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Positive Effects of Human Action on the Establishment of Native Stingless Bees in an Urban Environment

Heloane Rocha Nascimento[1], Alexandre Coletto da Silva[1], Alex Riu Fernandes[1], Gabriela Fraga Porto[2], Kleber Del-Claro[1]

1 - Instituto de Biologia, Universidade Federal de Uberlândia, Uberlândia-MG, Brazil
2 - Universidade de São Paulo, Programa de Pós-graduação em Entomologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Ribeirão Preto-SP, Brazil

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Corresponding author
Kleber Del-Claro
Instituto de Biologia, Universidade Federal de Uberlândia
Av. Amazonas nº 20, Umuarama
CEP 38405-302 - Uberlândia-MG, Brasil.
E-Mail: delclaro@ufu.br

Abstract

Facilitation is an ecological interaction in which an organism modifies the environment, benefiting other species. In urban areas, tree pruning conducted to prevent contact with electrical networks can create microhabitats, such as cavities and cut branches, that serve as nesting sites for arthropods, especially bees. This study tested the hypothesis that pruning facilitates the establishment of native stingless bees in urban environments. Research was carried out between November 2022 and November 2023 on the Umuarama campus of the Federal University of Uberlândia, Minas Gerais, Brazil. A total of 323 Sibipiruna trees (*Caesalpinia pluviosa*) distributed across a 160,000 m² area were evaluated. Each tree was tagged and inspected for bee nests; nest location and abundance were recorded, and collected bees were taxonomically identified. Chi-square analyses were used to assess the association between nest occurrence and tree pruning. Results showed that pruning significantly facilitated the establishment of native stingless bees, particularly in cut trunks and branches that became suitable nesting sites during decomposition. Although other nesting substrates were observed, these modified structures were clearly preferred. Native stingless bees play an important role as urban pollinators, contributing to biodiversity maintenance and the reproduction of ornamental and food plants. The findings highlight the importance of conserving urban pollinators through sustainable practices, including expanding green areas and reducing pesticide use. On the Umuarama campus, annual tree pruning functions not only as urban management but also as a facilitator of bee colonization, demonstrating that human activities can produce positive ecological impacts in urban landscapes.

Introduction

Insects were among the first animals to colonize terrestrial environments following the establishment of plants. Traits such as flight capability, complete metamorphosis, and, in some groups, advanced social behavior were fundamental to their evolutionary success (Grimaldi & Engel, 2005; Stork et al., 2015). These innovations enabled insects to occupy virtually all terrestrial ecosystems over the past 300 million years. Their success became even more pronounced during the Mesozoic, approximately 135 million years ago, when associations with angiosperms triggered extensive diversification and rapid adaptive radiations (e.g., Abrahamson, 1989; Labandeira, 1998). Since then, insect-plant interactions, whether antagonistic or mutualistic, have played a central role in shaping terrestrial ecological networks (Del-Claro & Torezan-Silingardi, 2021; Luna & Dátillo, 2021). Currently, although more than one million insect species have been formally described, the total number of extant species is estimated to exceed 5.5 million (Stork, 2018).

Among insects, which perform a wide range of essential ecological functions such as decomposition, herbivory, and predation, their role as pollinators is also particularly noteworthy. Among these pollinators, bees are central, as they pollinate a wide variety of plant species, ensuring their reproduction and contributing to the maintenance of biodiversity within ecosystems (Ollerton et al., 2011). While visiting flowers in search of nectar and pollen, bees promote the transfer of pollen grains between the reproductive structures of plants, facilitating fertilization and the formation of fruits and seeds (Torezan-Silingardi et al., 2021). This process is essential not only for the preservation of plant species but also for agricultural production, since many economically important crops depend on pollination carried out by bees (Garibaldi et al., 2013). Furthermore, the pollination activity of these insects contributes to ecosystem stability, directly influencing the availability of resources for various food chains (Ollerton et al., 2011; Torezan-Silingardi et al., 2021).

Bees also play a crucial role in urban environments, where they pollinate plants in gardens, community orchards, and green spaces, thereby promoting biodiversity and food production (Hall et al., 2017; Assad & Aleixo, 2024). Even amid increasing urbanization, bees help maintain ecological balance by facilitating the reproduction of a wide range of plant species, including fruit-bearing and ornamental plants. Furthermore, the presence of bees in cities underscores the importance of pollinator conservation and encourages sustainable practices, such as creating green spaces and reducing the use of harmful pesticides (Hall et al., 2017; Baldock, 2020; Assad & Aleixo, 2024).

Studies across different biomes show that insects, especially pollinators, are in constant decline due to overexploitation, habitat reduction, and pollution of natural environments (Dirzo et al., 2014; Torezan-Silingardi et al., 2021; Wagner, 2020; Assad & Aleixo, 2024). According to Potts et al. (2016), "there are well-documented declines of some wild and managed pollinators in several regions of the world. However, many effective policy and management responses can be implemented to protect pollinators and sustain pollination services". Worldwide, researchers and some governments are leading initiatives to investigate and reverse the causes of pollinator decline (Del-Claro et al., 2024).

Reforesting urban areas with native plants, trees, and shrubs plays an essential role in restoring biodiversity within urban centers. These plant elements not only enhance the landscape aesthetically, but also provide food resources, shelter, and nesting sites for several bee species, especially the native stingless bees commonly found in Brazil (Imperatriz-Fonseca & Nunes, 2010). For example, Silva and Ramalho (2014) investigated whether stingless bees (Meliponini) selectively use particular tree species or tree characteristics for nesting in the Atlantic Forest of northeastern Brazil. Surveying 89 nests across 32 ha of forest, the authors found nests in 41 tree species representing 22 plant families, with no preference for specific tree species, living versus dead trees, or wood hardness. The results suggest that nesting is determined primarily by the availability of suitable natural cavities rather than by the identity or physical properties of the host tree. Reflecting the high diversity of tree species in the environment may be crucial for maintaining a sustainable diversity of stingless bees (Silva & Ramalho, 2014).

Meliponini are fundamental bees for the pollination of ornamental and food plants, contributing to ecological balance and food security in cities. Human action, through the planning and implementation of squares, parks, and tree-lined streets, becomes a key factor in promoting a healthier and more sustainable urban environment, integrating nature into the daily lives of urban populations (Kremen et al., 2007; Imperatriz-Fonseca & Nunes, 2010). This action can increase the presence of stingless bees in urban environments, as Carvalho and Marchini (1999) showed on a university campus in Piracicaba, Brazil, where 97 nests belonging to 10 bee species were found.

Facilitation is a type of ecological interaction in which an organism modifies the environment, in both biotic and abiotic aspects, in ways that may favor the establishment of other species (Bruno et al., 2003; Bronstein, 2009). In urban environments, a clear example of this process can be observed in the pruning of trees carried out to prevent contact with electrical power lines. These human interventions frequently result in cut branches or cavities in the trunks, creating microhabitats that various arthropods can exploit. Among these organisms, bees are particularly noteworthy, as they often use these spaces as nesting sites, benefiting from the structures created by these modifications. In the municipality of Uberlândia, it is common for branches and trunks of sidewalk trees to be pruned, as occurs annually on the Umuarama campus of the Federal University of Uberlândia. We viewed this human activity as an opportunity to test the hypothesis that tree pruning creates microhabitats that facilitate nest establishment by native stingless bees (Meliponini) in an urban environment.

Methods

The present study was conducted in the municipality of Uberlândia, at the Umuarama campus of Federal University of Uberlândia (18.8988° S, 48.2722° W), between November 2022 and November 2023. Observations were carried out during daytime hours by one observer assisted by an accompanying assistant. Field assistance during the collections and observations conducted by the first author was required throughout the entire study. The first author has dyskinetic cerebral palsy (CP/CID 680.3), uses a wheelchair for mobility, and experiences difficulty handling measurement and recording instruments in the field. Therefore, she was assisted by the co-authors and her mother, Mrs. Cleidivane Rocha, during all stages of field data collection.

For this study, all 323 individuals of *Caesalpinia pluviosa* (Leguminosae – Caesalpinioideae), commonly known as sibipiruna, located on the Umuarama campus of the Federal University of Uberlândia, along all streets in the squares near blocks 2A and 2B, the library parking area square, encompassing a total area of 160,000 m² (400 m × 400 m), were marked. Each tree was tagged with an aluminum label and examined to determine the presence or absence of bee nests. Whenever nests were found, it was verified whether they were located on branches or trunks, and whether the nesting site was associated with pruning or with another undisturbed part of the plant. Subsequently, the total number of nests present on each tree was recorded. Five individuals from each nest (N = 5) were collected using an entomological net. After collection, the specimens were placed in a killing chamber containing ether. Once euthanized, the bees were stored in Eppendorf tubes labeled with the tree number, street location, and nest height. The collected individuals were identified to species level at the Faculty of Philosophy, Sciences and Letters of Ribeirão Preto, University of São Paulo, by Eduardo A. B. Almeida, a taxonomist specializing in the group.

Statistical Analyses

To evaluate nest distribution in *Caesalpinia pluviosa* trees, we performed two chi-square goodness-of-fit tests. In the first analysis, we compared the number of trees with bee nests and without bee nests among the 323 sampled individuals. The observed frequencies were tested against the expectation of equal distribution between categories using the chi-square test.

In the second analysis, considering only trees that contained nests, we evaluated whether bee nests were more frequently established in pruning-associated sites or in non-pruned parts of the trees. Nesting sites were classified as either associated with pruning (e.g., cavities or openings formed by branch or trunk cuts) or non-pruned structures (e.g., natural protrusions between branches or at the base of the trunk). The observed frequencies were again compared using a chi-square goodness-of-fit test.

All analyses were performed in the R environment (R Core Team), and the data were visualized using bar plots generated with the `ggplot2` package.

Results

Among the 323 sampled individuals of *C. pluviosa*, 62 bee nests belonging to five distinct species were identified in 92 trees: 40 nests of the stingless bee "Iraí", *Nannotrigona testaceicornis* (Apidae: Meliponinae; Fig 1); 8 nests of the "lemon bee", *Scaptotrigona depilis* (Apidae: Apinae); 6 nests of the small stingless bee "mirim mosquito", *Plebeia droryana* (Apidae: Meliponinae); 5 nests of the "yellow jataí", *Tetragonisca angustula* (Apidae: Apinae); and 3 nests of "Jataizão", *Tetragona clavipes* (Apidae: Apinae).

The results showed that significantly more *Caesalpinia pluviosa* trees lacked bee nests than contained nests within the sampled area (Fig 2). Among the 323 sampled individuals, 231 had no nests, whereas 92 contained at least one bee nest ($\chi^2 = 59.817$, df = 1, $p < 0.0001$).

Fig 1. Nest of the most abundant bee species, *Nannotrigona testaceicornis*, nesting in the trees sampled on the Umuarama campus of the Federal University of Uberlândia, Minas Gerais, Brazil.

Details of the bees, photographs by Cristiano Menezes; Source: https://abelha.org.br/fichas-catalograficas-das-especies-relevantes-para-a-meliponicultura-serie-1/

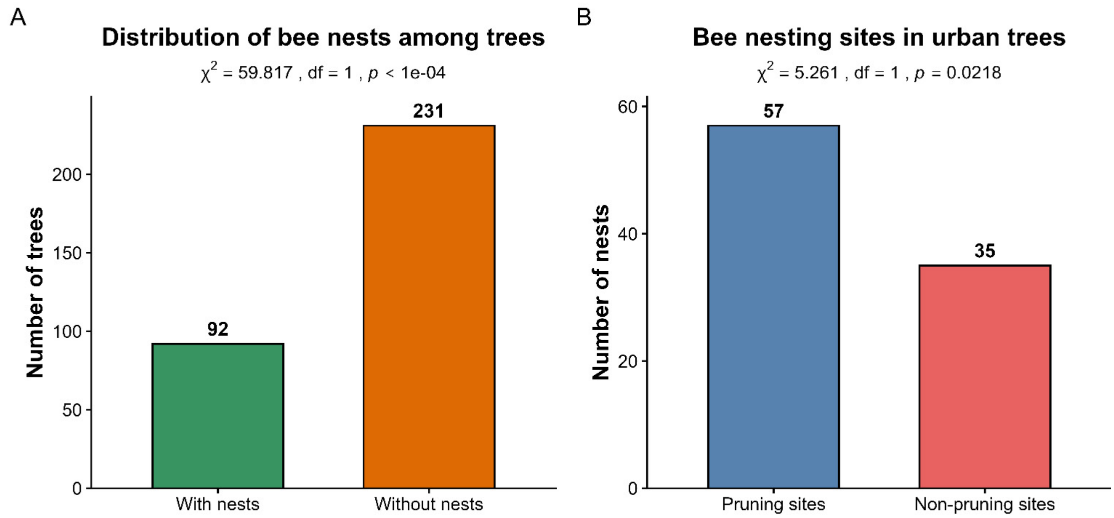

Fig 2. Distribution of stingless bee nests in *Caesalpinia pluviosa* trees on the Umuarama campus of the Federal University of Uberlândia, Minas Gerais, Brazil. (A) Distribution of trees with and without bee nests among the 323 sampled individuals. Significantly more trees lacked nests than contained nests ($p < 0.0001$). (B) Distribution of bee nests according to nesting site location within trees. More nests were established in pruning-associated structures than in non-pruned portions of the trees ($p = 0.0218$).

Regarding nest establishment sites, 57 nests were located in pruning-associated structures, such as cavities or openings formed after branch or trunk cutting. In contrast, only 35 nests were found in non-pruned portions of the trees, including natural protrusions between branches or at the base of the trunk. This difference was also significant ($\chi^2 = 5.261$, df = 1, $p = 0.0218$; Fig 2).

Discussion

The central hypothesis of this study – that tree pruning acts as a facilitating factor for the establishment of native stingless bees in urban environments – was confirmed. To our knowledge, this is the first study to specifically investigate the effects of pruning on the occurrence of stingless bee nests in urban environments. The results suggest that pruning-associated structures may facilitate nest establishment by stingless bees in urban trees. Meliponine and Apinae bees frequently used untreated cut trunks or branches of *Caesalpinia pluviosa* as nesting sites, possibly because the wood gradually becomes softer due to decomposer activity. A significant preference for pruning-associated nesting sites was observed (Fig 2). Although bees also nested in other portions of the trees, including natural cavities in trunks and at the base of the trees, most nests were associated with pruned structures. These findings indicate that pruning may create suitable microhabitats for stingless bee nesting in urban environments.

Urban bees constitute essential pollinating agents whose activity in natural and urban green areas substantially contributes to biodiversity and food security (Hall et al., 2017; Assad & Aleixo, 2024). Other authors previously showed that they are abundant in urban environments of Brazil (Carvalho & Marchini, 1999). Cortopassi-Laurino et al. (2009) demonstrated that cavities in woody trees constitute essential nesting resources for the persistence of native stingless bee populations, with tree taxa belonging to the families Fabaceae and Lauraceae, as well as the genus *Eucalyptus,* being identified as particularly important in reforested environments (see also Siqueira et al, 2012).

Even under conditions of increasing urbanization, these insects maintain their ecological relevance, as demonstrated by this study conducted on a university campus located in an urban area (e.g., Carvalho and Marchini, 1999). The bees nesting in the sibipiruna trees on campus promote the reproduction of several plant species, including those with ornamental and food value, such as Surinam cherry trees, jabuticaba trees, and a variety of vegetables and culinary herbs found in the study area (pers. obs.). The presence of bees in urban environments reinforces the need for pollinator conservation and encourages the adoption of sustainable practices, such as expanding vegetated areas and controlling pesticide use harmful to entomological fauna (Hall et al., 2017; Baldock, 2020; Assad & Aleixo, 2024). Vieira et al. (2016) reassessed stingless bee nesting in an urban area after eight years by comparing species richness, nest abundance, and nesting substrates between two sampling periods. They found an increase in both species richness and nest abundance despite urban expansion. Nesting patterns shifted from natural tree cavities to artificial structures, indicating behavioral flexibility in some species. The authors concluded that certain stingless bees can successfully adapt to urban environments, although the conservation of tree cover remains essential for maintaining their diversity.

In the municipality of Uberlândia, pruning the branches and trunks of roadside trees is a common practice, as occurs annually on the Umuarama campus of the Federal

University of Uberlândia. Our results indicate that, in addition to its role in urban management, this practice may also function as a form of ecological facilitation (Bronstein, 2009), creating opportunities for the establishment of native stingless bees in urban environments. These findings highlight that human activities, often considered solely from the perspective of negative impacts, may also promote positive ecological interactions, with direct implications for pollinator conservation and the maintenance of ecosystem services in urban landscapes.

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Author's Contribution

HRN: conceptualization, methodology, writing-original draft.
ACS: conceptualization, methodology.
AR: methodology.
GFP: methodology, validation.
KDC: conceptualization, methodology, writing-original draft, writing-review & editing.

All authors have gone through and approved the manuscript.

Consent to participate – Informed consent was obtained from all individual participants included in the study.

Compliance with ethical standards – This article does not contain any studies with human participants performed by any of the authors.

Conflict of interest – The authors declare that they have no conflicts of interest.

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