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**Short Communication**

# Flight Activities and Pollen Load of *Geniotrigona thoracica* in Tanah Laut Regency, South Kalimantan, Indonesia

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**ABSTRACT**
*Geniotrigona thoracica* is a stingless bee with a high potential for honey production and pollination. This study analysed its flight activity and pollen diversity in Tanah Laut, South Kalimantan. Flight activity was recorded at four time intervals, while pollen was collected from foragers and nest cells. Environmental factors (temperature, light intensity, humidity) were measured and analysed using ANOVA and GLM. Results showed stable flight activity with a peak at 06:00–08:00. Temperature only affected bees returning without pollen. Herbaceous plants dominated pollen sources, supporting pollination and providing essential nutrients for colony sustainability.



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*Geniotrigona thoracica* is a species of stingless bee widely recognized for its high honey production, particularly in Southeast Asia. This species possesses a relatively large body size, ranging from 7.97 to 8.35 mm, and constructs honey pots with diameters of approximately 6–9 mm (Saufi & Thevan 2015; Purwanto et al. 2022). These morphological traits are thought to enhance its storage capacity and foraging efficiency, thereby increasing overall productivity. Beyond honey production, *G. thoracica* also yields other economically valuable products such as propolis and bee bread, which are rich in bioactive compounds and widely used in traditional medicine. In addition to its economic value, *G. thoracica* serves vital ecological roles as a pollinator for various flowering plant species in natural and agricultural landscapes (Agussalim et al. 2017, 2020; Chuttong et al. 2022). Its ability to adapt to managed meliponiculture systems while providing ecosystem services makes this species a promising candidate for sustainable apiculture development and biodiversity conservation.

The daily flight activities of *G. thoracica* are not limited to foraging alone but encompass a range of essential behaviours that support colony survival. Worker bees engage in foraging trips to collect pollen as a protein source, nectar as a carbohydrate source, and resins for nest construction and defense (Nunes-Silva et al. 2010; Leonhardt et al. 2011). These resources are critical for larval development, adult nutrition, and the structural integrity of the colony. In addition to resource collection, bees also leave the nest to remove waste material, including dead individuals, excreta, and remnants of brood cells (Nunes-Silva et al. 2013). Such waste management behaviour is essential for preventing disease and maintaining nest hygiene. The division of labour and time allocation for different tasks outside the nest reflect a high degree of social organization, typical of eusocial insects such as stingless bees (Leonhardt et al. 2011). Understanding these flight-related behaviours is crucial for interpreting the ecological interactions between *G. thoracica* and its surrounding environment.

Environmental conditions significantly influence the flight patterns and foraging efficiency of stingless bees. In particular, abiotic factors such as temperature, light intensity, humidity, and resource availability can directly affect the stingless bees decision to leave the nest and the duration of their foraging trips (Gadhiya & Pastagia 2019). In the case of *G. thoracica*, temperature influences the metabolic energy required for flight, while light intensity may affect the bees' ability to navigate and detect flowers. Humidity also plays a role in pollen viability and nectar concentration, which in turn can impact floral attractiveness. These environmental variables vary throughout the day and across different seasons, thus shaping the temporal patterns of bee activity. For stingless bees, optimal foraging often occurs within a narrow range of environmental conditions, and extreme weather can restrict flight or reduce resource collection (Kartikasari et al. 2023). Therefore, understanding how these factors interact with bee behaviour is essential for meliponiculture management, particularly when designing artificial nests or placing colonies in agricultural landscapes. This study aims to analyse the flight activity patterns of *G. thoracica* and the diversity of pollen from forage plants. The findings are expected to provide a valuable reference for beekeepers in designing feeding strategies and implementing appropriate management practices to optimize honey production. The importance of this research lies in its potential contribution to improving sustainable stingless beekeeping, enhancing honey yield, and promoting biodiversity through pollination services. Although previous studies have examined the foraging behaviour and ecological roles of stingless bees, comprehensive research that combines flight activity analysis with pollen diversity identification in *G. thoracica* remains limited. This state-of-the -art study integrates behavioural and botanical data to better understand the ecological interactions of this species. The novelty of this research lies in its dual approach to evaluating both temporal flight patterns and floral resource usage, offering new insights that can inform habitat enrichment and targeted conservation strategies.

This study was conducted in June 2024 at a stingless bee farm in Tanah Laut Regency, South Kalimantan Province, Indonesia (3°19′00.01″ S, 115°40′ 59.99″ E) (Figure 1). This study utilized a range of tools and materials to support both fieldwork and laboratory analysis. Insect nets with a diameter of 30 cm and fine nylon mesh were used to capture foraging worker bees. Collected pollen was stored in 1.5 mL microcentrifuge tubes (Eppendorf type). Pollen was removed from the bees' corbiculae using sterile stainless-steel tweezers (12 cm in length), while pot-pollen was collected using sterile plastic spatulas (10 cm in length). Environmental variables were measured using a digital thermo-hygrometer (HTC-1 model; temperature accuracy ± 1 °C, humidity accuracy ± 5 %) and a lux meter (LX1010B model; measurement range up to 50,000 lux; accuracy ± 5 %) for light intensity. Bee activity was recorded using a smartphone video camera (1080p resolution) mounted on a tripod, and individual bees were counted manually using a hand counter clicker. Data were analyzed using R software version 4.2.0, applying Oneway ANOVA and General Linear Models (GLM). For pollen identification, the acetolysis method was employed following the standard procedure by Erdtman (1972), using acetic anhydride and concentrated sulfuric acid as reagents. Pollen identification was based on references from the Pollen Flora of Taiwan (Huang 1972) and the Australian Pollen and Spores Atlas (APSA 2017).

Pollen foraging activity was observed through three specific behaviours: bees flying out of the nest, returning to the nest with pollen, and returning to the nest without pollen. Bee activity was recorded during four times intervals: 06:00–08:00, 09:00–11:00, 13:00–15:00, and 16:00–18:00. Each colony was observed and recorded for 6 minutes per interval. The number of bees engaged in each activity were determined from video recordings and quantified using a hand counter. Data were analysed using Oneway ANOVA to evaluate significant differences in activity across the time intervals. The measured environmental conditions included light intensity, humidity, and temperature. The analysis aimed to determine the effect of environmental conditions on bee pollen-foraging activity. Additionally, Oneway ANOVA was performed to test for significant differences ($P < 0.05$) in each environmental condition across the time intervals. Environmental data were analysed using a General Linear Model (GLM) with a Gaussian distribution in R software (Paradis 2005) to evaluate their influence on bee foraging activity. A Oneway ANOVA was performed for each environmental factor at each time interval to determine significant differences ($P < 0.05$).

Pollen collection was conducted from the pollen basket on the legs and the pollen pots of *G. thoracica*. Bees were captured using insect nets, and the

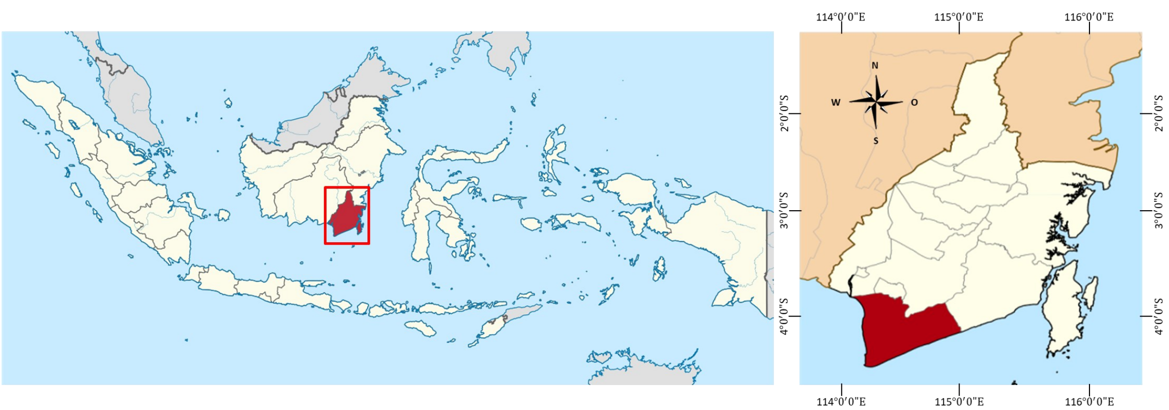



**Figure 1.** Sampling map sites in Tanah Laut Regency, South Kalimantan Province, Indonesia.

pollen was extracted using sterile tweezers. The bee pollen was placed into 1.5 mL tubes, and the bees were subsequently released. Three individual bees per colony (10 colony) were captured for each time interval. Additionally, pollen was collected from the pollen pots using a sterile spatula and placed into 1.5 mL tubes. Pollen was taken from three pollen pots per colony. Pollen samples were stored in 1.5 mL tubes for further analysis. This approach was intended to obtain more comprehensive results regarding the pollen diversity of *G. thoracica*. Pollen diversity was analysed using the acetolysis method (Erdtman 1972), which is a standard procedure for preparing pollen samples for identification. Pollen identification referred to the Pollen Flora of Taiwan (Huang 1972) and the Australian Pollen and Spores Atlas (https://apsa.anu.edu.au/) (APSA 2017).

The number of *G. thoracica* individuals flying out of the nest did not differ significantly (P = 0.09) across the observation time intervals. However, between 06:00–08:00, it was observed that *G. thoracica* likely leaves the nest in large numbers to forage. This is evident from the peak activity of *G. thoracica* returning to the nest with pollen during this period (Figure 2). This finding is consistent with the observations of Atmowidi et al. (2018) reported that the foraging activity of three stingless bee species i.e., *T. laeviceps*, *H. itama*, and *L. terminata* in Sumber Klampok Village, West Bali, typically begins in the morning. Although the species observed in that study differ from *G. thoracica*, their foraging patterns exhibit a similar peak activity period in the early hours of the day. Stingless bees employ various communication methods during foraging, including the use of pheromones and vibrational signals (Hrncir et al. 2013). According to Willmer and Stone (2004), from sunrise until 08:00, many flowers release nectar, which leads to a high number of bees foraging during this time. *G. thoracica* leaves the nest between 09:00–11:00 and 13:00–15:00, likely in search of nectar. Nectar is an essential resource for the bee colony, as a larval feed preparation and for mixing organic compounds within the nest. Worker bees will drop nectar into the honey pot (Oskin & Ovsyannikov 2019). *G. thoracica* leaves the nest between 16:00–18:00, likely to forage for nectar, as evidenced by the higher number of bees returning to the nest without pollen compared to those returning with pollen (Figure 2). The results of this study are consistent with the daily foraging activity of *Apis* sp. reported by Erwan (1999) in Nyalindung, Sukabumi, Indonesia, where foraging activity was higher between 16:00–18:00 than between 09:00–15:00. Although Erwan (1999) focused on *Apis* sp. rather than stingless bees such as *G. thoracica*, the similarity in peak foraging times suggests that environmental factors such as nectar availability and temperature may influence foraging behavior across different bee taxa. This supports the notion that both *Apis* sp. and stingless bees optimize their foraging schedules in response to external environmental conditions.

Foraging activity is carried out by worker bees to search for and locate forage sources, which are then communicated to other worker bees (Kartikasari et al. 2023). According to Sriagtula and Sowmen (2018), plants with varying flowering seasons can influence the availability of sufficient forage resources for bees throughout the year. Bees can harvest pollen and nectar to store in the nest when plants are abundant. The availability of forage in the nest is used to meet daily feeding needs and stored for times when forage resources are scarce in the field. The results presented in Table 1 support this behaviour, showing that *G. thoracica* collected pollen from a wide range of plant species, including 17 species from 12 families. This indicates that worker bees actively explore and communicate diverse floral sources to ensure colony nutritional needs are met. The predominance of herbaceous plants in the pollen spectrum suggests that these plants are more accessible and preferred due to factors such as flower density, blooming period, and proximity to the nest. The diversity of pollen collected reflects effective recruitment and communication among foragers, consistent with the typical foraging strategies of stingless bees, which rely on pheromone trails and resource marking to guide nestmates to profitable floral patches. The difference in the number of individuals leaving and returning to the nest may be related to variations in foraging duration, task allocation among worker bees, or the loss of individuals during foraging trips. Some bees may spend longer periods outside collecting resources from distant or abundant floral patches, while others return earlier after shorter foraging bouts, leading to the observed discrepancy between outgoing and incoming counts (Gadhiya & Pastagia 2019).

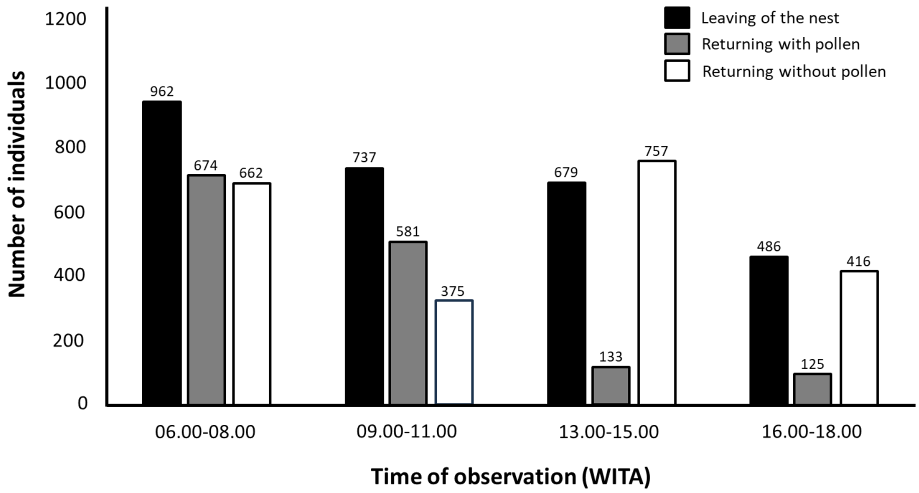



**Figure 2** . Flight activities of *G. thoracica* workers.

The results of the General Linear Model (GLM) with a Gaussian distribution showed that light intensity, temperature, and humidity did not significantly affect the flight activity of *G. thoracica* leaving the nest ($P > 0.05$). These three environmental factors also had no significant effect on the activity of *G. thoracica* returning to the nest with pollen ($P > 0.05$). This outcome may be attributed to the behavioral flexibility and physiological adaptation of *G. thoracica* to the local environmental conditions in the study area. The stingless bee may have adjusted its foraging behavior to operate within a favorable microclimate range, thereby reducing the apparent impact of these environmental variables on certain activities. Additionally, stingless bees such as *G. thoracica* do not use the waggle dance to communicate foraging information like *Apis* sp. Instead, they rely on the use of pheromone trails and resource marking behaviours to recruit nestmates to profitable food sources (Hrncir et al. 2013). This pheromone-based recruitment system allows for efficient foraging even under variable environmental conditions, which may explain why light intensity and humidity showed no significant effect in this study. In contrast, temperature had a significant impact on the activity of *G.*

**Table 1**. Analysis of the influence of environmental factors on the activity of *G. thoracica*.

| Environmental factors | Leaving of the nest | | Returning with pollen | | Returning without pollen | |
|---|---|---|---|---|---|---|
| | Coefisien estimate | P value | Coefisien estimate | P value | Coefisien estimate | P value |
| Light intensity | $-4.81 \times 10^{-6}$ | 0.99 | $3.12 \times 10^{-4}$ | 0.53 | $-6.40 \times 10^{-4}$ | 0.11 |
| Temperature | -0.93 | 0.60 | -2.39 | 0.11 | 2.41 | *0.04 |
| Humidity | 0.09 | 0.92 | 0.51 | 0.63 | 0.02 | 0.95 |

* Significant at $P < 0.05$ (general linear Gaussian model test).

*thoracica* returning to the nest without pollen (P = 0.04), possibly due to the energetic cost of flight increasing under high temperature stress.

The stingless bees foraging activity decreased as a result of the daytime rise in ambient temperature. Erwan et al. (2020) stated that temperature is one of the key factors influencing the activity of Trigona species both inside and outside the nest. Bees instinctively regulate their flight based on energy efficiency, and as ambient temperature rises, the energy demand for flight increases (Ulanda et al. 2024). In contrast, light intensity and humidity showed no significant effect on the foraging activity of *G. thoracica* in this study. This may be due to the bees' behavioral adaptation to local microclimatic conditions near the nest entrance, which remain relatively stable throughout the day, especially in shaded or semi-forested environments where stingless bees typically nest.

Worker bees of *G. thoracica* will stay at the entrance of the nest to warm up their bodies before flying. If environmental conditions do not permit leaving the nest, such as during rain or strong winds, the worker bees will not engage in activities to meet the needs within the nest (Stabentheiner et al. 2007). Among the many worker bees, some are tasked with collecting nectar, some with collecting pollen, and others with collecting both pollen and nectar simultaneously (Budiarsa et al. 2023). Pollen collection activity is more than resin collection in the morning, but when it is noon resin collection activity is more than pollen collection. This is because in the morning generally available pollen is more than in the afternoon. Peak foraging activity in *Trigona* spp. in Serawak (Malaysia) occurs at 10:30 am. Worker bees carry more pollen in the morning (07:30) than nectar, but in the afternoon (14:30), workers carry more nectar than pollen (Nagamitsu & Inoue 2002). The highest activity of *T. laeviceps* in strawberry plantations occurs at 13:30-14:00 WIB (Harahap et al. 2013).

Foraging activities for pollen, nectar, and water depend on weather conditions and the colony needs. Air temperature, humidity, and light intensity are widely recognized as environmental factors that can influence bee foraging activity. However, in this study, the General Linear Model (GLM) results showed that light intensity and humidity did not significantly affect the foraging activity of *G. thoracica* (P > 0.05). This apparent contradiction may be explained by differences in species-specific responses and local environmental stability. While studies on other stingless bee species, such as *Tetragonula laeviceps* (Harahap et al. 2013), have shown variable correlations between weather factors and foraging behavior, *G. thoracica* in this study area may be well adapted to microclimatic conditions near the nest that buffer against fluctuations in light and humidity. Furthermore, stingless bees rely more on pheromone trails and spatial memory than on visual cues, which could reduce their dependence on external light conditions. Similarly, high humidity may not pose a limitation under stable tropical conditions where relative humidity remains within an acceptable range for foraging. Therefore, while humidity and light intensity are recognized as influential factors in broader ecological contexts, their effects may not always be significant depending on species behaviour, nest location, and environmental constancy.

In this study, the number of *G. thoracica* individuals leaving the nest was consistently higher than the number returning, especially during peak foraging hours. This discrepancy may be attributed to several factors (Figure 2). Firstly, foraging bees may spend varying amounts of time outside the nest depending on the availability and distance of floral resources. As a result, the number of returning individuals at any given time may not directly correspond to those that previously departed. Secondly, environmental stressors such as high temperature during midday (as observed in this study) may reduce the success rate of foraging trips, causing bees to return without pollen or prolong their foraging duration. This is supported by Ulanda et al. (2024), who noted that elevated ambient temperatures increase the energetic cost of flight, potentially reducing foraging efficiency. Additionally, some bees may engage in tasks other than pollen collection, such as scouting or water foraging, which might not be accounted for in pollen return observations. Similar findings were reported by Harahap et al. (2013), where stingless bees showed asynchronous departure and return patterns due to task specialization and environmental conditions. Thus, the observed difference between outgoing and returning foragers highlights the complex nature of stingless bee foraging behavior and the influence of temporal and environmental factors on their activity.

Bees and flowering plants share a mutualistic relationship in which plants provide nectar and pollen as food sources, while bees assist in the pollination of flowers (Agussalim et al. 2017). The factors that attract bees to visit flowers include color, scent, and the size of the pollen (Putri et al. 2025). Pollen is the primary protein source for bees, and its composition depends on the plant species producing it. High-nutrient pollen is crucial for the growth and physiological development of worker bees. The protein in pollen is essential for the development of potential queen bees, workers, and males. Adequate protein intake is important for the development of body tissues, muscles, and glands in worker bees. Worker bees must collect pollen from a variety of plants because the nutritional content of each pollen type varies, thus meeting the protein needs of the entire colony (Thakur & Nanda 2020). According to observations by Asma et al. (2019), 25 % of honey bees leave the nest to forage are collecting pollen.

Based on morphological character observations of pollen, 17 species from 12 plant families were identified: Arecaceae, Cannaceae, Caricaceae, Compositae, Convolvulaceae, Leguminosae, Moraceae, Muntingiaceae, Myrtaceae, Poaceae, Solanaceae, and Rubiaceae (Table 2). This number is lower than the 26 plant species identified in a similar study on *G. thoracica* conducted at a beekeeping farm in Pesawaran Regency, Lampung Province (Sidik et al. 2022). The difference in pollen diversity may be attributed to regional variations in vegetation, land use, or flowering phenology. In both studies, herbaceous plants were the dominant source of pollen, indicating a consistent foraging preference among *G. thoracica* populations. Herbaceous plants typically have longer or staggered blooming periods, grow in large numbers in clustered habitats, and possess simpler floral structures that match the mouth morphology of stingless bees, making them easier and more efficient to forage (Sun & Frelich 2011; Dujardin et al. 2011). Moreover, these plants are often located closer to the ground and nearer to the nest, reducing energy costs during foraging.

Although the dominance of herbaceous plants was also reported in *G. thoracica* colonies in Banda Aceh (Putri et al. 2025), some studies, such as Agussalim et al. (2017), found greater use of tree pollen, particularly in agroforestry environments. This variation suggests that floral resource composition is highly influenced by local habitat types. Furthermore, Sidik et al. (2022) recorded pollen from families such as Euphorbiaceae and Piperaceae, which were absent in the present study, reinforcing the idea that landscape diversity and sampling season significantly affect the range of floral sources. The number and variety of plants visited by stingless bees influence the type of honey produced: bees that forage on diverse species tend to produce multifloral honey, whereas those foraging on limited sources may produce monofloral honey with a dominant pollen type (Chauhan et al. 2017). Overall, these findings confirm that while stingless bees generally prefer herbaceous plants, the exact pollen profile they collect is shaped by environmental context and local floral availability.

**Table 2**. Types of pollen collected by *G. thoracica*.

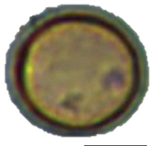
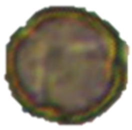
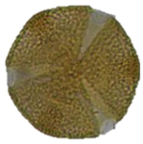
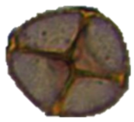
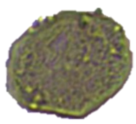
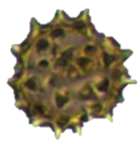
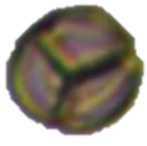
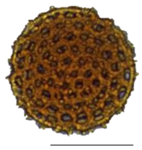
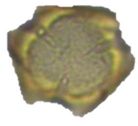
| Plant species | Family | Habitus | Size (μm) | Aperture | Exine ornamentation | Predominant pollen type | Polar view |
|---|---|---|---|---|---|---|---|
| *Artocarpus* sp. | Moraceae | Tree | 20.40-40.65 | Tricolporate | Echinate | Important Minor Pollen Type |  |
| *Cocos nucifera* L. | Arecaceae | Tree | 20.52-25.15 | Tricolpate | Echinate | Important Minor Pollen Type |  |
| *Carica papaya* L. | Caricaceae | Tree | 20.63-24.02 | Tricolpate | Reticulate | Important Minor Pollen Type |  |
| *Caesalpinia pulcherrima* (L.) Sw. | Leguminosae | Tree | 23.00-30.33 | Tricolporate | Rugulate | Important Minor Pollen Type |  |
| *Melaleuca leucadendra* (L.) L | Myrtaceae | Tree | 28.41-30.76 | Tricolporate | Reticulate | Secondary Pollen Type |  |
| *Muntingia calabura* L. | Muntingiaceae | Tree | 15.22-20.64 | Tricolpate | Reticulate | Secondary Pollen Type |  |
| *Senna siamea* (Lam.) H.S. Irwin & Barneby | Leguminosae | Herb | 20.45-30.71 | Tricolporate | Echinate | Important Minor Pollen Type |  |
| *Mimosa invisa* Colla | Leguminosae | Herb | 14.66-25.10 | Tricolporate | Echinate | Important Minor Pollen Type |  |
| *Canna hybrida* L. | Cannaceae | Herb | 28.40-30.42 | Tricolpate | Reticulate | Important Minor Pollen Type |  |
| *Bidens pilosa* L. | Compositae | Herb | 22.10-30.50 | Tricolporate | Echinate | Secondary Pollen Type |  |
| *Spermacoce ocimoides* Burm.f. | Rubiaceae | Herb | 15.63-25.55 | Tricolporate | Reticulate | Secondary Pollen Type |  |
| *Echinochloa colona* (L.) Link | Poaceae | Herb | 26.74-35.44 | Tricolporate | Rugulate | Important Minor Pollen Type |  |

**Table 2**. Types of pollen collected by *G. thoracica*.

| Plant species | Family | Habitus | Size (μm) | Aperture | Exine ornamentation | Predominant pollen type | Polar view |
|---|---|---|---|---|---|---|---|
| *Solanum melongena* L. | Solanaceae | Herb | 18.50-26.07 | Tricolpate | Reticulate | Secondary Pollen Type |  |
| *Mimosa pudica* L. | Leguminosae | Herb | 15.10-25.72 | Tricolporate | Echinate | Important Minor Pollen Type |  |
| *Ipomoea obscura* (L.) Ker Gawl. | Convolvulaceae | Herb | 25.62-30.91 | Tricolpate | Reticulate | Important Minor Pollen Type |  |
| *Cosmos sulphureus* | Compositae | Herb | 20.00-32.61 | Tricolpate | Reticulate | Secondary Pollen Type |  |
| *Capsicum annuum* L. | Solanaceae | Herb | 19.25-25.35 | Tricolporate | Reticulate | Secondary Pollen Type |  |

In conclusion, this study shows that although the activity of *G. thoracica* flying out of the nest did not differ significantly throughout the observation period, peak activity occurred in the morning between 06:00 and 08:00, when many individuals were foraging for pollen. Nectar foraging was also observed during other periods, with lower peaks in the afternoon. Environmental factors such as temperature, humidity, and light intensity did not significantly affect the flight activity of *G. thoracica*, except for temperature, which influenced the activity of returning without pollen. The diversity of plants visited by *G. thoracica* was dominated by herbaceous plants, which are more accessible and have longer blooming periods, contributing to the diversity of pollen collected and the type of honey produced. The mutualistic relationship between *G. thoracica* and flowering plants supports the pollination process and ensures a sustainable food resource for the stingless bees.

## AUTHORS CONTRIBUTION

M.T. collected and analysed the data and wrote the manuscript. H.P. analysed the data and wrote the manuscript. H.P., S.S, and T.A. designed the research and supervised all the process.

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## CONFLICT OF INTEREST

There is no conflict of interest regarding the research or the research funding.

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