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Original Article

High population levels lead *Glycaspis brimblecombei* (Hemiptera: Aphalaridae) to unrecorded feeding and oviposition behaviors on *Eucalyptus urograndis* plants

Altos níveis populacionais levam *Glycaspis brimblecombei* (Hemiptera: Aphalaridae) a diferentes comportamentos de alimentação e oviposição em plantas de *Eucalyptus urograndis*

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Abstract

The red gum lerp psyllid, *Glycaspis brimblecombei* Moore, 1964 (Hemiptera: Aphalaridae), an insect pest originating in Australia and which feeds only on *Eucalyptus* L'Hér. (Myrtales: Myrtaceae) plants, has spread to several countries. The populations of this insect commonly reach high populations on *Eucalyptus* plants since its entry into Brazil, and also indicated an unrecorded behavioral. The objectives of this study were to describe a peculiar adaptation in the feeding habit of *G. brimblecombei* and to register the new habit. The oviposition and feeding by *G. brimblecombei*, commonly, on the leaves of *Eucalyptus*, started to occur, also, on lignified twigs. This suggests a not yet recorded adaptation of this insect to reduce insect × plant intraspecific competition.

Keywords: intraspecific competition, insect behavior, *Eucalyptus camaldulensis*, eucalypt pest, red gum lerp psyllid.

Resumo

O psilídeo de concha, *Glycaspis brimblecombei* Moore, 1964 (Hemiptera: Aphalaridae), um inseto praga originário da Austrália e que se alimenta apenas de plantas de *Eucalyptus* L'Hér. (Myrtales: Myrtaceae), se espalhou por vários países. Esse inseto, geralmente, atinge grandes populações em plantas de *Eucalyptus* desde sua entrada no Brasil e, também, indicou um comportamento diferente. Os objetivos deste estudo foram descrever uma adaptação peculiar no hábito alimentar de *G. brimblecombei* e registrar o novo hábito. A oviposição e alimentação por *G. brimblecombei*, geralmente, nas folhas de *Eucalyptus*, passaram a ocorrer, também, em ramos lignificados. Isso sugere uma adaptação diferente desse inseto para reduzir a competição intraespecífica inseto × planta.

Palavras-chave: competição intraespecífica, comportamento dos insetos, *Eucalyptus camaldulensis*, praga do eucalipto, psilídeo de concha.

1. Introduction

The red gum lerp psyllid, *Glycaspis brimblecombei* Moore, 1964 (Hemiptera: Aphalaridae) is native to eastern Australia (Tuller et al., 2017; Yurt and Karaca, 2018) and feeds only on plants of the *Eucalyptus* L'Hér (Myrtales: Myrtaceae) genus (Petro et al., 2017; Jere et al., 2019). The *G. brimblecombei* prefers species from the river red gum group, especially *Eucalyptus camaldulensis* Dehnh. (Brennan et al., 2001). However, it has adapted to other species of this genus, such as *Eucalyptus blakelyi* Maiden, *Eucalyptus brassiana* S.T. Blake, *Eucalyptus bridgesiana* R.T. Baker, *Eucalyptus camphora* R. Baker, *Eucalyptus dealbata* A. Cunn. ex Schauer, *Eucalyptus*

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diversicolor F. Muell., *Eucalyptus globulus* Labill., *Eucalyptus lehmannii* (Schauer) Benth., *Eucalyptus mannifera* Mudie, *Eucalyptus nicholii* Maiden & Blakely, *Eucalyptus nitens* (H. Deane & Maiden) Maiden, *Eucalyptus rudis* Endl., *Eucalyptus sideroxylon* A. Cunn. ex Woolls, *Eucalyptus tereticornis* Sm., and *Eucalyptus urophylla* S.T. Blake (Moore, 1970; Brennan and Gill, 1999; Brennan et al., 2001).

Glycaspis brimblecombei is a pest with great potential for invasion, as reinforced by international agencies, including the Food and Agriculture Organization of the United Nations (FAO) (Reguia and Peris-Felipo, 2003; Ferreira-Filho et al., 2017; Mannu et al., 2018) and has spread across many different regions of the world (Valente and Hodkinson, 2009; Cuello et al., 2018). The countries with reports of *G. brimblecombei* include Algeria, Ethiopia, Madagascar, Mauritius, Morocco, South Africa, Tunisia, and Zambia, in Africa; Israel and Turkey in Asia; France, Greece, Italy, Montenegro, Portugal, and Spain in Europe; Mexico and the United States of America in North America; Australia and New Zealand in Oceania; Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Uruguay, and Venezuela in South America (Burckhardt et al., 2008; Laudonia and Garonna, 2010; Malumphy et al., 2013; Bella and Rapisarda, 2013; Tsagkarakis et al., 2014; Attia and Rapisarda, 2014; Karaca et al., 2015; Bouvet et al., 2005; Chungu et al., 2017; Yirgu and Anjulo, 2019).

The area planted with *Eucalyptus* in Brazil was 7.5 million hectares in 2021, with an average productivity of 39 m^3 per ha (Pavan et al., 2021; André et al., 2021). The entry of *G. brimblecombei* in Brazil, through the state of São Paulo in 2003 (Santana and Burckhardt, 2007), started to demand the adoption of control strategies, burdening the cost of this culture (Boavida et al., 2016; Dias et al., 2017). The cost of applying systemic insecticide to control of *G. brimblecombei* ranged from R$40.00 to R$150.00 per round in the state of Santa Catarina, Brazil in 2011 (Garcia et al., 2011). Nymphs and adults of this insect suck the sap causing discoloration, drying and leaf fall, and top dieback of *Eucalyptus* plants (Pereira et al., 2013). In addition, excrement (honeydew) from the initial feed of *G. brimblecombei*, which is rich in sugars, facilitates the development of sooty mildew by reducing the rate of photosynthesis and the development of the plant (Huerta et al., 2010; Spodek et al., 2015). Successive damage with high infestations of *G. brimblecombei* can cause the fall of 20 to 30% of the leaves and up to a 40% mortality rate of *Eucalyptus* plants (Laudonia et al., 2014; Ferreira-Filho et al., 2015).

Glycaspis brimblecombei lays eggs on the surface of the leaves, where their nymphs insert the stylets into the phloem directly through the sheath to feed (Perris-Felipo et al., 2011; Ribeiro et al., 2015), avoiding reaching the oil glands (Brennan and Weinbaum, 2001a). Younger nymphs introduce the stylet between mesophilic cells and those in the fifth stage use an intracellular route (Pereira et al., 2013) with greater survival, of adults on mature *Eucalyptus* leaves (Brennan and Weinbaum, 2001a, b). *Glycaspis brimblecombei* reproduces sexually, laying six to 45 eggs per leaf, preferably on those younger (Firmino-Winckler et al., 2009). The nymphs of *G. brimblecombei* use honeydew and other chemical components produced by Malpighian tubules to build their cone-shaped covers (lerp), for protection, on the leaf surface (Sharma et al., 2013). *Glycaspis brimblecombei* has five instars, with a life cycle of 15 to 34 days and several generations per year in countries such as Brazil (Firmino-Winckler et al., 2009) and Italy (Laudonia et al., 2014).

The objectives of this study were to describe an unprecedented adaptation in the feeding habit of *G. brimblecombei* and to register the new habit.

2. Methods and Materials

2.1. Experimental site

The feeding habit of *G. brimblecombei* was examined on two-year-old clone hybrid plants of *Eucalyptus urograndis* (*E. urophylla* × *E. grandis*) in Bom Despacho, state of Minas Gerais, Brazil (19° 44' S × 45° 15' O, 768 m above sea level) and on one year old *E. camaldulensis* clone plants in Luiz Antônio, state of São Paulo, Brazil (21° 33' S × 47° 42' O, 638 m above sea level). The damage by *G. brimblecombei* was compared between two groups of plants: this insect, only, on leaves (a) or on lignified leaves and twigs (b). Two stands, each with a group of plants "a" or "b", were examined per municipality. The average area per stand was 40 ha. The distance between stands in the same municipality was 1.0 and 2.0 Km in Bom Despacho and Luiz Antônio, respectively. The damage was observed from July to September 2018 and 2019, months of the greatest occurrence of this pest in Brazil, due to the low intensity of rain and relative humidity (Masson et al., 2009; Oliveira et al., 2012; Silva et al., 2013). No control method was applied in the plantations since 30 days before and during the evaluation period. All photographs were taken using an HP Photosmart 945 – 5 megapixel digital camera, 8 × zoom (Palo Alto, California, United States of America).

2.2. Population density

The population density of *G. brimblecombei* was evaluated by sampling 100 leaves per plant (20 plants per municipality, 10 plants per stand, randomly selected within them) in the middle third of the crown (Oliveira et al., 2012; Boavida et al., 2016), with leaf collection, manually, using a ladder. One collection was carried out per month per year of evaluation.

3. Results

3.1. Population density

The population density of *G. brimblecombei* was high in both municipalities, with more than 100 nymphs per *Eucalyptus* leaf (Figure 1A).

3.2. Unrecorded feeding and oviposition habits

Unrecorded feeding behavior and oviposition of *G. brimblecombei* were seen during the observation period of this insect in the field. This insect oviposited and nymphs

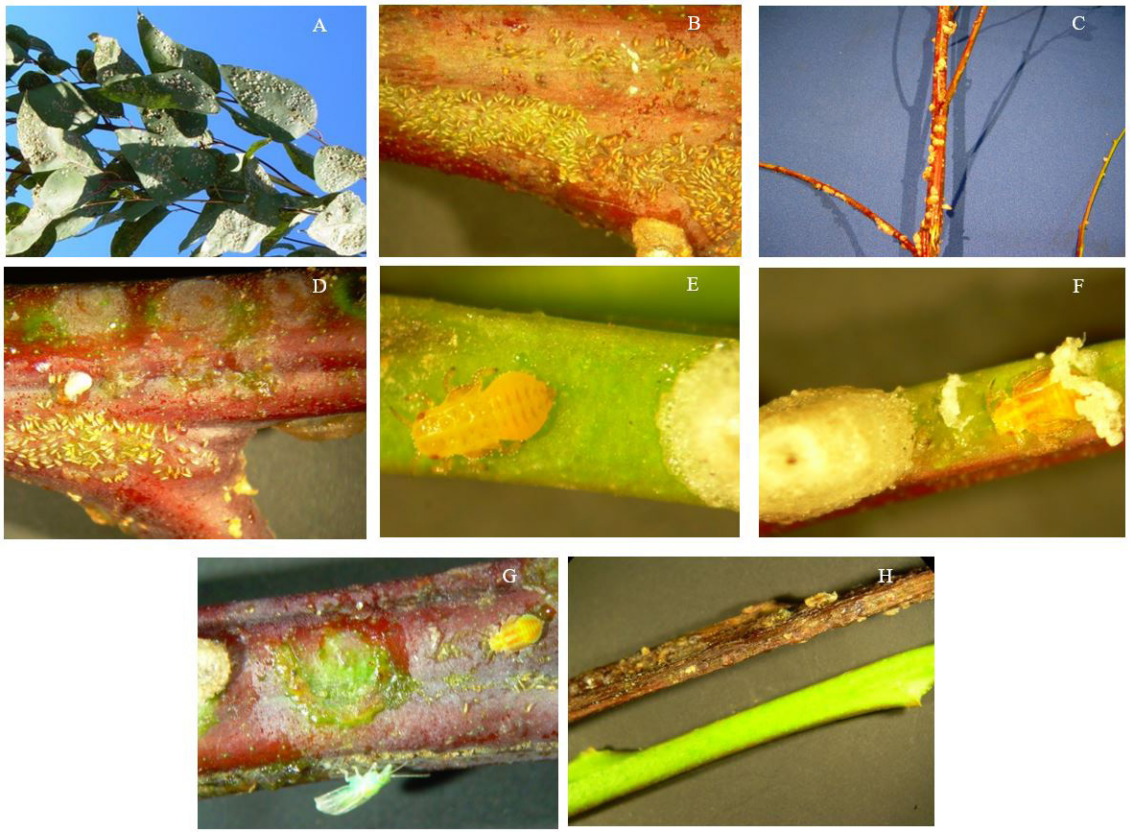

Figure 1. *Glycaspis brimblecombei* (Hemiptera: Aphalaridae) infestation with more than 100 nymphs per leaf of two-year-old *Eucalyptus urograndis* (*Eucalyptus urophylla* × *Eucalyptus grandis*) (Myrtales: Myrtaceae) in Bom Despacho, state of Minas Gerais, Brazil (A); eggs (B), lerps (C) and lerps marks (D) indicating feeding by the nymphs; fourth (E) and fifth (F) instar nymphs feeding on the lignified twigs after the manual removal of their shells; fifth instar nymphs and newly-formed *G. brimblecombei* adult (G); healthy twig compared to a dry twig due to damage by *G. brimblecombei* (H).

were observed feeding on lignified twigs of plants of both *E. camaldulensis* and *E. urograndis* clones (Figures 1B-1F). The presence of adults on these twigs indicates that *G. brimblecombei* completed its cycle on this plant part (Figure 1G). Leaf fall was more pronounced from plants with a high population density of *G. brimblecombei* (i.e. insects on leaves and lignified twigs), with drying of the entire twig (twig dieback) and a greater reduction on the emission of new leaves by the plants (Figure 1H), than in those with damage, by this pest, which was restricted to the leaves.

4. Discussion

Reports that adults and nymphs of *G. brimblecombei* feed only on leaf tissue are common (Perris-Felipo et al., 2011; Pereira et al., 2013; Ribeiro et al., 2015). The population of *G. brimblecombei*, in plantations of *E. camaldulensis* and *E. urograndis*, severely damaged by this pest (i.e. nymphs on leaves and lignified twigs) had a drastic reduction, after an intense leaf fall at the end of the dry season, probably due to food depletion and that herbivores feeding only on a plant genus are more sensitive to changes in the food availability (Steinbauer et al., 2016). Feeding by hemipterans on lignified twigs requires more energy to produce a greater amount of allelochemical detoxifying enzymes. The feeding on phloem suggests a high potential for these enzymes to bind to the Ca^{++} of this plant vascular tissue to make sugars as food available to hemipterans (Sharma et al., 2014). In addition, the association of Aphalaridae species with endosymbiont bacteria induces changes in plant tissues. These bacteria and enzymes, like the pectinases in these insect salivary glands, allow them to mobilize primary metabolites quickly (Sharma and Raman, 2017).

The high density of *G. brimblecombei*, from the beginning to the end of the dry season, may have been due to the abundance of food, the low population of its parasitoid, *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera: Encyrtidae) and the non-application of insecticides. This parasitoid was found, for the first time in Brazil, in 2003 in Piracicaba, state of São Paulo, shortly after the detection of *G. brimblecombei* (Berti Filho et al., 2003). However, its population has remained low in the field in Brazil (Ferreira-Filho et al., 2008; Silva et al., 2013; Ferreira-Filho et al., 2017).

The adaptation of feeding site in the same host by *G. brimblecombei* is apparently due to the reduction of its favorite food, as the damage by this insect was greater on

the abaxial surface of *E. camaldulensis* and on the adaxial surface of the *E. urophylla* × *E. camaldulensis* and *E. urophylla* × *E. grandis* hybrids. This was attributed to the ability of this insect to tolerate physical and chemical defenses due to the long coexistence with *E. camaldulensis* in Australia and to the greater flow of nutrients and its low desiccation on the abaxial surface (Firmino-Winckler et al., 2009; Tuller et al., 2017).

The uncommon adaptation in the feeding habit of *G. brimblecombei* in the present study was similar to that reported for the syzygium leaf psyllid, *Trioza eugeniae* Froggatt, 1901 (Hemiptera: Triozidae), which moved from the abaxial part of the plants, preferred for feeding, to the adaxial in conditions of greater intraspecific competition with *Sygygium paniculatum* Gaertn. (Myrtales: Myrtaceae) (Luft and Paine, 1997). Factors such as water stress (common in the Brazilian midwest region during winter) and/or genetic improvement of plants (production of *Eucalyptus* hybrids susceptible to the pest with branch morphology that allows them to feed), in addition to competition, may have contributed to the adaptation in feeding behavior by *G. brimblecombei*.

The adaptation in the feeding site, by nymphs of *G. brimblecombei*, from the leaves to lignified twigs, seems to be more drastic than those of other hemipteran, mainly due to the difference in hardness and rigidity between the tissues of leaves and twigs of the *Eucalyptus*. An adaptation of feeding location has also been reported for the soybean pests, *Dichelops melacanthus* (Dallas, 1851), *Euschistus heros* (F., 1798), *Nezara viridula* (L., 1758) (Hemiptera: Pentatomidae), and *Neomegalotomus parvus* (Westwood, 1842) (Hemiptera: Alydidae) that prefer seeds and fruits, but in the absence of this resource they feed on vegetative tissues (Panizzi, 2000). *Empoasca fabae* (Harris, 1841) (Hemiptera: Cicadellidae) feeds on twigs of the alfalfa plants, *Medicago sativa* L. (Fabales: Fabaceae), but migrates to the petiole and, later, to the leaves of this plant, the least preferred place for feeding, in highly infested genotypes or with high trichome density (Shockley et al., 2002).

The high susceptibility of *E. camaldulensis* and *E. urograndis* plants and favorable climatic conditions for the development of *G. brimblecombei* may facilitate the population increase of this pest. This insect, in high populations, also uses alternative resources and reproduces and develops on the lignified twigs of the plants of these species.

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