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Seasonal population abundance of the assembly of solitary wasps and bees (Hymenoptera) according to land-use in Maranhão state, Brazil

Michela Costa Batista Matos[a], Shênia Santos Silva[b], Adenir Vieira Teodoro[a,b,*]

[a] Graduate Programme in Agroecology, Universidade Estadual do Maranhão, São Luís, MA, Brazil
[b] Embrapa Coastal Tablelands, Aracaju, SE, Brazil

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ABSTRACT

Solitary wasps and bees (Hymenoptera) play a key role in ecosystem and agroecosystem functioning. Crops may benefit from biological pest control and pollination carried out by predatory solitary wasps and solitary bees, respectively. Here, we aimed at evaluating the abundance and faunistic compositions of solitary wasps and bees in respect to land-use (pasture, alley cropping, young fallow and old fallow) over an entire year using trap nests in the Brazilian northeastern state of Maranhão. Land-use did not influence the abundance of solitary wasps and bees, however, levels of dominance, abundance and frequency of the species *Pachodynerus guadulpensis* Saussure, *Isodontia* sp. 1, *Isodontia* sp. 2, *Trypoxylon nitidum* Smith and *Megachile cfr. framea* Schrottky varied with land-use. The abundance of wasps and bees varied over the period of the year with populations peeking in January (bees), and June and July (wasps). Relative humidity explained most of the variation for the abundance of wasps while temperature explained higher portions of the variance for the abundance of bees. There was an interaction between period of the year and land-use for the abundance of wasps (but not for bees). We concluded that total population abundance of solitary wasps and bees were not affected by the land-use however, levels of dominance, abundance and frequency of some species of these hymenopterans changed according to land-use. Also, relative humidity and temperature were important environmental variables explaining the abundances of wasps and bees.

Introduction

Solitary wasps and bees (Insecta: Hymenoptera) are important components in ecosystem and agroecosystem functioning (Tylianakis et al., 2005; Buschini and Woiski, 2008). Predatory solitary wasps play a key role in reducing crop pests such as Lepidoptera larvae (Tylianakis et al., 2005) or Orthoptera nymph (Soares et al., 2001). However, some species of solitary wasps also feed on beneficial arthropods like spiders (Santoni and Del Lama, 2007). Solitary bees are efficient pollinators of native and cultivated plants and their decline may have a negative impact on crop yields (Klein et al., 2003; Kremen et al., 2007; Ricketts et al., 2008; Giannini et al., 2015). These hymenopterans are also bioindicators since they are sensitive to environmental disturbance like changes in the microclimate and in food resources availability (Klein et al., 2002; Tylianakis et al., 2004, 2005, 2006; Buschini and Woiski, 2008).

Several factors may affect populations of solitary wasps and bees, such as prey abundance, floral resources diversity, and availability of places for nesting and microclimatic conditions (Klein et al., 2002; Tylianakis et al., 2006). Different types of land-use present distinct patterns of biotic and abiotic factors, which are essential for solitary wasps and bees and therefore may affect the distribution and density of these hymenopterans (Klein et al., 2002; Tylianakis et al., 2006; Batista Matos et al., 2013; Stangler et al., 2015). Thus, distinct land-use types spread throughout a region may complement each other, and contribute to the maintenance of populations of solitary wasps and bees and, consequently to maintain the ecological services provided by these insects (Tscharntke et al., 2005, 2007; Kremen, 2005). Temporal variation in abiotic factors such as air humidity and temperature as well as seasonal availability of resources may influence many arthropod populations including solitary wasps and bees (Guedes et al., 2000; Tylianakis et al., 2005; Teodoro et al., 2009; Stangler et al., 2015). Herein, we evaluated the effects of land-use on the abundance and faunistic compositions of wasps and bees that nest in pre-existing cavities in pasture, alley cropping, young fallow and old fallow, over

* Corresponding author.
E-mail: adenir.teodoro@embrapa.br (A.V. Teodoro).

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a whole year. We used data from a previous study (Batista Matos et al., 2013), which elucidated the effects of land use on patterns of species richness and composition of these hymenopterans. The following questions were addressed: (1) Population abundance of solitary wasps and bees change according to land-use? (2) Temperature and air relative humidity variations affect the abundances of these insects? (3) The species dominance, abundance and frequency of the assemblies of these hymenopterans vary according to land-use?

Material and methods

Study area

The experiment was conducted in study sites located around the municipality of Miranda do Norte (3°36′S, 44°34′W, elevation 44 m), Maranhão state, in northeastern Brazil. The mean temperature in this region is 27 °C and the mean annual rainfall is 1.615 mm, with marked rainy (January–May) and dry (June–December) seasons. The natural vegetation was completely replaced by staple crops and pasture cultivated mainly by smallholders. Secondary vegetation fragments (fallows) of different sizes and successional stages are interspersed into a crop and pasture matrix (Batista Matos et al., 2013).

Four land-use types commonly found in the study region were selected: (1) pastures of non-managed signal grass (*Brachiaria brizantha* Hochst Stapf) with sparsely distributed babassu palms (*Attalea speciosa* Mart. ex. Spreng); (2) alley croppings of 8–9 years old and characterized by alleys of the leguminous tree species *Leucaena leucocephala* (Lam.) R. de Wit.) and *Clitoria fairchildiana* R. Howard between which crops like rice, maize, beans and cassava are grown during the rainy season; (3) young fallows with approximately 8 years old and mostly dominated by *Mimosa caesalpiniifolia* Benth shrubs; and (4) old fallows with ca. 20 years and characterized by babassu and *tucum* palms (*Astrocaryum vulgare* Mart.) in addition to leguminous trees like *Dioclea latifolia* Benth and *Bauhinia* spp. Firewood and timber removal of valuable tree species are common in both young and old fallows. We selected four study sites (with at least 1 ha) for each land-use type, totaling 16 study sites. The minimal distance between study sites was around 400 m (Batista Matos et al., 2013).

Trap nests and sampling

Trap nests are tubular spaces prepared for sampling solitary wasps and bees species which nest in pre-existing cavities (Tscharntke et al., 1998; Tylianakis et al., 2004; Buschini and Woiski, 2008; Sobek et al., 2009; Batista Matos et al., 2013). Each trap nest consisted of 15 internodes of dry bamboo, with inner diameters ranging from 2 to 20 mm and approximately 20 cm in length, wrapped with a wire. Four trap nests were installed in each study site in the corners of a square (5 m × 5 m) located at least 30 m away from the edge, totaling 64 trap nests (960 internodes) in all study sites. Each trap nest was tied to a wooden post with a wire (1.5 m from the ground). Sticky glue (Isca Cola, Ijuí, Brasil) was applied monthly around the wire to prevent ants and other crawling arthropods from entering the internodes. Samplings were monthly conducted during an entire year (December 2008–November 2009) by collecting nested internodes and replacing them for empty ones. The nested internodes were diagonally placed in carton boxes (20 cm × 5 cm) in the laboratory and observed daily until the emergence of adult insects. Afterwards, the hymenopterans were separated in morphospecies and sent for identification. Voucher specimens were deposited in the collection of the department of Zoology of the Universidade Federal Paraná, Curitiba, Paraná state, Brazil.

Environmental variables

The abiotic environmental factors temperature and relative humidity were monthly recorded in each study site under standardized conditions (on sunny days between 8:00 and 14:00) throughout an entire year by placing a digital thermohygrometer (910.15chp, Alla Brazil) above ground in the middle of the quadrat for 5 min.

Statistical analyses

Repeated Measures ANOVAs were used to determine the effect of land-use types on the abundance of solitary wasps and bees throughout the year using Statistica 8.0. One-way ANOVAs followed by post hoc Fisher LSD test ($P < 0.05$) were carried out to investigate differences among land-use types within each month.

Faunistic analyses of the community of solitary wasps and bees were further carried out for each land-use type, using the software ANAFAU developed by ESALQ/USP (Lofego and Moraes, 2006). These analyses consisted on the calculation of: [i] dominance, according to the method of Kato (Laroca and Mielke, 1975), where species presenting frequency higher than $1/S$, where S is the total number of species in the community, are considered dominant (D) while species presenting frequencies smaller than $1/S$ are considered non-dominant (ND); [ii] abundance, considered as the total number of individuals from each species per sample unit and classified as rare (r) when the species abundance is below the confidential interval (CI) calculated for the mean at 1% probability, disperse (d) when the species abundance is between the inferior limits of the mean CI at 5% and 1% probability, common (c) when the species abundance is between the inferior and superior limits of the mean CI at 5% probability, abundant (a) when the species abundance is between the superior limits of the mean CI at 5% and 1% probability, very abundant (va) when the species abundance is higher than the superior limit of the mean CI at 1% probability, and [iii] frequency, considered as the percentage of individuals of one species in relation to the total number of specimens and classified, according to the CI of the mean at 5% as low frequent (LF) when the frequency is lower than the inferior limit of the mean CI, frequent (F) when the frequency is between the inferior and superior limits of the mean CI, very frequent (VF) when the frequency is higher than the superior limit of the mean CI. The software submits the outliers to a residue analysis and the additional classifications for dominance (super dominance [SD]), abundance (super abundance [sa]) and frequency (super frequency [SF]) may apply. For further explanations on the calculations of the parameters above see Silveira Neto et al. (1976) and Lofego and Moraes (2006).

Hierarchical partitioning analyses were utilized to evaluate the relative contribution of the abiotic environmental variables temperature and relative air humidity on the abundance of solitary wasps and bees using the software R (Mc Nally and Walsh, 2004) with "hier.part" and "gtools" packages (R 2.10.1, R Development Core Team, 2010). This analysis estimates the percentage of explained variance of each variable in joint and independent contributions with all other variables, considering all possible models in a multivariate regression (Mc Nally, 1996, 2000; Heikkinen et al., 2005). Data were log $(x+1)$ transformed whenever necessary.

Results

A total of 17 wasp species (Chrysididae, Crabronidae, Leucospidae, Mutillidae, Pompilidae, Sphecidae and Vespidae) and 8 bees species (Apidae and Megachilidae) (Table 1) were collected. Vespidae was the most abundant wasp family with 821 specimens (5 species), followed by Crabronidae with 529 specimens (3 species),