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Analysis of productivity from four stingless bees (Apidae: Meliponini) and forages in urban forest, South Sulawesi, Indonesia

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Abstract. *Budiaman, Rahman AF, Nurhayati, Jumadi NH, Khatima K, Prastiyo A. 2025. Analysis of productivity from four stingless bees (Apidae: Meliponini) and forages in urban forest, South Sulawesi, Indonesia. Asian J For 9: 144-151.* Non-timber forest products that are widely used by the community as additional income and are easy to do are stingless bee cultivation (meliponiculture). The productivity of stingless bees in several species is still not widely studied, and it is important to know the potential of stingless bee species that can be used for honey production and other products. This study aimed to compare the productivity of four stingless bees in the urban forest (Awani Bee Garden), South Sulawesi. The analysis used in this study was One-Way Analysis of Variance (ANOVA), Pearson correlation analysis, Principal Component Analysis (PCA), and descriptive analysis. The results showed that *Tetragonula sapiens* (Cockerell, 1911) had the highest productivity in the number of honey pots (50.50±6.97), number of brood cells (601.22±59.71), honey production (15.72±1.35 g), and propolis production (29.01±1.99 g). In contrast, *Tetragonula sarawakensis* (Schwarz, 1937) had the lowest productivity. Nest temperature was strongly related to productivity parameters, namely, the number of honey pots (0.853), the number of brood cells (0.857), honey production (0.942), and propolis production (0.956), while nest humidity had a weak relationship. PCA analysis showed that nest temperature, honey production, propolis production, and number of brood cells dominated PC1 (74.1%), with *T. sapiens* close to optimal productivity. The availability of 27 species of forage plants, which are important sources of nectar, pollen, and resin for the bees, supported these results, such as *Mangifera indica* L. and *Artocarpus altilis* (Parkinson) Fosberg. Of the four types of stingless bees studied, the best cultivated in the urban forest area was *T. sapiens* species, with almost all the highest production. These results emphasize the importance of managing nest conditions and feed diversity in supporting stingless bee productivity.

Keywords: Bee ecology, bee product yield, forage diversity, meliponiculture, nest microclimate

INTRODUCTION

Urban forests, as green urban areas with ecological functions, serve as potential habitats for honey bees, including stingless bees (Apidae: Meliponini). Despite the environmental pressure from urbanization, these bees have shown remarkable adaptability to urban environments (Souza et al. 2025). Their tolerance to disturbances and ability to utilize various feed sources, such as wild and cultivated plants (Vazhacharickal et al. 2024), is truly impressive. The vegetation in urban forests provides primary feed in the form of nectar, pollen, and resin, which are needed to maintain colony activity and produce products such as honey, bee bread, and propolis (Hristov et al. 2020). Variations in plant composition in a location greatly affect bee productivity because each bee species prefers certain types and qualities of feed sources (Kaluza et al. 2016). Importantly, the existence of urban forests in South Sulawesi plays a significant role in biodiversity conservation, serving as a place for stingless bee cultivation, as well as a biodiversity conservation area and the utilization of ecosystem services in urban areas.

Stingless bees are social insects that produce honey and other products, such as propolis and bee bread, with high economic and ecological value, especially in tropical areas such as Indonesia. These bees are widely distributed in tropical and subtropical regions, with more than 500 species identified globally (Bueno et al. 2023). The presence of stingless bees in Indonesia has begun to be considered an alternative to honey bee cultivation because of their ability to adapt to the environment and not being at risk of stinging (Prastiyo et al. 2024). Honey from these bees also has high bioactive value, including antibacterial and antioxidant activity (Martinello and Mutinelli 2021). This unique feature makes their honey a treasure trove of health benefits, intriguing researchers and health enthusiasts alike. In addition to honey, other products such as propolis and bee bread also have commercial potential. Stingless bees also play a role in plant pollination, which supports biodiversity and ecosystem sustainability (Toledo-Hernández et al. 2022). This role benefits urban forest ecosystems rich in species and depend on pollinator interactions. Differences influence stingless bee productivity in species, environment, and availability of feed sources (Flo et al. 2018). Environmental factors such as temperature and humidity also significantly determine colony activity and production (Abou-Shaara et al. 2017).

Awani Bee Garden is one of the stingless bee cultivation locations developing in South Sulawesi, with agroecosystem conditions in urban forests. Urban forest has diverse potential, thus supporting the sustainability of stingless bee colonies and educational spaces (Vazhacharickal et al. 2020). Local studies on the relationship between environmental conditions and bee productivity are still limited, so this study will also play a role in supporting the development of sustainable bee cultivation. A vegetation-based approach with mapping of superior feed sources can be used to conserve and enrich bee feed plants (Ignatieva et al. 2023). Stingless bee cultivation management can support the existence of forests as buffer ecosystems (Wayo et al. 2025).

The four stingless bee species studied were *Tetragonula laeviceps* Smith (1857), *Tetragonula drescheri* (Schwarz, 1939), *Tetragonula sapiens* (Cockerell, 1911), and *Tetragonula sarawakensis* (Schwarz, 1937). Each stingless bee species shows different variations in productivity depending on environmental conditions and available feed sources (Suhri et al. 2021). Productivity differences may be influenced by preferences for feed types and the effectiveness of converting feed sources into bee products (Abrahamczyk and Kessler 2015). Bee feed sources are the main factors determining stingless bee colonies. Types of plants that flower throughout the year are the main determinants in maintaining the production of bee colonies (Al-Ghamdi et al. 2016). Natural and urban forests provide a diversity of plant species that produce feed that cultivated plants cannot replace. The existence and preservation of the surrounding forest are crucial for the sustainability of stingless bee cultivation. Research on stingless bee productivity has been widely eyed amidst the increasing public interest in sustainable bee cultivation. In addition to the economic potential of honey products and derivatives, stingless bee cultivation also supports biodiversity conservation (Harianja et al. 2023). The development of stingless bee cultivation in Indonesia can empower rural communities and diversify the local economy. Forested, well-maintained, and managed areas can be a natural resource for stingless bee cultivation. The challenges in this cultivation are low technical understanding, lack of data on cultivation conditions, and changes in land use around the cultivation area.

This study aims to analyze the productivity of four stingless bee species and their relationship to feed sources and nest conditions. The parameters observed include the number of honey pots, the number of bee bread pots, the number of brood cells, the weight of honey, the weight of bee bread, and the weight of propolis produced. In addition, flowering feed sources were identified during the research period around the research location, as well as temperature and humidity conditions in the nest, to see the relationship between nest conditions and productivity. The results of this study are expected to provide an overview of the most productive bee species at the research location. Thus, this study contributes to sustainable stingless bee cultivation based on urban forest ecosystems.

MATERIALS AND METHODS

Research location

The research location was Awani Bee Garden, Faculty of Forestry, Universitas Hasanuddin, Makassar, South Sulawesi, Indonesia (Figure 1). Located at coordinates 5°7'48.339"S 119°29'0.38"E, the stingless bee cultivation and education site lies within an urban forest and occupies gently sloping terrain at an elevation of 9 meters above sea level. Established on September 8, 2021, the site is managed by the Faculty of Forestry. It serves as an open-air laboratory for research as well as a learning space for students and the wider community. The area is surrounded by green space and designed to support interactions between stingless bees and vegetation, providing forage sources such as trees and shrubs.

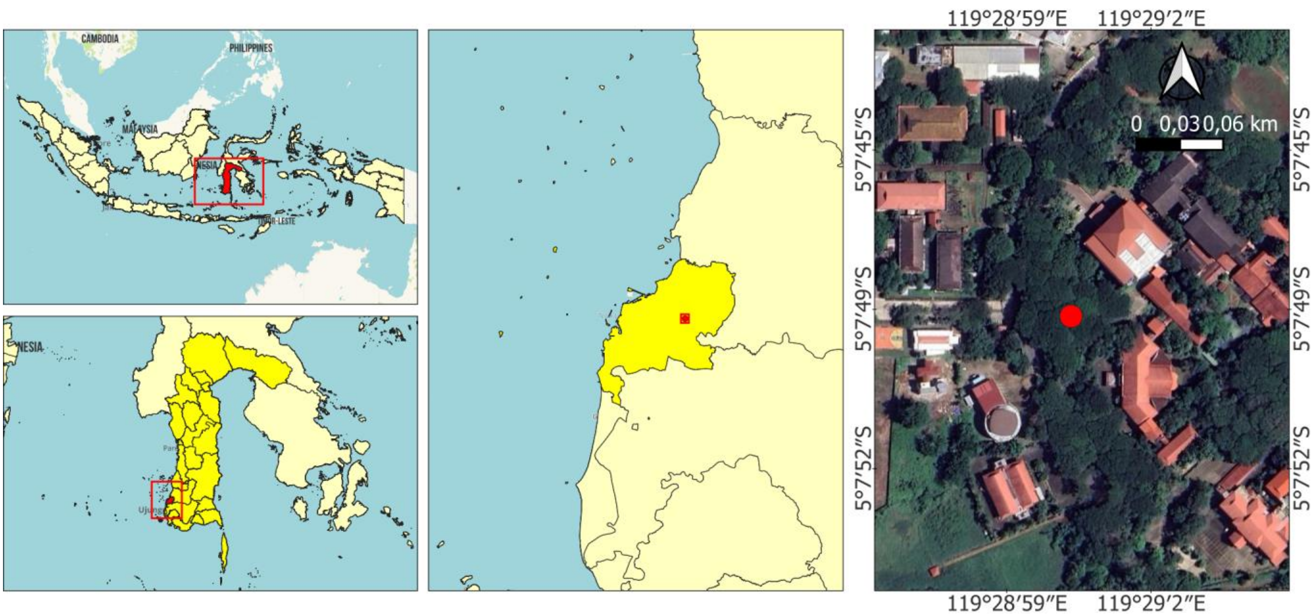

Figure 1. Map of research location at Awani Bee Garden, Makassar, South Sulawesi, Indonesia

Procedures

This study was conducted over three months (12 weeks), specifically from October to December 2024. The collection was carried out in a wet tropical climate, as Makassar falls within a humid equatorial zone. A total of 12 colonies were used as samples, with three colonies for each species. The bee boxes used measured 15×25×15 cm. All colonies were of the same age (1 month) post-transfer. The procedures in this study were adapted from Erwan et al. (2023) and further developed by incorporating correlation analysis between colony productivity and internal nest conditions, including temperature and humidity.

Number of honey pots, bee bread, and brood cells

Observations of the number of honey pots, bee bread pots, and brood cell counts in the four stingless bee species were conducted directly. Calculation of all parameters is done using counters. The four stingless bee species have nest structures that are quite similar (Figure 2).

Production of honey, bee bread, and propolis

The production of honey, bee bread, and propolis was obtained at the end of the study. The honey pot in each hive was taken with a knife and collected, then squeezed and weighed with a digital scale (Radwag AS 220/C/2) with an accuracy of 0.0001 g. Likewise, the bee bread that had been separated from the pot was weighed. Propolis was cleaned with honey, and bee bread was collected and weighed.

Measurement of nest temperature and humidity

Measurement of nest temperature and humidity was carried out every week of observation in the morning (07:00-09:00), afternoon (11:00-13:00), and evening (15:00-17:00). Measurements were carried out for 12 weeks of observation using a thermohygrometer (HTC-2).

Identification of bee forage sources

Feed sources for stingless bees were identified within a radius of 150 m from the nest for the Genus *Tetragonula*, with the most visits below that radius (Erwan et al. 2023). Observations were made during the research period, and flowering feed sources were recorded. Identification of nectar and pollen was carried out directly by taking flower samples, where nectar can be seen in the sweet liquid found at the base of the petals, and pollen on the flower pistil.

Data analysis

Analysis of honey pots, bee bread pots, brood cells, honey production, bee bread production, propolis production, nest temperature, and nest humidity was conducted using One-Way Analysis of Variance (ANOVA) (Aleme et al. 2017) in SPSS version 22. Pearson correlation analysis (Negera et al. 2024) examined the relationship between nest temperature and humidity and the productivity of the four stingless bee species. Principal Component Analysis (PCA) was performed to interpret (Wan et al. 2017) the effects of nest temperature and humidity on stingless bee productivity. Bee forages were analyzed descriptively (Agussalim et al. 2018).

RESULTS AND DISCUSSION

Productivity of four stingless bees and nest conditions

Observation results of four stingless bee species showed significant variations in the productivity of honey pots, bee bread pots, brood cells, and propolis production (Table 1). *Tetragonula sapiens* bees obtained the highest results in almost all productivity parameters, including honey pots (50.50±6.97), brood cells (601.22±59.71), honey production (15.72±1.35 g), and propolis (29.01±1.99 g). In contrast, *T. sarawakensis* showed the lowest productivity, especially in producing bee bread (2.58±1.28 g) and bee bread pots (4.95±0.86). Nest conditions, such as temperature and humidity, were relatively stable between species, with an average temperature of 28.3°C and humidity of 76.4%. Various species show different productivity characteristics in honey production, propolis, and brood cells (Erwan et al. 2023).

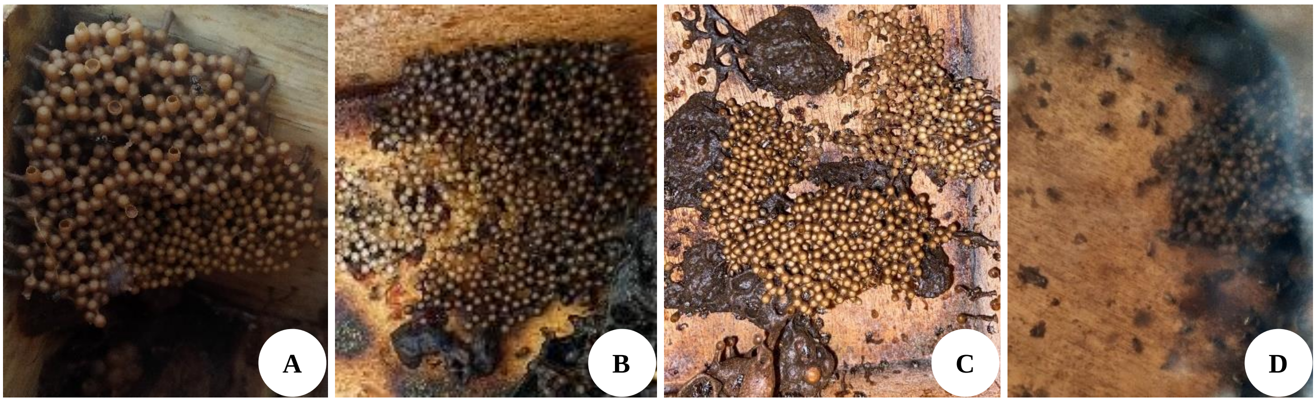

Figure 2. Nests of the four stingless bees in Awani Bee Garden, Makassar, South Sulawesi, Indonesia. A. *Tetragonula laeviceps*; B. *Tetragonula drescheri*; C. *Tetragonula sapiens*; and D. *Tetragonula sarawakensis*

The results indicate that *T. sapiens* species has a higher productivity potential than other species in the same environmental conditions. This advantage is related to adapting the species' behavior in obtaining feed sources and colony management in producing products (Erwan et al. 2023). The productivity of stingless bees is influenced by the colony's structure and the collecting feed (Agus et al. 2019). The study by Simone-Finstrom et al. (2017) also explained that the productivity of propolis and honey is related to the colony's size and nest management.

Tetragonula laeviceps and *T. drescheri* bees showed moderate production characteristics with their respective potentials. The *T. laeviceps* bee colony produced the highest number of pot bee bread (25.72±11.83), while *T. drescheri* had fairly good propolis production (16.57±3.13 g). However, the number of brood cells and honey produced was still below that of *T. sapiens* bees. This difference explains bees' ecological interaction and foraging behavior, which differ among species. The productivity conditions of the bee colony are closely related to the conditions of the surrounding environment (Neov et al. 2019).

The temperature and humidity conditions of the nest did not differ significantly between the four species. This factor plays a more significant role in maintaining the stability of the nest and can indirectly determine the variation in productivity between species. Microclimate stability plays a role in supporting the development of larvae and bee production (Nganso et al. 2024). Therefore, *T. sapiens* showed the best productivity in Awani Bee Garden as an area in the middle of an urban area with many anthropogenic disturbances. This success in an urban environment offers hope for bee conservation in such areas. The condition of the meliponiculture area is the key to the success of stingless bee cultivation (May-Itzá et al. 2022).

Correlation of productivity from four stingless bee species and nest temperature and humidity

Correlation analysis showed a very strong relationship between several stingless bee productivity parameters and nest temperature, and conversely, nest humidity did not show a significant correlation (Table 2). Nest temperature showed a positive and very strong correlation with the number of honey pots (0.853), number of brood cells (0.857), honey production (0.942), and propolis production (0.956). These results are in line with the results of the one-way ANOVA analysis (Table 1), where *T. sapiens* had the highest nest temperature (28.36±0.94°C) and showed the highest productivity in several parameters, including the number of honey pots, number of brood cells, and honey and propolis production.

Tetragonula sapiens bees that live at the highest nest temperature produce the most honey compared to other species, indicating that a nest temperature of around 28.3°C is ideal for the colony. Temperature conditions in beekeeping are around 28°C for maintaining colony activity in collecting and processing nectar (Razanova et al. 2021). Nest humidity shows a weak correlation with all productivity parameters, including correlations with honey production (0.208), propolis production (0.077), and number of brood cells (0.290). Although the humidity value between species is almost uniform (76%), no strong relationship was found with production results. Humidity can be influenced by surrounding conditions, including the design of the beehive (Prastiyo et al. 2023).

Table 1. Productivity of four stingless bee species (*Tetragonula* spp.) and nest conditions

Parameters	*T. laeviceps*	*T. drescheri*	*T. sapiens*	*T. sarawakensis*
Honey pot number (pots)	21.44±12.47[a]	13.16±0.63[a]	50.50±6.97[b]	15.70±3.01[a]
Bee bread pot number (pots)	25.72±11.83[b]	10.14±2.21[a]	15.42±1.83[ab]	4.95±0.86[a]
Brood cell number (eggs)	304±140.79[a]	285.58±43.60[a]	601.22±59.71[b]	245.72±35.16[a]
Production of honey (g/3 months)	6.97±10.72	8.69±2.40	15.72±1.35	8.60±4.57
Production of bee bread (g/3 months)	12.18±10.67	12.42±2.75	7.31±2.16	2.58±1.28
Production of propolis (g/3 months)	13.27±3.56[a]	16.57±3.13[a]	29.01±1.99[b]	15.47±3.96[a]
Nest temperature (°C)	28.25±0.98	28.28±0.92	28.36±0.94	28.30±0.06
Nest humidity (%)	76.50±4.26	76.39±4.04	76.47±4.02	76.45±0.06

Note: Values followed by different letters in each row indicate significant differences at $p<0.05$

Table 2. Correlation of productivity from four stingless bee species with nest temperature and humidity

Parameters	Honey pot number (pots)	Bee bread pot number (pots)	Brood cell number (eggs)	Production of honey (g/3 months)	Production of bee bread (g/3 months)	Production of propolis (g/3 months)	Nest temperature (°C)	Nest humidity (%)
Honey pot number	1							
Bee bread pot number	0.264	1						
Brood cell number	0.985*	0.232	1					
Production of honey	0.967*	0.040	0.980*	1				
Production of bee bread	-0.146	0.644	-0.047	-0.215	1			
Production of propolis	0.926*	-0.061	0.956*	0.991*	-0.216	1		
Nest temperature	0.853*	-0.278	0.857*	0.942*	-0.489	0.956*	1	
Nest humidity	0.433	0.652	0.290	0.208	-0.159	0.077	0.074	1

Note: The (*) indicates a very strong correlation between parameters

The number of brood cells has a very strong correlation with propolis production (0.956), which indicates the growth of the colony population in increasing nest defense activity through propolis. Propolis protects the hive from pathogens and is needed in producing honey pots, bee bread, and brood cells (Borba et al. 2017). *Tetragonula sapiens* bees recorded the highest propolis production and number of brood cells. This explains that *T. sapiens* colony has the most active and productive colony. Active bee colonies produce large amounts of propolis as a response to the risk of environmental disturbances (Dequenne et al. 2022).

Effect of nest temperature and humidity on stingless bee productivity

Conducted PCA to understand the multivariate relationship between productivity parameters and nest conditions of the four stingless bee species (Figure 3). The PCA results (PC1 and PC2) showed 91.4% of the total data variation, dominated by PC1 with 74.1%. Parameters on PC1, such as honey production, propolis production, number of brood cells, and nest temperature, showed that productivity was influenced by nest temperature. These results align with previous correlation analysis, which showed that nest temperature has a strong relationship with several parameters. PCA analysis is useful in identifying and interpreting dominant environmental factors in beekeeping. PCA with a multivariate approach functions in bees' ecological and behavioral data (Sousa et al. 2016).

The PCA interpretation image shows that *T. sapiens* is located in the same quadrant as high productivity variables, such as honey and propolis production, and high nest temperature, thus reinforcing that this species is most responsive to optimal nest conditions. In contrast, *T. sarawakensis* and *T. drescheri* tend to be located far from productivity, indicating that both species have a low relationship to nest temperature conditions and production results. This strengthens the previous correlation results, where nest temperature is not strongly correlated in these species due to different adaptations. PCA emphasizes that nest temperature preferences influence productivity between species. PCA analysis is used to separate groups of bee species based on the parameters used (Kalaycıoğlu et al. 2017). The colony's success is largely determined by the suitability of the species to a particular microhabitat (Pereira et al. 2025). Therefore, the selection of species for production purposes is very important and still considers the surrounding environmental conditions.

Nest humidity has a low contribution to PC1 and PC2, which aligns with previous correlation results that showed a weak relationship to all productivity parameters. Nest humidity does not have a dominant role and is relatively small in explaining the variation in stingless bee productivity at the research location. Stingless bee cultivation management is advised to pay more attention to temperature conditions in the nest. PCA shows the effect of nest temperature on each parameter and reveals the relationship between productivity parameters. Stingless beekeepers should not only focus on the final results, such as honey or propolis, but also maintain nest conditions that support colony population growth. The colony management approach aligns with the principles of integrated ecology in meliponiculture (Barbiéri and Francoy 2020). The population of bee colonies greatly determines the capacity for foraging and production (Rodney and Purdy 2020).

Bee forage sources at Awani Bee Garden

The diversity and availability of bee feed source plants in Awani Bee Garden determine the productivity level of the four stingless bee species studied. During the study period, 27 types of plants were identified as flowering (Table 3), most of which provide nectar and pollen sources to support honey formation, bee bread, and colony growth. Plants such as *Mangifera indica* L., *Artocarpus altilis* (Parkinson) Fosberg, and *Artocarpus heterophyllus* Lam. contribute resin providers for propolis production (Putri et al. 2025).

Based on the results (Table 1), *T. sapiens* has the highest productivity in several parameters, largely due to its ability to optimize feed from various flowering plants throughout the year. The positive relationship between productivity and feed availability is further strengthened by the correlation results showing that the number of honey pots, brood cells, and propolis production have a very strong relationship to nest temperature (Table 2). Of course, the main thing is supported by the available feed sources. Abundant feed sources can increase bee production (Requier et al. 2015). The high productivity of *T. sapiens* and *T. laeviceps* depends on the presence of plants that combine nectar and pollen, such as *Lagerstroemia indica* L., *Tridax procumbens* L., *Ixora grandiflora* Zoll. & Moritzi, and other plants. In contrast, *T. sarawakensis'* productivity is relatively low (Table 1), due to its inability to compete in utilizing the variety of feed available at the research location. This is also supported by PCA (Figure 3), where *T. sapiens* is located close to optimal productivity and environmental variables.

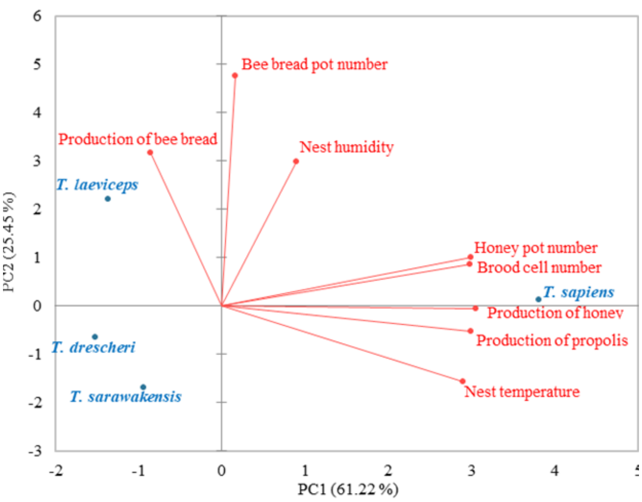

Figure 3. Biplot PCA of the relationship between the productivity of the four stingless bee species and nest conditions

Feed sources affect the quantity of yield, the quality of the nest, and the colony's health (Trinkl et al. 2020). Plants such as *Ficus septica* Burm.fil. and *Hibiscus rosa-sinensis* L., rich in nectar, help maintain the energy supply. The nectar that becomes honey is a carbohydrate bees need (Wright et al. 2018). At the same time, plants such as *Macaranga tanarius* (L.) Müll.Arg. or *Paspalum conjugatum* P.J.Bergius provide a source of pollen, as an important protein for larval development. Pollen brought by bees will be converted and processed in the nest into bee bread (Kieliszek et al. 2018). Honey and bee bread are very much needed by bees as feed reserves during the lean season (Sultana et al. 2024). The lean season for honey bees is when the environmental conditions are dry or rainy (Lavinas et al. 2025). In the dry season, the lack of flowering feed sources disrupts bee production, and in the rainy season, bees will remain in the nest. This preference for bee feed sources explains the differences in nest structure between more adaptive species, such as *T. sapiens*, compared to other species. Although the microenvironment (temperature and humidity of the nest) is relatively homogeneous (Tables 1 and 2), the ability to access and convert available feed is a major differentiating factor in the productivity of each species.

Resin plants such as *M. indica*, *A. altilis*, and *A. heterophyllus* are important for propolis production, especially for *T. sapiens*, which recorded the highest yield of 29.01 g/3 months. Bees use propolis as an antimicrobial agent in the nest and an indicator of colony health (Pusceddu et al. 2021). The availability of local resin with chemical quality that meets bees' needs also determines the colony's success in maintaining productivity amidst microenvironmental pressures. Vegetation management that maintains local resin-producing species is a strategy in stingless bee cultivation (Shanahan and Spivak 2021). Enrichment of bee feed needs to be improved to support the sustainability of bee colonies. Considering the relationship between feed sources, nest conditions, and bee productivity, it can be concluded that the selection and preservation of plant species around the cultivation location are crucial factors in developing healthy and productive colonies. Multifunctional plant species, such as *M. indica* and *A. altilis*, must be a priority in managing agroecological landscapes around urban forests. These findings also strengthen the landscape ecology approach in developing sustainable stingless bee farming (Potts et al. 2010; Williams et al. 2011; Kaluza et al. 2016).

Table 3. Plant types of bee forage plants in Awani Bee Garden

Plant types	Scientific name	Forage source
Crape myrtle	*Lagerstroemia indica* L.	Nectar and pollen
Teak	*Tectona grandis* L.f.	Nectar and pollen
Candlenut	*Aleurites moluccanus* (L.) Wild.	Nectar and pollen
Jamaican cherry	*Muntingia calabura* L.	Nectar and pollen
Mango	*Mangifera indica* L.	Nectar, pollen, and resin
White mulberry	*Morus alba* L.	Pollen
Jackfruit	*Artocarpus heterophyllus* Lam.	Pollen and resin
Papaya	*Carica papaya* L.	Nectar and pollen
Breadfruit	*Artocarpus altilis* (Parkinson) Fosberg	Nectar, pollen, and resin
Sea hibiscus	*Hibiscus tiliaceus* L.	Nectar and pollen
Chinese violet	*Asystasia gangetica* (L.) T.Anderson	Nectar and pollen
Jungle flame	*Ixora grandiflora* Zoll. & Moritzi	Nectar and pollen
Ylang-ylang	*Cananga odorata* (Lam.) Hook.f. & Thomson	nectar and pollen
Parasol leaf tree	*Macaranga tanarius* (L.) Müll.Arg.	Pollen
Coatbuttons	*Tridax procumbens* L.	Nectar and pollen
China rose	*Hibiscus rosa-sinensis* L.	Nectar and pollen
Custard apple	*Annona reticulata* L.	Nectar
Royal palm	*Roystonea regia* (Kunth) O.F.Cook	Nectar and pollen
Palm grass	*Setaria palmifolia* (J.Koenig) Stapf	Pollen
Chinese evergreen	*Aglaonema* sp.	Nectar
False daisy	*Eclipta prostrata* (L.) L.	Pollen
Hauili fig tree	*Ficus septica* Burm.fil.	Pollen
Asthma plant	*Euphorbia hirta* L.	Nectar and pollen
Sensitive plant	*Mimosa pudica* L.	Nectar and pollen
Carabao grass	*Paspalum conjugatum* P.J.Bergius	Pollen
Purple nutsedge	*Cyperus rotundus* L.	Nectar
Little ironweed	*Cyanthillium cinereum* (L.) H.Rob.	Nectar and pollen

The productivity of four stingless bee species in urban forests was significantly influenced by species variation, temperature, and micro-humidity conditions in the nest, and the availability of feed sources consisting of nectar, pollen, and resin. *Tetragonula sapiens* showed the highest productivity in terms of the number of honey pots, bee bread pots, brood cells, production of honey and propolis, which were statistically strongly correlated with optimal nest temperature (29.3°C) and high relative nest humidity (76.4%). PCA analysis confirmed that *T. sapiens* was strongly associated with environmental variables that supported productivity, especially those related to dominant feed sources such as *M. indica* and *A. altilis*, which provided a combination of nectar, pollen, and resin. The diversity and function of feed plants around the cultivation location determined the colony's success in producing honey, propolis, and bee bread while influencing nest structure and reproduction rates. Thus, sound and sustainable management of the feed landscape is key to increasing stingless bee productivity, especially through multifunctional plants and optimization of nest microclimate conditions.

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