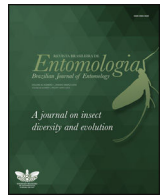




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First record of *Heteropsylla caldwelli* Burckhardt (Hemiptera: Psyllidae) from Brazil and its population dynamics on earpod tree in Rio Grande do Sul



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ABSTRACT

Heteropsylla caldwelli Burckhardt (Psyllidae, Ciriacreminae) is reported for the first time from Brazil (States of Minas Gerais, Paraná, Rio Grande do Sul) from *Enterolobium contortisiliquum* (Vell.) Morong. The earpod tree, from *Albizia edwallii* (Hoehne) Barneby and J.W. Grimes and *Senegalia polyphylla* (DC.) Britton (Fabaceae, Mimosoideae), all previously unknown hosts. The population dynamics of the psyllid were investigated in a seven-year-old plantation of *E. contortisiliquum* in an abandoned open-pit coal mine in Candiota, Rio Grande do Sul during two years. The population showed peaks in spring and summer, correlating directly with the mean air temperature and the population size of microhymenoptera.

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Introduction

The genus *Heteropsylla* comprises 40 species of plant-sap sucking insects occurring from the southern United States in the north to Northern Argentina and Chile in the south, which are monophagous or oligophagous on mimosoid Fabaceae (Hodkinson and Muddiman, 1993; Muddiman et al., 1992). Species identification is often difficult as morphological differences between some species are small.

Some species, e.g. *Heteropsylla cubana* Crawford, *Heteropsylla huasachae* Caldwell and *Heteropsylla mimosae* Crawford, have significantly expanded their natural geographical ranges. The spread of *H. cubana*, associated with *Leucaena* spp., is particularly spectacular. From its origin in Mexico, Central America, the Caribbean and northern South America, it spread around the world within a decade via Hawaii, Southeast Asia, Australia and India to tropical Africa (Aléné et al., 2012; Muddiman et al., 1992). The species can become a severe pest where *Leucaena* is intentionally planted. In some areas *Leucaena leucocephala* (Lam.) de Wit has escaped cultivation and is considered an invasive weed. There, *H. cubana*

may help to control its spread (Walton, 2003). Another species, the Brazilian *Heteropsylla spinulosa* Muddiman, Hodkinson and Hodkinson, has been introduced into Queensland and Western Samoa to control *Mimosa diplotricha* C. Wright ex Sauvalle (Willson and Garcia, 1992).

Species diversity, distribution and host associations within the genus *Heteropsylla* are well documented for North and Central America but less for tropical South America (Muddiman et al., 1992). In particular, little is known from Brazil from where only three species have been reported: *H. cubana*, as introduction on *Leucaena* spp., *H. spinulosa* from *M. diplotricha* and *Heteropsylla tenuata* Muddiman, Hodkinson and Hodkinson possibly from *Enterolobium contortisiliquum* (Vell.) Morong (Burckhardt and Queiroz, 2012).

For most Brazilian psyllid species, little is known about their population dynamics (Burckhardt and Queiroz, 2012). Exceptions are introduced insect pests such as the eucalypt psyllids (Santana et al., 2009). Some information is also available for gall inducing species (Carneiro et al., 2013). *H. cubana* and *H. spinulosa*, two fairly well-studied species, are polyvoltine and overwinter as egg, immature or adult on their host (Hodkinson, 2009). Polyvoltinism is common in tropical and South temperate psyllid species with free-living immatures.

The earpod tree, *E. contortisiliquum*, ranges from Argentina, Uruguay, Paraguay, southern, central and eastern Brazil to Bolivia

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Fig. 1. Psyllids sampling with a beating net in the middle in a seven-year-old plantation of *Enterolobium contortisiliquum* in an abandoned open-pit coal mine in Candiota, RS, between May 2014 and April 2016.

and is utilised for a variety of purposes. It is planted as shade tree in streets and gardens as well as in agroforestry systems, e.g., for cocoa and yerba mate. Its rapid growth and nitrogen-fixing abilities make it useful for revegetation, soil stabilisation and improvement, as well as land reclamation. It is tolerant of copper-contaminated soil. The tree is also harvested for its timber and medicinal uses, and the foliage is eaten by cattle (Praciak et al., 2013).

Recently, a second *Heteropsylla* species was discovered on *E. contortisiliquum* in Brazil, i.e. *Heteropsylla caldwelli*, a species which develops also on *Albizia adinocephala* (Donn. Sm.) Britton and Rose and *Enterolobium cyclocarpum* (Jacq.) Griseb. Originally *H. caldwelli* was described from Argentina and Paraguay (Burckhardt, 1987) and subsequently reported from Panama (Brown and Hodkinson, 1988), Colombia, Costa Rica, Trinidad (Muddiman et al., 1992) and Nicaragua (Maes et al., 1993). Here we report *H. caldwelli* for the first time from Brazil (States of Minas Gerais, Paraná, Rio Grande do Sul), list new host-plants and discuss its population dynamics in relation to some abiotic (mean air temperature and precipitation) and biotic (predator and parasitoids) factors based on a two-year study of the species in a seven-year-old plantation of *E. contortisiliquum* in an abandoned open-pit coal mine in Rio Grande do Sul.

Material and methods

Material

In the context of a larger project on the psyllid fauna of Brazil, DB and DLQ prospected over 200 localities in 14 Brazilian states from 2010 to 2017. The specimens were collected into 70% ethanol using a sweep net and aspirator (Queiroz et al., 2017). The material is deposited in the *Naturhistorisches Museum Basel*, Switzerland (NHMB), the *Laboratório de Entomologia, Embrapa Florestas*, Colombo, PR, Brazil and the *Museu de Zoologia, Universidade de São Paulo*, SP, Brazil. Specimens, including paratypes, of *H. caldwelli* from Argentina, Colombia, Panama and Paraguay were examined from the collections of the *Muséum d'histoire naturelle*, Genève, Switzerland, and the NHMB.

The samples for the study of the population dynamics were taken by LMM from May 2014 to April 2016 in monthly intervals with a beating net bearing a funnel attached in the middle (Fig. 1). Every month, 20 samples were taken by inserting the net into the foliage which was then shaken ten times. The psyllids retained in the collecting funnel were stored in plastic bags, labelled and then sorted and identified in the Laboratory of Forest Entomology of the

Federal University of Santa Maria, RS, Brazil. The identifications of some psyllid samples were checked by DB (samples deposited in NHMB).

Population dynamics

The site, where the population dynamics of *H. caldwelli* was studied, is located in the municipality of Candiota, S 31°33.3' and W 53°42.9' at 270 m asl, State of Rio Grande do Sul, Brazil. The area is part of the Pampa biome, which extends from the southern half of Rio Grande do Sul in Brazil to the Province of Misiones in Argentina. The average annual rainfall is 1414 mm, with rainfall predominantly in September and October, corresponding to a Cfa climate type, i.e., humid subtropical, with hot summer (Alvares et al., 2014). The mean temperature in the coldest month is below 18 °C, that of the hottest month 22 °C (Moreno, 1961).

The earpod trees that we studied were seven-years-old when we started our investigation in a site covering a surface of approximately 1.5 ha. At the beginning of our study the trees had a mean diameter at chest height of 7.79 cm and a mean height of 3.17 m. They were planted for renaturing an abandoned open-pit coal mine.

For analysing the influence of abiotic factors on the population dynamics, the mean air temperature (°C) and the accumulated precipitation (mm) were chosen, as these two factors are known to influence psyllid populations (Hodkinson, 2009). The meteorological data were obtained from a meteorological station situated at one km from the centre of the earpod tree plantation. As biotic variables, we chose the abundance of following groups of predators and parasitoids (not identified): Araneae, Coleoptera, Diptera, Formicidae, microhymenoptera and Thysanoptera.

Spearman's correlation, suitable for data with non-parametric distribution, was calculated using the statistical programme Action Stat (Estatcamp, 2014), an extension programme installed in Microsoft Office Excel 2010.

Results

Distribution and host plants

We collected *H. caldwelli* in Brazil in the following three states: **Minas Gerais**, 1 female, Vazante, Fazenda Bainha, near source of Curtume river, S 17°53.3/7' W 46°55.2', 640–690 m, 13–14.vii.2012, degraded Cerrado vegetation (D Burckhardt and DL Queiroz); 4 male, 7 female, same but Fazenda Bainha, S 17°52.9/53.0' W 46°53.0/55.1', 660–670 m, 29–30.x.2012, *E. contortisiliquum*, Cerrado vegetation, edges of disturbed forest, eucalypt plantation, creek; 38 male, 32 female, 47 immatures, same but Fazenda Bainha, near source of Curtume river, S 17°53.3/7' W 46°55.2', 640–690 m, 11.ix.2014, degraded Cerrado vegetation; 1 male, Fazenda Bocaina, S 17°53.6' W 46°54.7', 642 m, 12.ix.2014, edges of cerrado forest; 1 male, same but Vazante, S 17°58.1' W 46°54.3', 723 m, 27.xii.2011, disturbed vegetation along dirt road; 54 male, 64 f\$, 86 immatures, same but Patos de Minas, Parque Mocalambo, S18°35.0/1' W46°30.3/4', 830 m, 24.xii.2011, *E. contortisiliquum*, park; 17 male, 13 female, 14 immatures, 1 skin, same but 11.vii.2012, *Senegalia polyphylla*; 1 female, same but 27.x.2012, *Libidibia ferrea*. – **Paraná**, 2 male, 3 female, Ponta Grossa, Parque Estadual de Vila Velha, S 25°13.8–14.9' W 49°59.5–50°01.8', 860–900 m, 17–18.ii.2016, *E. contortisiliquum*, *Araucaria* forest, transitional forest, *Baccharis* scrub (D Burckhardt and DL Queiroz); 1 female, same but Colombo, Embrapa campus, S 25°19.2–20.1' W 49°09.4–10.1', 920 m, 1–5.iv.2013, *Albizia hassleri*, remnants of Atlantic forest, waste place with *Baccharis* spp., various plantations; 1 male, Curitiba, Centro Politécnico, UFPR (Universidade Federal do

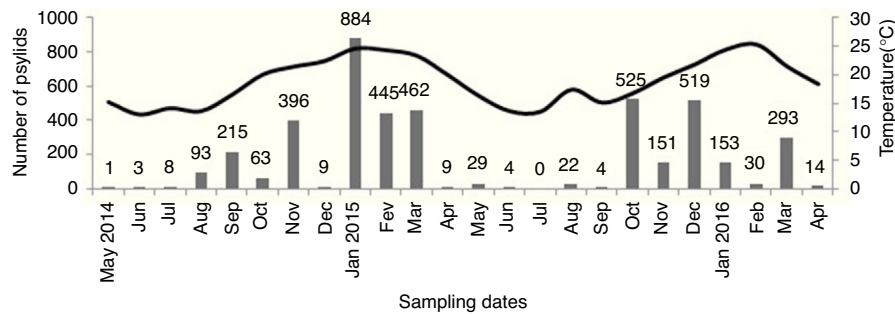


Fig. 2. Population dynamics of *Heteropsylla caldwelli* (bars) and mean air temperature variation (in °C) in a seven-year-old plantation of *Enterolobium contortisiliquum* in an abandoned open-pit coal mine in Candiota, RS, between May 2014 and April 2016.

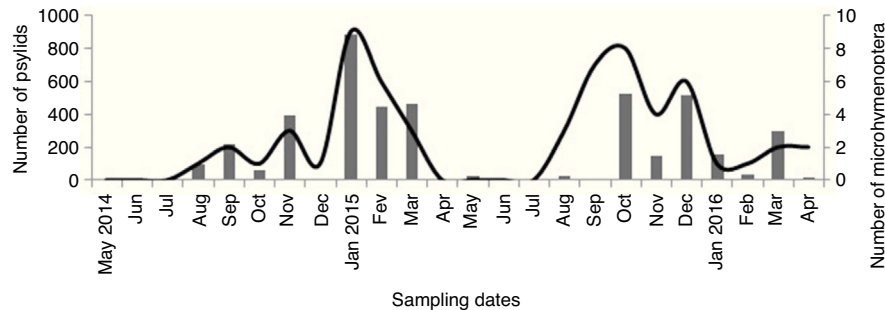


Fig. 3. Population dynamics of *Heteropsylla caldwelli* (bars) and Microhymenoptera (line) in a seven-year-old plantation of *Enterolobium contortisiliquum* in an abandoned open-pit coal mine in Candiota, RS, between May 2014 and April 2016.

Paraná), S 25°26.8' W 49°13.9', 890 m, 4.i.2012, park with planted trees, remnants of *Araucaria* forest; 4 male, 3 female, same but 5–6.ii.2016, *Albizia edwallii*; 3 female, same but Curitiba, Parque São Lourenço, S25°23.1' W49°15.9', 940 m, 19.x.2012, *Anadenanthera colubrina*, planted park vegetation; 1 female, same but Curitiba, Jardim Botânico, S25°26.5' W49°14.3', 910 m, 2.iv.2013, *Anadenanthera peregrina*, planted park vegetation; 3 male, 1 female, 12 immatures, same but Curitiba, Parque Bacacheri, S25°19.2–20.1' W49°09.4–10.1', 920 m, 17.i.2016, *A. edwallii*, park, remnants of Atlantic forest. – **Rio Grande do Sul**, 4332 adults, Candiota, S 31°33.3' W 53°42.9', v.2014–iv.2016 (LM Machado).

Population dynamics

For the studies on population dynamics in Candiota, we examined a total of 4332 adult *H. caldwelli*, 2588 in the first (59.7%) and 1744 (40.3%) in the second year. In the first year (May 2014–April 2015), the population peaked in January 2015 with 884 individuals collected. The lowest number was found in May 2014 with only one sampled individuals. In the second year (May 2015–April 2016), the population peaked in October 2015 with 525 individuals, then in December with 519. The lowest value in the second year was found in July with no specimen recorded. This was the sole period during the two years where no *H. caldwelli* were found at all (Fig. 2).

There was no relationship between the abundance distributions of the two evaluated years (0.43; $p > 0.05$) with Spearman's Correlation analysis. For the meteorological variables, there was no significant correlation between accumulated precipitation and psyllid abundance (-0.013 ; $p > 0.05$), but there was a correlation between average air temperature and psyllid abundance (0.658; $p = 0.0004$) (Fig. 2). For the biotic factors, there was no significant correlation between the abundance of predators and parasitoids and that of *H. caldwelli* ($p > 0.05$), with the exception of the microhymenoptera where the correlation was significant (0.58; $p = 0.0027$) (Fig. 3).

The highest population number of microhymenoptera (884 psyllids versus nine microhymenoptera) was in January 2015. In October of 2015, eight specimens of microhymenoptera were sampled, coinciding with the population increase of *H. caldwelli* (Fig. 3). The moderately significant correlation between psyllids and their parasitoids found in our study may be due to the low abundance of both populations with values near or equal to zero in May, June, July and December 2014 and also in May, June and July 2015 (Fig. 3).

Discussion

The species *H. caldwelli* was recorded from Argentina, Paraguay, Colombia, Panama, Costa Rica and Nicaragua associated with *Albizia adenocephala* (Costa Rica, Panama) and *E. cyclocarpum* (Trinidad) (Maes et al., 1993; Muddiman et al., 1992). Its occurrence in Brazil on *E. contortisiliquum*, which we report here for the first time, is therefore not surprising. Whether the large distribution range of *H. caldwelli* is natural or a result of its widely planted host, *E. contortisiliquum*, is difficult to answer at present. As for other psyllids, little is known about *Heteropsylla* in Brazil. Previously only three species, viz. *H. cubana*, *H. spinulosa* and *H. tenuata*, possibly also from *E. contortisiliquum*, have been reported from Brazil (Burckhardt and Queiroz, 2012).

A. edwallii (Hoehne) Barneby and J.W. Grimes, *E. contortisiliquum* and *S. polyphylla* (DC.) Britton, all mimosoid Fabaceae, are reported here for the first time as hosts of *H. caldwelli* based on the immatures found on these plants. Adults were collected also on the related species *A. hassleri* (Chodat) Burkart, *A. colubrina* (Vell.) Brenan and *A. peregrina* (L.) Speg. which are likely hosts but immatures are needed to confirm their host-status (Burckhardt et al., 2014). This relatively wide host-range accords with host information on *H. caldwelli* provided by Muddiman et al. (1992), viz. *Albizia adenocephala* and *E. cyclocarpum*, and is in line with the wide host ranges of other *Heteropsylla* species (Muddiman et al., 1992).

For most Brazilian psyllids, little is known about their population dynamics. The fluctuations of population peaks of *H. caldwelli*

during the study period can be explained by the high abundance in the first year from January to March 2015 (1791 specimens = 69.20% of all specimens collected in the first year). This is comparable to a population outbreak, i.e., a high concentration of insects in a short period of time (in our case, three months of the 12 months evaluated). In the second year, there was a sudden increase in temperature in August, preceding the usual time of temperature rise, which may have prompted an early increase in the abundance of psyllids before the usual period of occurrence (summer). The population peaks in the second year occurred in October and December 2015, i.e., earlier than that of the first year.

Geiger and Gutiérrez (2000) studying the ecology of *H. cubana*, a species closely related to *H. caldwelli*, concluded that the period between December and February is the most favourable for the development of this psyllid. This coincides with our observations, particularly for the first year of collection, when from December to February the abundance with 1338 individuals (= 51.70% of the yearly total) was highest. According to Walton (2003), the development of *H. cubana* is better at temperatures above 20 °C, which is only partly consistent with our results: in January 2015, the population peak occurred when the average air temperature was above 20 °C, in the second year, however, the population peaked the first time in October 2015, when the average air temperature was still below 20 °C and a second time in December 2015, with the average air temperature above 20 °C (Fig. 2).

The patterns of the population fluctuation of *H. caldwelli* and the microhymenoptera in our study is similar to that observed by Ferreira Filho et al. (2008), who also identified positive correlations between the population distribution of the lerp psyllid *Glycaspis brimblecombei* Moore and the encyrtid *Psyllaephagus bliteus* Riek used its the biological control.

Conclusions

The occurrence of *H. caldwelli* in Brazil is not surprising as it has been reported from several neighbouring countries. In the South and Southeast of Brazil, the species is widely distributed. In Brazil, the psyllid has been collected on *A. edwallii*, *E. contortisiliquum* and *S. polyphylla*, all previously unknown hosts. More collecting is required, particularly in the north, to see if *H. caldwelli* develops in Brazil also on other hosts such as *A. hassleri*, *A. colubrina*, *A. peregrina* and *E. cyclocarpum*, on which adults were collected or which are host in other countries. More work is also needed to see if the outbreaks of *H. caldwelli* are related to phases of flush of the host and if the presence of the psyllid damages or negatively influences its host.

Conflicts of interest

The authors declare no conflicts of interest.

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