.1 d, respectively, and these values were significantly shorter than those at 15, 18, and 25 °C, but not different from that at 21 °C (Table 2). The longevity of *C. noackae* adults was 2 to 3 fold greater at 15, 18, and 25 °C than at 28 and 31 °C.

Discussion

The increased longevity of *C. noackae* adults fed honey agrees with observations of other parasitoid species in the laboratory, such as *Ibalia leucospoides* (Hochenwarth) (Hymenoptera: Ibalidae), in which longevity was increased by 10 d when adults were fed (Fischbein et

Table 1. Adult longevity of *Cleruchoides noackae* (Hymenoptera: Mymaridae) (mean ± SE and variation interval) with several concentrations of honey in chambers at 25 ± 2 °C, 70 ± 10% RH, and a 12:12 h L:D photoperiod (n = 10).

Food	Mean longevity ± SE (d)	Variation interval (d)
Honey 100%	3.4 ± 0.51 a	3–4
Honey 50%	3.3 ± 0.94 a	2–5
Honey 10%	3.7 ± 1.70 a	2–7
Water	1.7 ± 0.48 b	1–2
Without food	1.2 ± 0.42 b	1–2

Means followed by the same letter do not differ by the Kruskal–Wallis test.

Table 2. Adult longevity of *Cleruchoidea noackae* (Hymenoptera: Mymaridae) (mean \pm SE and variation interval) fed 100% honey at 6 constant temperatures in climatic chambers at 70 \pm 10% RH and a 12:12 h L:D photoperiod ($n = 10$).

Temperature (°C)	Mean longevity \pm SE (d)	Variation interval (d)
15	2.9 \pm 0.3 a	2–4
18	3.3 \pm 0.2 a	3–4
21	2.2 \pm 0.3 ab	1–4
25	3.5 \pm 0.6 a	1–6
28	1.1 \pm 0.1 b	1–2
31	1.1 \pm 0.1 b	1–2

Means followed by the same letter do not differ by the Kruskal–Wallis test.

al. 2013). Furthermore, *Tachinaephagus zealandicus* Ashmead (Hymenoptera: Encyrtidae) showed 2 to 3 fold greater longevity when fed honey and water than water alone (Almeida et al. 2002). The parasitoid *D. rapae* (Jamont et al. 2013) and the hyperparasitoid *Gelis agilis* (F.) (Hymenoptera: Ichneumonidae) (Harvey et al. 2012) also lived longer with honey than with sugar alone. This can be explained by the fact that honey is a highly concentrated solution of at least 181 substances such as sugars, proteins, enzymes, amino acids, minerals, and vitamins (Alvarez-Suarez et al. 2009).

The benefits of feeding *C. noackae* with honey at 3 concentrations may not be a standard for parasitoids. Honey fed at 50% concentration increased the longevity of *Apanteles metesae* (Nixon) (Hymenoptera: Braconidae), but honey fed at higher concentrations decreased the longevity of this natural enemy (Salmah et al. 2012). This effect may be explained by honey, at low concentration, containing more water than carbohydrates, whereas high concentrations of honey contain more energy than water. Thus, excess energy or low water content can reduce the parasitoid’s longevity (Salmah et al. 2012).

The shorter longevity of *C. noackae* without sugar is similar to that observed for *A. melinus*, whose females lived 30.5 d with honey and 17 d without food (Heimpel et al. 1997). Moreover, the longevity of *A. metesae* was longer when adults were fed 50% honey and 20% sucrose than when fed 50% sucrose or only distilled water (Salmah et al. 2012). Females of *D. rapae* showed greater longevity when fed with extrafloral nectar plus water, 20% honey, and honeydew plus water than those held without food (Jamont et al. 2013). These food sources may allow the acquisition of nutrients such as sugars, proteins, enzymes, amino acids, minerals, and vitamins from honey (Alvarez-Suarez et al. 2009) and sugars and lipids from the extrafloral nectar. Providing food to adult parasitoids is important because these natural enemies have only the energy accumulated during their immature stage, which may restrict longevity, fecundity, parasitism rate, ability to locate hosts, and flight (Lewis et al. 1998; Fadamiro & Heimpel 2001; Winkler et al. 2009).

Longevity of *C. noackae* in response to temperature was similar to that of *Meteorus ictericus* (Nees) (Hymenoptera: Braconidae) (Burgi & Mills 2013). The adaptation of the parasitoid to climatic conditions is important for its efficiency in biological control (Yu & Byers 1994). Temperature is one of the most important factors in acclimation of introduced parasitoids (Loni 1997), making it important to define the responses of these natural enemies to this factor (Ables et al. 1976).

Increased longevity of *C. noackae* at low temperature agrees with data for egg parasitoids such as *Trissolcus simoni* (Mayr) (Hymenoptera: Scelionidae) between 20 and 32 °C (Kivan & Kilic 2005) and *Trichogramma pretiosum* Querino & Zucchi (Hymenoptera: Trichogrammatidae) from 15 to 33 °C (Zago et al. 2007). Increased longevity may be associated with reduced activity and metabolism at lower temperatures (Gerling 1972; Bleicher & Parra 1990). Suboptimal temperatures

can shorten the lifespan (Jalali & Singh 1992; Torres et al. 2002), reduce body size (Rundle et al. 2004) and energy reserves (Renault et al. 2003), increase the development period (Prattisoli et al. 2004), and reduce emergence and fecundity of parasitoids (Colinet & Boivin 2011). However, the intensity of the response varies with natural enemy species (Lessard & Boivin 2013); for example, the parasitoid *Bracon vulgaris* Ashmead (Hymenoptera: Braconidae) showed 2-fold greater longevity at 20 °C than that at 25 and 30 °C (Wanderley et al. 2007), and *Trichospilus diatraeae* Cheria & Margabandhu (Hymenoptera: Eulophidae) showed longevity of 34.4 and 1.5 d at 16 and 28 °C, respectively (Rodrigues et al. 2013).

The reduction in the longevity of *C. noackae* adults at higher temperatures is similar to that reported for the parasitoids *Trichogramma pretiosum* Riley and *Trichogrammatodea annulata* De Santis (Hymenoptera: Trichogrammatidae) (Maceda et al. 2003), *T. diatraeae* (Rodrigues et al. 2013), and *Palmistichus elaeis* Delvare & LaSalle (Hymenoptera: Eulophidae) (Pereira et al. 2011) between 10 and 31 °C. The lowest survival may have resulted from increased metabolic activity and destruction or denaturation of enzymes in the insects (Mohan et al. 1992). The low survival of *C. noackae* at high temperatures indicates that this parasitoid has few possibilities of field adaptation to warm temperatures. Therefore, one option for its use in management programs should be to release large numbers of *C. noackae* adults in these warm regions.

The parasitoid *C. noackae* showed greatest longevity when fed with honey at concentrations of 100, 50, and 10% and reared at 15 and 18 °C. The provision of food at appropriate temperature is important for the production of *C. noackae* in the laboratory. The findings of this study can help in defining strategies for the rearing to release this parasitoid in biological control programs against *T. peregrinus*.

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References Cited

Ables JR, Shepard M, Holman JR. 1976. Development of the parasitoids *Spalangia endius* and *Muscidifurax raptor* in relation to constant and variable temperature: simulation and validation. *Environmental Entomology* 5: 329–332.

Almeida MAF, Prado AP, Geden CJ. 2002. Influence of temperature on development time and longevity of *Tachinaephagus zealandicus* (Hymenoptera: Encyrtidae), and effects of nutrition and emergence order on longevity. *Environmental Entomology* 31: 375–380.

Alvarez-Suarez J, Tulipani S, Romandini S, Vidal AY, Battino M. 2009. Methodological aspects about determination of phenolic compounds and in vitro evaluation of antioxidant capacity in the honey: a review. *Current Analytical Chemistry* 5: 293–302.

Ayaz A, Karasu E, Karaborklu S, Tuncbilek A. 2008. Effects of cold storage, rearing temperature, parasitoid age and irradiation on the performance of *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae). *Journal of Stored Products Research* 44: 232–240.

Bleicher E, Parra JRP. 1990. Espécies de *Trichogramma* parasitoides de *Alabama argillacea*. Determinação das exigências térmicas de três populações. *Pesquisa Agropecuária Brasileira* 25: 215–219.

Burgi LP, Mills NJ. 2013. Developmental strategy and life history traits of *Meteorus ictericus*, a successful resident parasitoid of the exotic light brown apple moth in California. *Biological Control* 66: 173–182.

Carpintero DL, Dellapé PM. 2006. A new species of *Thaumastocoris* Kirkaldy from Argentina (Heteroptera: Thaumastocoridae: Thaumastocorinae). *Zootaxa* 1228: 61–68.

- Chen L, Onagbola EO, Fadamiro HY. 2005. Effects of temperature, sugar availability, sex, mating, and size on the longevity of phorid fly *Pseudacteon tricuspis* (Diptera: Phoridae). *Environmental Entomology* 34: 246–255.
- Colinet H, Boivin G. 2011. Insect parasitoids cold storage: a comprehensive review of factors of variability and consequences. *Biological Control* 58: 83–95.
- de Carvalho Spínola-Filho PR, Leite GLD, Soares MA, Alvarenga AC, de Paulo PD, Tuffi-Santos LD, Zanuncio JC. 2014. Effects of duration of cold storage of the eggs on percent parasitism and adult emergence of each of ten Trichogrammatidae (Hymenoptera) species. *Florida Entomologist* 97: 14–21.
- Evans EW, Anderson MR, Bowling PD. 2010. Targeted sugar promotes parasitism of the cereal leaf beetle *Oulema melanopus*. *Agricultural and Forest Entomology* 12: 41–47.
- Fadamiro HY, Heimpel G. 2001. Effects of partial sugar deprivation on lifespan and carbohydrate mobilization in the parasitoid *Macrocentrus grandii* (Hymenoptera: Braconidae). *Annals of the Entomological Society of America* 94: 909–916.
- Fischbein D, Bernstein C, Corley JC. 2013. Linking reproductive and feeding strategies in the parasitoid *Ibalia leucospoides*: Does feeding always imply profit? *Evolutionary Ecology* 27: 619–634.
- Frazer BD, McGregor RR. 1992. Temperature-dependent survival and hatching rate of eggs of seven species of Coccinellidae. *The Canadian Entomologist* 124: 305–312.
- Garcia A, Figueiredo E, Valente C, Monserrat VJ, Branco M. 2013. First record of *Thaumastocoris peregrinus* in Portugal and of the Neotropical predator *Hemerobius bolivari* in Europe. *Bulletin of Insectology* 66: 251–256.
- Garnas JR, Hurley BP, Slippers B, Wingfield MJ. 2012. Biological control of forest plantation pests in an interconnected world requires greater international focus. *International Journal of Pest Management* 58: 211–223.
- Gerling D. 1972. The developmental biology of *Telenomus remus* Nixon (Hym., Scelionidae). *Bulletin of Entomological Research* 61: 385–388.
- Harvey JA, Cloutier J, Visser B, Ellers J, Wäckers FL, Gols R. 2012. The effect of different dietary sugars and honey on longevity and fecundity in two hyperparasitoid wasps. *Journal of Insect Physiology* 58: 816–823.
- Heimpel GE, Rosenheim JA, Kattari D. 1997. Adult feeding and lifetime reproductive success in the parasitoid *Aphytis melinus*. *Entomologia Experimentalis et Applicata* 83: 305–315.
- Ide SM, Ruiz CG, Sandoval AC, Valenzuela JE. 2011. Detección de *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) asociado a *Eucalyptus* spp. en Chile. *Bosque* 32: 309–313.
- Jacobs DH, Naser S. 2005. *Thaumastocoris australicus* Kirkaldy (Heteroptera: Thaumastocoridae): a new insect arrival in South Africa, damaging to *Eucalyptus* trees. *South African Journal of Science* 101: 233–236.
- Jalali SK, Singh SP. 1992. Differential response of four *Trichogramma* species to low temperatures for short term storage. *Entomophaga* 37: 159–165.
- Jamont M, Crépellère S, Jaloux B. 2013. Effect of extrafloral nectar provisioning on the performance of the adult parasitoid *Diaeretiella rapae*. *Biological Control* 65: 271–277.
- Kivan M, Kilic N. 2005. Effects of temperature on reproductive capacity and longevity of *Trissolcus simoni*, an egg parasitoid of *Eurygaster integriceps*. *Journal of Pest Science* 78: 105–108.
- Laudonia S, Sasso R. 2012. The bronze bug *Thaumastocoris peregrinus*: a new insect recorded in Italy, damaging to *Eucalyptus* trees. *Bulletin of Insectology* 65: 89–93.
- Lessard E, Boivin G. 2013. Effect of low temperature on emergence, fecundity, longevity and host-feeding by *Trichogramma brassicae*. *Biocontrol* 58: 319–329.
- Lewis WJ, Stapel JO, Cortesero AM, Takasu K. 1998. Understanding how parasitoids balance food and host needs: importance to biological control. *Biological Control* 11: 175–183.
- Lin N, Huber JT, La Salle J. 2007. The Australian genera of Mymaridae (Hymenoptera: Chalcidoidea). *Zootaxa* 1596: 1–111.
- Loni A. 1997. Developmental rate of *Opius concolor* (Hymenoptera: Braconidae) at various constant temperatures. *Entomophaga* 42: 359–366.
- Maceda A, Hohmann CL, Santos HR. 2003. Temperature effects on *Trichogramma pretiosum* Riley and *Trichogrammatodea annulata* De Santis. *Brazilian Archives of Biology and Technology* 46: 27–32.
- Martínez G, Bianchi M. 2010. Primer registro para Uruguay de la chinche del eucalipto, *Thaumastocoris peregrinus* Carpintero y Dellappé (Hemiptera: Thaumastocoridae). *Agrociencia* 14: 15–18.
- Mohan BR, Verma AN, Singh SP. 1992. Biology of *Apanteles flavipes* (Cameron)—a potential parasitoid of *Chilo partellus* (Swin.) infesting forage sorghum. *Journal of Insect Science* 5: 144–146.
- Mutitu K, Garnas JR, Hurley BP, Wingfield MJ, Harney M, Bush SJ, Slippers B. 2013. Biology and rearing of *Cleruchoides noackae* (Hymenoptera: Mymaridae), an egg parasitoid for the biological control of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae). *Journal of Economic Entomology* 106: 1979–1985.
- Nadel RL, Noack AE. 2012. Current understanding of the biology of *Thaumastocoris peregrinus* in the quest for a management strategy. *International Journal of Pest Management* 58: 257–266.
- Nadel RL, Slippers B, Scholes MC, Lawson SA, Noack AE, Wilcken CF, Bouvet JP, Wingfield MJ. 2010. DNA barcoding reveals sources and patterns of *Thaumastocoris peregrinus* invasions in South Africa and South America. *Biological Invasions* 12: 1067–1077.
- Nadel RL, Wingfield MJ, Scholes MC, Lawson SA, Noack AE, Naser S, Slippers B. 2012. Mitochondrial DNA diversity of *Cleruchoides noackae* (Hymenoptera: Mymaridae): a potential biological control agent for *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae). *Biocontrol* 57: 397–404.
- Noack AE, Coviella CE. 2006. *Thaumastocoris australicus* Kirkaldy (Hemiptera: Thaumastocoridae): first record of this invasive pest of *Eucalyptus* in the Americas. *General and Applied Entomology* 35: 13–14.
- Noack AE, Cassis G, Rose HA. 2011. Systematic revision of *Thaumastocoris* Kirkaldy (Hemiptera: Heteroptera: Thaumastocoridae). *Zootaxa* 3121: 1–60.
- Pandey RR, Johnson MW. 2005. Effects of cool storage on *Anagrus ananatis* Gahan (Hymenoptera: Encyrtidae). *Biological Control* 35: 9–16.
- Pereira FF, Zanuncio JC, Zanuncio JC, Pratisoli D, Tavares MT. 2008. Species of Lepidoptera defoliators of eucalypt as new hosts for the polyphagous parasitoid *Palmistichus elaeis* (Hymenoptera: Eulophidae). *Brazilian Archives of Biology and Technology* 51: 259–262.
- Pereira FF, Zanuncio JC, Oliveira HN, Grance ELV, Pastori PL, Gava-Oliveira MD. 2011. Thermal requirements and estimate number of generations of *Palmistichus elaeis* (Hymenoptera: Eulophidae) in different *Eucalyptus* plantations regions. *Brazilian Journal of Biology* 71: 431–436.
- Pratisoli D, Fernandes O, Zanuncio JC, Pastori PL. 2004. Fertility life table of *Trichogramma pretiosum* and *Trichogramma acacioi* (Hymenoptera: Trichogrammatidae) on *Sitotroga cerealella* (Lepidoptera: Gelechiidae) eggs at different constant temperatures. *Annals of the Entomological Society of America* 97: 729–731.
- Pratisoli D, Zanuncio JC, Vianna UR, Andrade JS, Zanotti LCM, Da Silva AF. 2005. Biological characteristics of *Trichogramma pretiosum* and *Trichogramma acacioi* (Hym.: Trichogrammatidae), parasitoids of the avocado defoliator *Nipteria panacea* (Lep.: Geometridae), on eggs of *Anagasta kuehniella* (Lep.: Pyralidae). *Brazilian Archives of Biology and Technology* 48: 7–13.
- Renault D, Hance T, Vannier G, Vernon P. 2003. Is body size an influential parameter in determining the duration of survival at low temperatures in *Alphitobius diaperinus* Panzer (Coleoptera: Tenebrionidae)? *Journal of Zoology* 259: 381–388.
- Rodrigues MAT, Pereira FF, Kassab SO, Pastori PL, Glaeser DF, Oliveira HN, Zanuncio JC. 2013. Thermal requirements and generation estimates of *Trichospilus diatraeae* (Hymenoptera: Eulophidae) in sugarcane producing regions of Brazil. *Florida Entomologist* 96: 154–159.
- Rundle BJ, Thomson LJ, Hoffmann AA. 2004. Effects of cold storage on field and laboratory performance of *Trichogramma carverae* (Hymenoptera: Trichogrammatidae) and the response of three *Trichogramma* spp. (*T. carverae*, *T. nr. brassicae*, and *T. funiculatum*) to cold. *Journal of Economic Entomology* 97: 213–221.
- Salmah M, Basri MW, Idris AB. 2012. Effects of honey and sucrose on longevity and fecundity of *Apanteles metesae* (Nixon), a major parasitoid of the oil palm bagworm, *Metisaplana* (Walker). *Sains Malaysiana* 41: 1543–1548.
- Soares MA, Leite GLD, Zanuncio JC, De Sá VGM, Ferreira CS, Rocha SL, Pires EM, Serrão JE. 2012. Quality control of *Trichogramma atopovirilia* and *Trichogramma pretiosum* (Hym.: Trichogrammatidae) adults reared under laboratory conditions. *Brazilian Archives of Biology and Technology* 55: 305–311.
- Soliman EP, Wilcken CF, Pereira JM, Dias TKR, Zache B, Pogetto D, Barbosa L. 2012. Biology of *Thaumastocoris peregrinus* in different *Eucalyptus* species and hybrids. *Phytoparasitica* 40: 223–230.
- Sopow S, George S, Ward N. 2012. Bronze bug, *Thaumastocoris peregrinus*: a new eucalyptus pest in New Zealand. *Surveillance* 39: 43–46.
- Tenhuberg B, Siekmann G, Keller MA. 2006. Optimal time allocation in parasitic wasps searching for hosts and food. *Oikos* 113: 121–131.
- Tezze AA, Botto EN. 2004. Effect of cold storage on the quality of *Trichogramma nerudai* (Hymenoptera: Trichogrammatidae). *Biological Control* 30: 11–16.
- Torres JB, Musolin DL, Zanuncio JC. 2002. Thermal requirements and parasitism capacity of *Trissolcus brochymenae* (Ashmead) (Hymenoptera: Scelionidae) under constant and fluctuating temperatures, and assessment of development in field conditions. *Biocontrol Science and Technology* 12: 583–593.
- Vollhardt IMG, Bianchi FJA, Wäckers FL, Thies C, Tscharnkte T. 2010. Spatial distribution of flower vs. honeydew resources in cereal fields may affect aphid parasitism. *Biological Control* 53: 204–213.
- Vorsino AE, Wieczorek AM, Wright MG, Messing RH. 2012. Using evolutionary tools to facilitate the prediction and prevention of host-based differentiation in biological control: a review and perspective. *Annals of Applied Biology* 160: 204–216.

- Wäckers FL. 2001. A comparison of nectar and honeydew sugars with respect to their utilization by the hymenopteran parasitoid *Cotesia glomerata*. *Journal of Insect Physiology* 47: 1077–1084.
- Wanderley PA, Ramalho FS, Zanuncio JC. 2007. Thermal requirements and development of *Bracon vulgaris*, a parasitoid of the cotton boll weevil. *Phytoparasitica* 35: 336–345.
- Wilcken CF, Soliman EP, Nogueira de Sá LA, Barbosa LR, Dias TKR, Ferreira-Filho PJ, Oliveira RJR. 2010. Bronze bug *Thaumastocoris peregrinus* Carpintero and Dellapé (Hemiptera: Thaumastocoridae) on eucalyptus in Brazil and its distribution. *Journal of Plant Protection Research* 50: 201–205.
- Winkler K, Wäckers FL, Kaufman LV, Larraz V, van Lenteren JC. 2009. Nectar exploitation by herbivores and their parasitoids is a function of flower species and relative humidity. *Biological Control* 50: 299–306.
- Yu DS, Byers JR. 1994. Inundative release of *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) for control of European corn borer in sweet corn. *The Canadian Entomologist* 126: 291–301.
- Zago HB, Pratisoli D, Barro R, Gondim Jr MGC, Santos Jr HJG. 2007. Capacidade de parasitismo de *Trichogramma pratissolii* Querino & Zucchi (Hymenoptera: Trichogrammatidae) em hospedeiros alternativos, sob diferentes temperaturas. *Neotropical Entomology* 36: 84–89.
- Zanuncio AJV, Pastori PL, Kirkendall LR, Lino-Neto J, Serrao JE, Zanuncio JC. 2010. *Megaplatypus mutatus* (Chapuis) (Coleoptera: Curculionidae: Platypodinae) attacks hybrid *Eucalyptus* L'Héritier de Brutelle clones in southern Espírito Santo, Brazil. *The Coleopterists Bulletin* 64: 81–83.