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First record of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae) in the Middle East, with biological notes on its relations with eucalyptus trees

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ABSTRACT

We present the first Middle-Eastern record of *Thaumastocoris peregrinus* Carpintero & Dellapé, an invasive pest that feeds and develops only on eucalyptus trees. This species was found in Israel for the first time in *Eucalyptus camaldulensis* stands in October 2014. A survey of several eucalyptus groves was conducted in Tel Aviv and its surroundings to assess the geographical distribution and host-plant associations of *T. peregrinus*. We summarize new and old data on this species, i.e., its identification, immature stages, biology, phenology, and damage caused to the host plant.

KEYWORDS: Bronze bug, biological invasion, *Eucalyptus*, gum trees, Israel, new record, pest.

INTRODUCTION

The genus *Eucalyptus* comprises over 700 species globally, most of which are indigenous to Australia from where the gum trees were introduced into Israel at the beginning of the 20th century for draining swamps. To date, with the exception of extreme desert areas, eucalyptus trees are found throughout Israel, with the most prominent species in Israel being *Eucalyptus camaldulensis* Dehnh, 1832. Eucalyptus trees were also planted in Israel for security reasons, particularly to conceal strategic roads against hostile activities (Burmil & Enis 2011). Nowadays their greatest benefit is probably in providing shade for recreational purposes, and many of us enjoy and take advantage of these areas, especially during hot summer months.

The genus *Thaumastocoris* has been recently revised to include 14 species, with nine species described as new (Noack *et al.* 2011). *Thaumastocoris peregrinus* Carpintero & Dellapé, commonly known as the bronze bug, was described from Argentina but is native to Australia (Noack *et al.* 2011; Garcia *et al.* 2013), where it is an important pest of *Corymbia* and *Eucalyptus* plantations (both Myrtaceae). This insect is also one of the major *Eucalyptus* pests in Africa (Kenya, Malawi, South Africa, Zimbabwe), Europe (Italy, Portugal), South America (Argentina, Brazil, Chile, Paraguay, Uruguay), Caribbean, and New Zealand (e.g. FAO 2012; Soliman *et al.* 2012; Garcia *et al.* 2013). Its presence in most of these countries is

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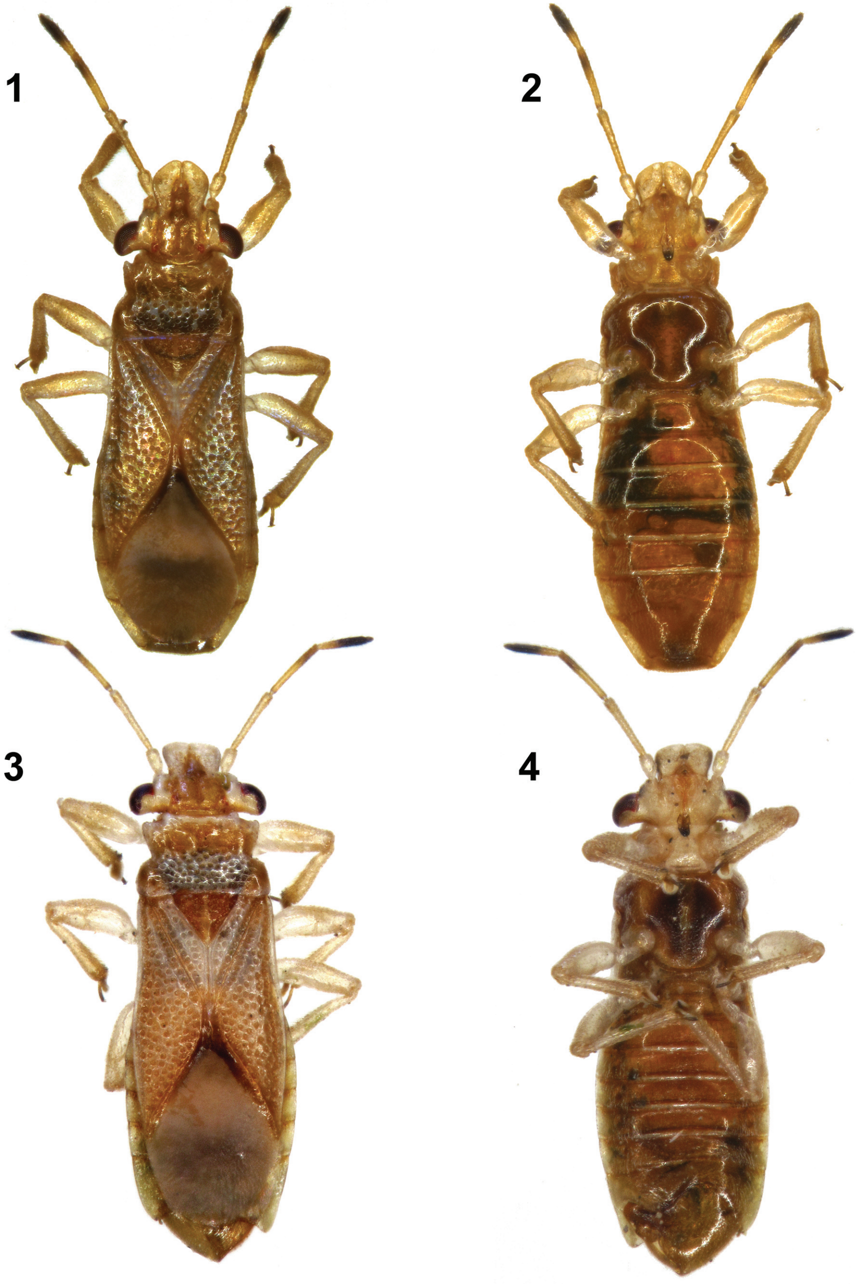

Figs 1–4. *T. peregrinus*, adult: (1, 2) female, dorsal (1) and ventral (2) views; (3, 4) male, dorsal (3) and ventral (4) views.

doubtlessly due to invasions, almost all of which were reported for the first time during the last decade. Lopes-da-Silva *et al.* (2014) gave an overview of possible routes of dispersal of this species, which may include transportation on young *Eucalyptus* plants, cut brunches and on wood.

T. peregrinus was first detected in Israel in October 2014 during our survey of pests on eucalyptus trees, when a huge population attacking *E. camaldulensis* was revealed. This discovery was somewhat surprising, as the family Thaumastocoridae is essentially Australian in distribution and had not been previously recorded from Israel. In this country it is a serious pest of *Eucalyptus*, leading to severe defoliation. In addition, it has been reported by some park visitors that these bugs cause skin irritation and rashes. However, this could be a manifestation of entomophobia, due to the unpleasant sensation that occurs when insects crawl over a person's bare skin. Such contentions should thus be verified before decisive conclusions are drawn regarding the medical significance of this pest.

Noack *et al.* (2009) found that trees treated with Imidacloprid in Australia showed a significant reduction in populations of *T. peregrinus* compared to untreated control trees. Thus, chemical treatment is effective in controlling *T. peregrinus* in the urban environment. Two species of mymarid parasitic wasps, *Cleruchoides noackae* Lin & Huber and *Stethynium* sp., have been established as egg parasitoids of *T. peregrinus* in Australia (Lin *et al.* 2007), and *C. noackae* is currently the main biocontrol agent at the international level (Nadel & Noack 2012). A single wasp emerges from each parasitized thaumastocorid egg via the operculum (Noack *et al.* 2011). In Brazil a few natural enemies have been reported, such as the green lacewing, a predatory bug *Atopozelus opsimus* Elkins (Hemiptera: Reduviidae), along with the entomopathogenic fungi *Beauveria bassiana* and unidentified Entomophtorales (Wilcken *et al.* 2010; FAO 2012). *Chrysoperla externa* (Hagen) (Neuroptera: Chrysopidae) is the first predatory insect to have been observed feeding on *T. peregrinus* nymphs (Wilcken *et al.* 2010). None of these parasitoids or predators has been recorded in Israel to date.

In their cladistic analysis of the Cimicimorpha, Schuh and Štys (1991) placed the Thaumastocoridae in the Miroidea, which also include the Miridae and Tingidae. The Thaumastocoridae differ clearly from the other two families by their mandibular plates that are greatly enlarged and conspicuous, usually exceeding and surrounding the apex of the clypeus. The mandibular plates of the other two families are small, inconspicuous, and do not exceed the apex of the clypeus.

The family Thaumastocoridae consists of three subfamilies (Schuh & Slater 1995; van Doesburg *et al.* 2010). The Thaumastocorinae are diagnosed by the pretarsus without pseudopulvilli, fossula spongiosa (a hairy structure on the apex of the tibia (Weirauch 2007)) present, and by only the left paramere in males. The Xylastodorinae have the pretarsus with pseudopulvilli, no fossula spongiosa, and no parameres in males. The Thaicorinae closely allied to the latter are recognized by the pretarsus with pseudopulvilli and no fossula spongiosa; no parameres have been observed in the only available male (Heiss pers. comm., 2016). The possession of a fossula spongiosa is shared by the Thaumastocorinae and some other families of cimicomorphan Heteroptera (Reduviidae, some Pachynomidae, Nabidae, Anthocoridae, Cimicidae, and Microphysidae) (Weirauch 2007).

MATERIALS AND METHODS

Experimental methods

This study is based on specimens of *T. peregrinus* stored in the insect collection of the Steinhardt Museum of Natural History, Israel National Research Center at Tel Aviv University. Five females and five males were measured from anterior tip of the head to the posterior tip of abdomen or fore wings. Morphological terminology follows Carpintero and Dellapé (2006) and Noack *et al.* (2011). Photographs were taken with a Canon PowerShot G9 camera, mounted on a Zeiss SteREO Discovery V20 microscope and processed using the CombineZP software. Transliterated names of localities in Israel follow the *Israel Touring Map* and *List of settlements* published by the Survey of Israel (2009).

Statistical methods – sampling and analyzing egg occurrence

The sampling was conducted utilizing a completely randomized delineation, with the treatments represented by number of eggs and egg clusters per plant, with a sample of 100 leaves randomly collected from the lower branches of a single tree in the Park Gan B'Ivrit in Rishon LeZiyyon (Fig. 20) on six different dates between

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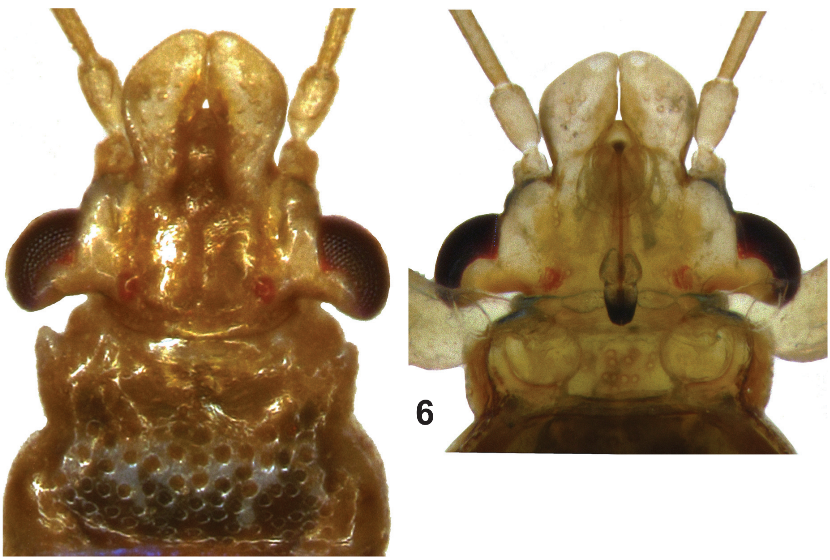


Figs 5, 6. *T. peregrinus*, adult, head, dorsal (5) and ventral (6) views.

October 2014 and March 2015. Both eggs and egg clusters were counted in the lab on the following day. The data were submitted to analysis of variance, and the means, compared by the data, were processed using the exponential correlation test of the CORREL (Excel Trendline) software. The relevant temperatures were obtained from the Meteorological Service, Israel (https://data.gov.il). Correlations were assessed using the Pearson's correlation coefficient. Multivariate analyses were performed using linear regression models in order to adjust for covariates. P values lower than 0.05 were considered as statistically significant. Statistical analysis was performed with usage of STATISTICA 10.0 software (Statsoft, Tulsa, OK, USA).

RESULTS

Family Thaumastocoridae Kirkaldy, 1908
Genus *Thaumastocoris* Kirkaldy, 1908
Thaumastocoris peregrinus Carpintero & Dellapé, 2006
(Figs 1–24)

Thaumastocoris australicus [nec *Thaumastocoris australicus* Kirkaldy, 1908: 778]: Jacobs & Neser 2005: 233 (South Africa; misident.); Noack & Coviella 2006: 13 (Argentina; misident.).

Identification: Adult. *Body* (Figs 1–4) dorsoventrally compressed and elongate. Submacropterous forms are known for both sexes but not yet found in Israel. No significant differences were found between the sexes: male length 2.3–2.9 mm, width 0.7–1.0 mm; female length 2.3–2.7 mm, width 0.7–0.8 mm.

Coloration light brown with darker areas; female generally darker than male.

Head (Figs 5, 6) broad, strongly projecting anteriorly, with semiglobose projecting eyes. *Mandibular plates* (Figs 5, 6) elongate, conspicuous, strongly recurved anterolaterally. *Labium* (Fig. 6) extending to level of fore coxa.

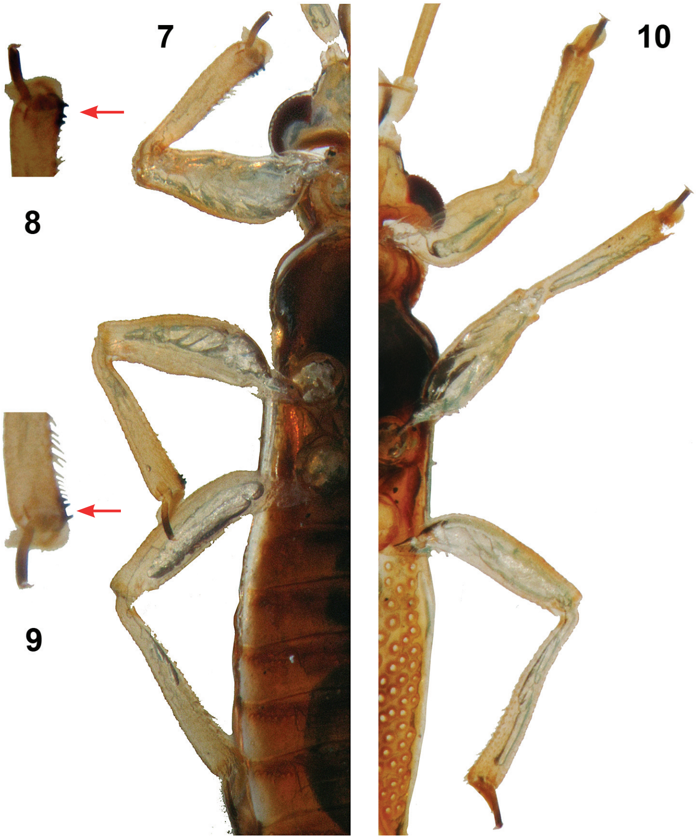
Thorax: pronotum with tubercle on anterolateral angle of anterior lobe (Fig. 5).

Legs (Figs 7–10): neither parempodia nor pulvilli present; all tibiae with flattened apical projection, the fossula spongiosa. Tibia of male anteroventrally with three black tubercles (arrowed on Figs 7–9), female (Fig. 10) without such tubercles.

Male reproductive tract (Figs 11–13) comprises a pair of testes with three globular follicles isolated by a peritoneal sheath, and two pairs of well-developed mesodermal tubular accessory glands (Souza *et al.* 2014).

Male external genitalia (Figs 11–13) comprise an asymmetrical and somewhat cylindrical pygophore (Figs 11, 12), oriented either to the right or to the left, although orientation to the right occurs more frequently (Carpintero & Dellapé 2006). The genitalia also comprise a U-shaped paramere (Fig. 13) that is evenly setose; setae becoming sparse apically. Aedeagus not observed.

Female reproductive tract of *T. peregrinus* is generally similar to that of the thaumastocorid *Proxylastodoris kuscheli* (van Doesburg *et al.* 2010). However *P. kuscheli* has three meroistic telotrophic ovarioles per ovary, whereas *T. peregrinus* has only two meroistic telotrophic ovarioles per ovary. The ovaries are deve-



Figs 7–10. *T. peregrinus*, legs: (7) male legs; (8) fore tibia of male, anteroventral view; (9) mid tibia of male, anteroventral view; (10) female legs.

Figs 11–13. *T. peregrinus*, adult, male genitalia: (11) genital capsule opened to right side, sternites 7 and 8 with pygophore, ventral view; (12) male pygophore, posterior view; (13) paramere.

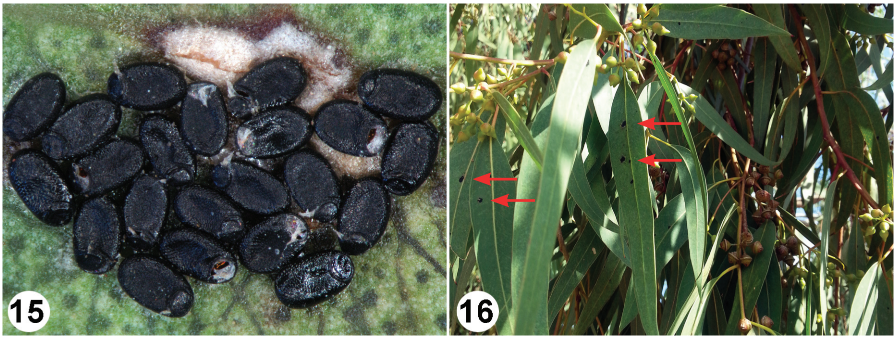
Fig. 14. *T. peregrinus*, female abdomen with two mature eggs, ventral view.

loped as large, ball-shaped reservoirs (Souza *et al.* 2014). In Heteroptera, the number of ovarioles per ovary ranges from 2 to 17 (Schuh & Slater, 1995). No spermathecae were observed, a phenomenon already reported for other Thaumastocoridae (van Doesburg *et al.* 2010).

Gravid females (Fig. 14) may retain mature eggs in unfavorable and stressful environmental conditions, such as the absence of the host plant and presence of predators, to reduce mortality of their offspring. However, forced egg retention in *T. peregrinus* can adversely affect vitellogenesis, oviposition pattern, and hatching rate (Souza *et al.* 2014).

Eggs (Figs 15, 16) black, ovoid, with rough chorion and a round operculum, with a deep and obvious depression dorsally; 0.50–0.61 mm long and 0.20–0.24 mm wide (N = 10). They are laid in clusters of 1–57 per leaf (N = 100) on leaves and twigs (Fig. 15).

Nymphs (Figs 19). Five instars. Body flattened dorsoventrally. Color of young individuals (1st–3rd instars) milk white to orange, with black spots on the thorax



Figs 15, 16. *T. peregrinus*, eggs: (15) clutch of 22 eggs; (16) clutches of eggs (arrowed) on *Eucalyptus camaldulensis* tree.

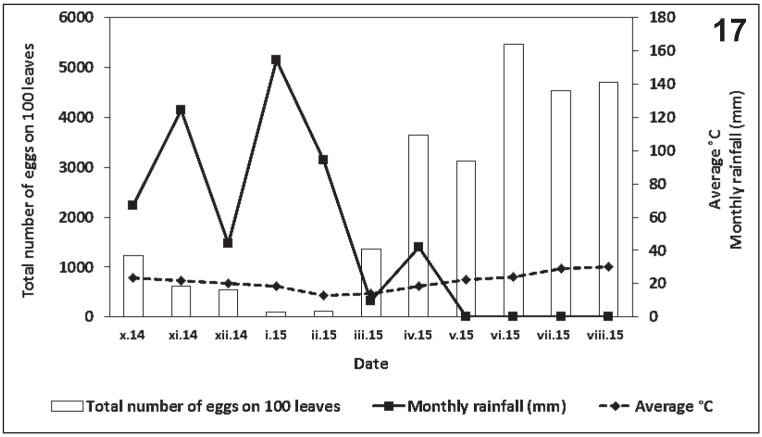
and first abdominal segment. Nymphs were always observed together with adults on heavily infested trees.

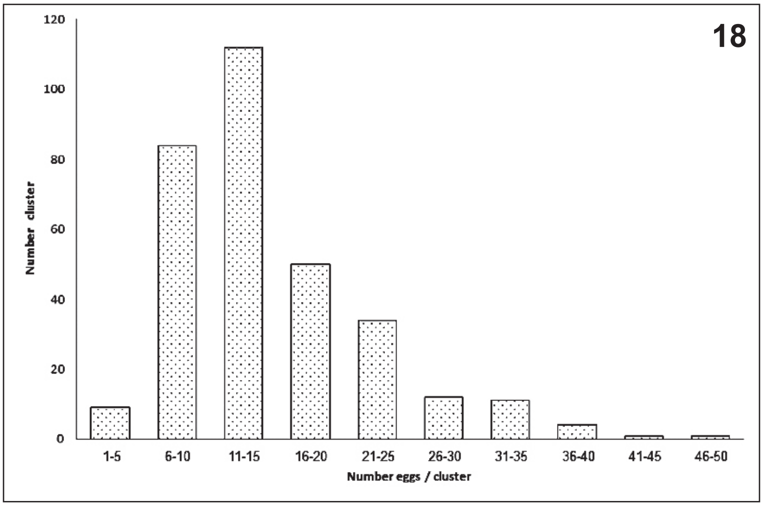
Material examined: Israel: Herzliyya Hill, 32º11'N 34º49'E, 13.vii.2016, A. Freidberg (11♂, 10♀, 5 5th instar nymphs); Ramat Gan, 32°03'12.5"N 34°49'25.8"E, 13.i.2015, T. Novoselsky (10♂, 2♀, 8 3rd instar nymphs, 19 4th instar nymphs, 20 5th instar nymphs); Gan Le'ummi Yarqon, 32°05'59.8"N 34°48'26.5"E, 10 m, 28.x.2014, Y. Turgeman (3♂, 2♀, 5 5th instar nymphs); same locality, 3.xi.2014, T. Novoselsky (3♂, 3♀, 4 5th instar nymphs pinned; 18♂, 51♀, 134 5th instar nymphs in alcohol); same locality, 5.xi.2014, A. Freidberg (43♂, 57♀, 77 5th instar nymphs); same locality, 18.iii.2015 (15♀, 4♂, 1 5th instar nymphs), 27.iv.2015 (17♀, 9♂), 6.viii.2015 (28♂, 27♀, 1 5th instar nymph), A. Freidberg, T. Novoselsky; Tel Aviv, Park HaYarqon, 32°06'02"N 34°48'43"E, 27.x.2014, A. Freidberg (1♀); Rishon LeZiyyon, 31°57'54.0"N 34°49'34.8"E, 63 m, 6.xii.2014 (10♂, 29♀, 35 5th instar nymphs, in alcohol), 27.x.2014 (10♂, 29♀, 35 5th instar nymphs, in alcohol), T. Novoselsky; Rishon LeZiyyon, 31°57'30.2"N 34°49'58.1"E, 70 m, 27.x.2014, A. Bar (3♂, 2 5th instar nymphs). All specimens were collected from *Eucalyptus camaldulensis*.

Distribution: Argentina, Australia (apparently the only native population), Brazil, Caribbean, Chile, Israel, Italy, Kenya, Malawi, New Zealand, Paraguay, Portugal, South Africa, Uruguay, Zimbabwe.

Biology: Little is known about the biology and phenology of *T. peregrinus*. The male produces an aggregation pheromone (González *et al.* 2012) and numerous adults of both sexes are found on the same leaf together with juvenile stages. We observed *T. peregrinus* between October 2014 and August 2015, whenever we visited the collecting sites, and bugs were seen feeding exclusively on *E. camaldulensis*, although some individuals were occasionally found on other trees, such as cypress and pistachio, adjacent to the infested *Eucalyptus*. The species is multivoltine. Nymphs of all instars and adults resemble each other in shape and color. Both adults and fifth instars move between branches and leaves. When disturbed, nymphs and adults usually remain closely attached to their host plant, although adults readily fly. Immatures may get transferred to susceptible trees by people or the wind.

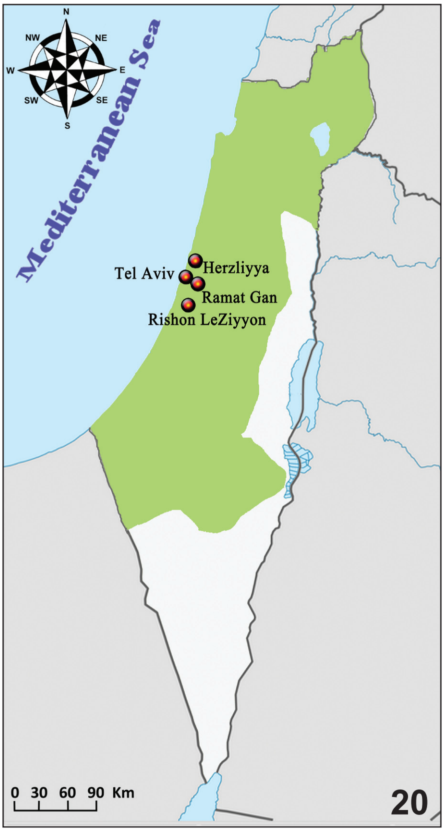
Monitoring the population: To understand the species seasonality, oviposition pattern and distribution of eggs on the leaves better, a sample of 100 leaves was





Figs 17, 18. *T. peregrinus*, egg counts: (17) relationship between number of eggs and air temperature; (18) relationship between number of eggs per plant and number of clusters.

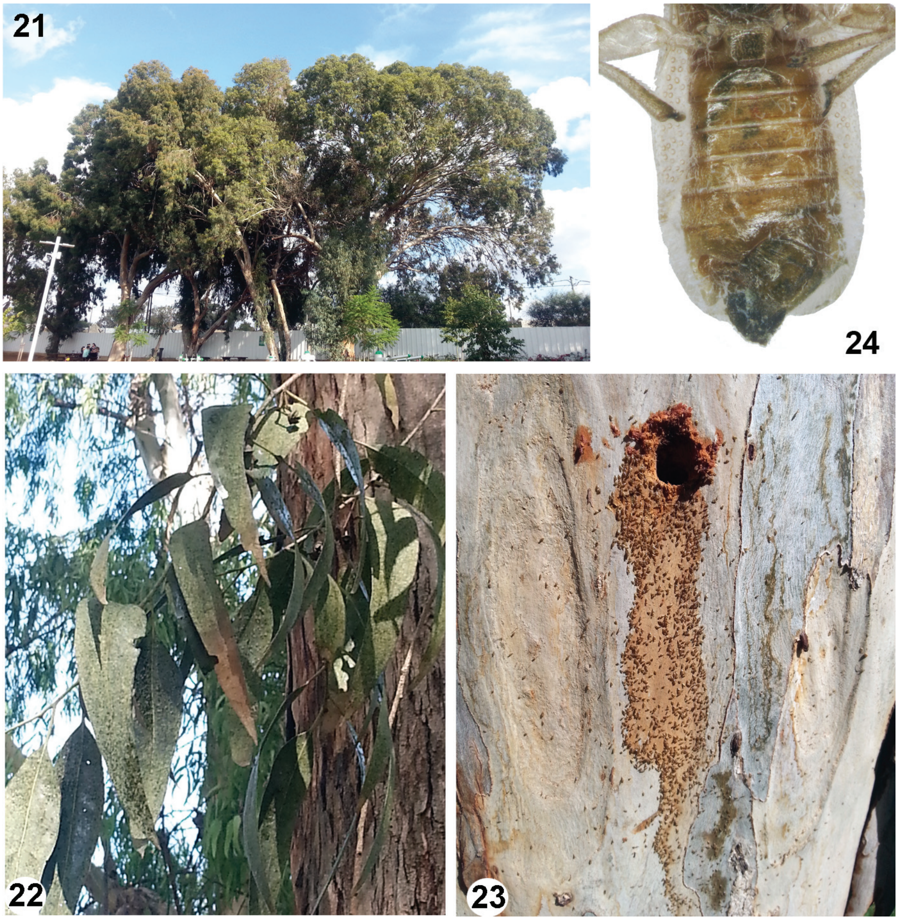
randomly collected from a single tree with a lot of accessible branches in the Gan B'Ivrit in Rishon LeZiyyon on six different dates between October 2014 and August 2015. Both eggs and egg clusters were counted in the lab on the following day (Figs 17, 18). We received strong negative correlation ($r=-0.775$, $p=0.005$) between the number of eggs of *T. peregrinus* and monthly rainfall, and positive correlation ($r=0.671$, $p=0.024$) between the number of eggs of *T. peregrinus* and average air temperature for each month (Fig. 17). In addition, we examined correlation between the number of eggs per plant and number of clusters, and again found strong positive correlation between these variables ($r=0.913$, $p=0.012$). Strong positive correlation ($r=0.944$, $p=0.005$) was found between the number



Figs 19, 20. (19) An aggregation of nymphs and adults of *T. peregrinus*; (20) collection localities of *T. peregrinus* in Israel plotted over distribution of *Eucalyptus camaldulensis* plantations (marked in green) in Israel (map adopted from http://www.wildflowers.co.il).

of eggs per clusters and number of clusters. Most clusters comprised 11–15 eggs (Fig. 18). These results indicate that counting eggs and egg clutches can be easily used for monitoring the overall population of this species after additional study such as developing methods for the counting of adults. Adults *T. peregrinus* were reproductive from October to January but not during part of the wet season mating period, from February to April. A significant decline in population was observed during the core of the wet season, from February to April, and the core of the dry season, from July to August. Oviposition during these periods was not observed.

Injury to *Eucalyptus* in Israel (Figs 15, 16, 19, 21, 22): *Thaumastocoris peregrinus* has been collected so far in Herzliya, Gan Le'ummi Yarqon in Ramat Gan and Gan B'Ivrit in Rishon LeZiyyon (Fig. 20), and all *Eucalyptus* trees present in these parks were infested by this pest. We observed symptoms of bronzing and silvering



Figs 21–24. Infestation of *Eucalyptus camaldulensis* by *T. perigrinus*, and potential means for controlling the bug: (21) an infested tree appearing healthy; (22) same tree, close-up showing damage; (23) numerous adults and nymphs on *E. camaldulensis* after treating the tree with 30 cc of the systemic insecticide Imidacloprid; (24) a dead adult covered with fungal hyphae (the white threads).

affecting the foliage, probably due to punctures made by the stylets of the insect mouthparts. This injury then developed into withering and progressive defoliation of the tree. From a distance, the trees appeared to be in fair condition, but upon approaching to them the damage became increasingly obvious (Figs 21, 22).

DISCUSSION

At present no measures have been identified to control *T. peregrinus* in Israel. Elsewhere, systemic insecticides have been found to be an effective tool for the management of *T. peregrinus* (Noack *et al.* 2009, and this publication; Fig. 23), but this approach is generally not feasible for large-scale application in parks because of the presence of people (especially children) and other animals, such as birds, that might get poisoned by the insecticide, and because of the potential damage to other insects (e.g. honey bees) and the entire ecosystem. To date, no potential natural enemy has been found in Israel, although we have detected dead adults and nymphs of *T. peregrinus* covered by fungal hyphae (Fig. 24), and this deserves further investigation.

We consider that at present this invasion is unstoppable. These insects seem to be very prolific, reproducing at a very high rate. They are so small that they remain unnoticed until their abundance becomes critical. Being able to move independently, they can probably also exploit hitchhiking on other animals, including humans. It is not unusual to find tens of bugs on a person's body, where they cause tickling and itching, or on clothing, from which they are very difficult to dislodge. We assume that within a short period of time this species will infest most or all areas with *Eucalyptus* trees in Israel.

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