

# Forage vegetation for stingless bees to support the sustainability of the meliponiculture in Tulak Tallu Village, South Sulawesi, Indonesia

SYAMSUDDIN MILLANG<sup>1</sup>, BUDIAMAN<sup>1,✉</sup>, YENI OKTAVIA<sup>1</sup>, ANDI PRASTIYO<sup>1</sup>, ENY YUNIATI<sup>2</sup>

<sup>1</sup>Department of Forestry, Faculty of Forestry, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Makassar 90245, South Sulawesi, Indonesia. Tel./fax.: +62-411-586200, ✉email: [budiaman@unhas.ac.id](mailto:budiaman@unhas.ac.id)

<sup>2</sup>Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Tadulako. Jl. Soekarno Hatta KM 9, Palu 94148, Central Sulawesi, Indonesia

Manuscript received: 11 November 2025. Revision accepted: 22 January 2026.

**Abstract.** Millang S, Budiaman, Oktavia Y, Prastiyo A, Yuniati E. 2026. Forage vegetation for stingless bees to support the sustainability of the meliponiculture in Tulak Tallu Village, South Sulawesi, Indonesia. *Biodiversitas* 27 (1): d270124. <https://doi.org/10.13057/biodiv/d270124>. The stingless bee is an insect that plays a crucial role in pollinating various flowering plants in tropical ecosystems. However, forage resource management remains limited because previous studies have focused mainly on the importance value index (IVI) without integrating flowering calendars and actual foraging activity. This study aims to identify forage plant species for stingless bees as a basis for better feed planning. Sampling was conducted across all vegetation growth strata from April to May 2024. Interviews, field data collection, and literature studies were conducted to record the flowering period. The results identified 39 plant species from 25 families as potential food sources. Vegetation analysis showed that the species with the highest IVI at each growth stage were coconut (*Cocos nucifera*) at the tree level (IVI = 55.20), jackfruit (*Artocarpus heterophyllus*) at the pole level (IVI = 48.53), calliandra (*Calliandra calothyrsus*) at the sapling level (IVI = 53.21), and goad weed (*Ageratum conyzoides*) at the seedling level (IVI = 29.79). The combination of multi-strata vegetation with asynchronous flowering patterns plays a role in maintaining the continuity of bee food availability throughout the season at the study site. These findings indicate that several types of plants around meliponiculture need to be identified to see the vegetation that is a food source for the continued development of bee colonies, especially at the research location.

**Keywords:** Bee feed, flowering calendar, importance value index, pollinator, rural vegetation

## INTRODUCTION

Indonesia is a country with abundant natural resource potential. Forest resources generally consist of wood, but in Indonesia, they extend beyond wood to include other forest products, such as Non-Timber Forest Products (NTFPs). Stingless bee products, such as honey and propolis, represent high-value NTFPs whose production is strongly influenced by local forage availability (Lowore et al. 2018; May-Itzá et al. 2022). Despite their diversity, the use of NTFPs such as honey and propolis from stingless bees is highly dependent on the availability of food sources around the nest, making vegetation composition and management a critical component of meliponiculture (Pérez-Morfi et al. 2024).

The stingless bee has a wide range of habitats for gathering and foraging for food. Food sources located close to the nest and at moderate elevations are more frequently visited and have higher bee abundance than those farther from the nest or at higher elevations. Stingless bees visit many and diverse plant flowers, especially in tropical areas, such as Fabaceae, Melastomataceae, Poaceae, Malvaceae, Asteraceae, Rubiaceae, Lamiaceae, Arecaceae, Apocynaceae, and Euphorbiaceae (Bueno et al. 2023). This is because the small body size of the species limits its ability to fly long distances or reach higher altitudes during foraging. The foraging range of stingless bees varies between 53.61-

162.21 m at different altitudes (Pratama et al. 2018). These ecological constraints indicate that forage availability within a limited radius is a key determinant of colony performance.

Vegetation influences air humidity in a habitat; therefore, the success of beekeeping is closely related to temperature, humidity, and the availability of vegetation as a food source. The density and diversity of vegetation directly affect colony productivity. When vegetation is dense and diverse, food availability is sufficient. Conversely, limited and less diverse vegetation leads to reduced food sources (Machado et al. 2020), resulting in weaker colonies and lower productivity (Budiaman et al. 2025). However, existing studies largely treat vegetation structure, IVI, or forage lists as separate components. Commonly visited plants include ageratum (*Ageratum conyzoides*), papaya (*Carica papaya*), sunflower (*Helianthus annuus*), acacia (*Acacia* sp.), guava (*Psidium guajava*), calliandra (*Calliandra calothyrsus*), sensitive plant (*Mimosa pudica*), chili (*Capsicum* sp.), and coconut (*Cocos nucifera*) (Trianto and Purwanto 2020). Thus, the integration of vegetation importance value, flowering phenology, and quantitative visitation intensity remains poorly explored.

These bees are social insects living in colonies and are well adapted to tropical and lowland climates. Their main products include honey, bee pollen, and propolis (Rozman et al. 2022; Harianja et al. 2023), as well as other hive

products such as bee bread and beeswax (Suprianto et al. 2020). Propolis helps regulate nest temperature and protect the colony from predators. Although the honey yield is lower than that of *Apis* sp. bees, they produce more propolis, as it serves as the primary defense material (Trianto and Purwanto 2020). Their honey has a sour taste and high resistance to fermentation, and its price is generally higher than *Apis* sp. honey (Trianto and Marisa 2020). Vegetation as a source of bee food is something that beekeepers need to pay attention to for sustainable cultivation.

Understanding the relationship between the species and its floral resources is crucial to ensuring the sustainability of apiculture in the future. In Sulawesi, particularly at local management scales, empirical data integrating forage availability, visitation dynamics, and flowering continuity are still limited. Limited forage can weaken colonies, reduce worker numbers, lower honey, pollen, and royal jelly production, and decrease queen productivity due to insufficient nectar and pollen as carbohydrate and protein sources. Therefore, this study aims to inventory forage plant species across vegetation strata, calculate the Importance Value Index (IVI), and integrate these data with flowering phenology to support sustainable meliponiculture management.

## MATERIALS AND METHODS

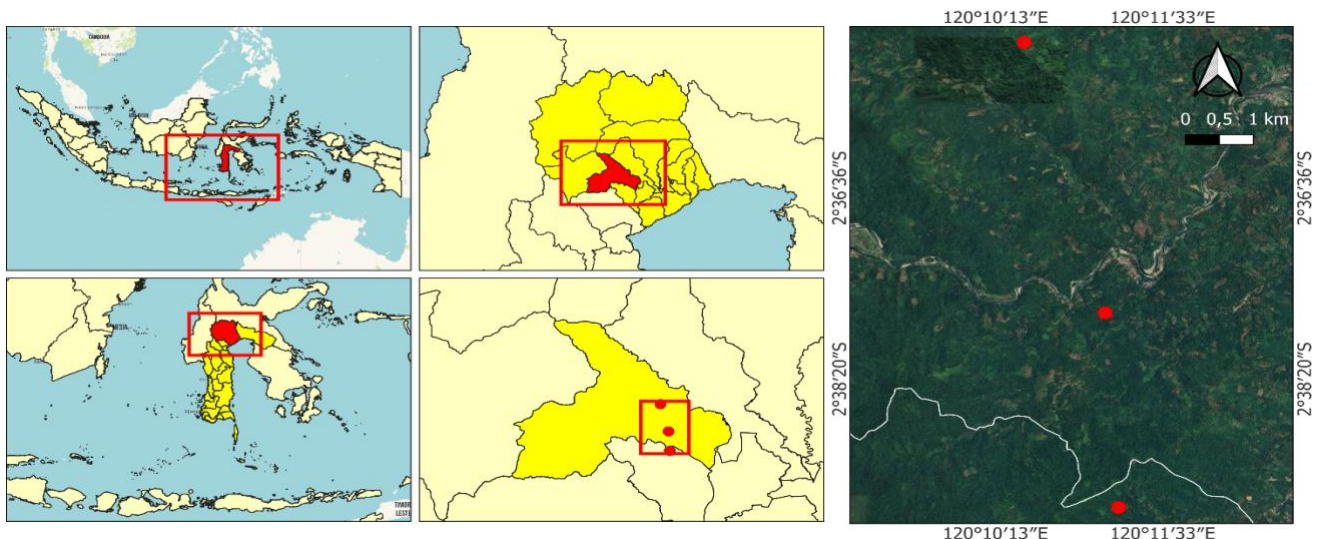
### Study site

This research was conducted from March to May 2024 in the Tulak Tallu Village, located in Sabbang Sub-district, North Luwu District, South Sulawesi Province, Indonesia (Figure 1). The forest area, covering approximately 88.9 km<sup>2</sup>, is classified as a lowland tropical rainforest. Study sites were located around Tulak Tallu Village (WGS84): Point 1 at 120°10'26.597"E and 2°35'16.232"S, point 2 at 120°11'05.280"E and 2°37'44.085"S, and point 3 at 120°11'11.681"E and 2°39'30.408"S. The three research points were selected by purposive sampling based on the largest number of colonies (40-60 colonies) and represented

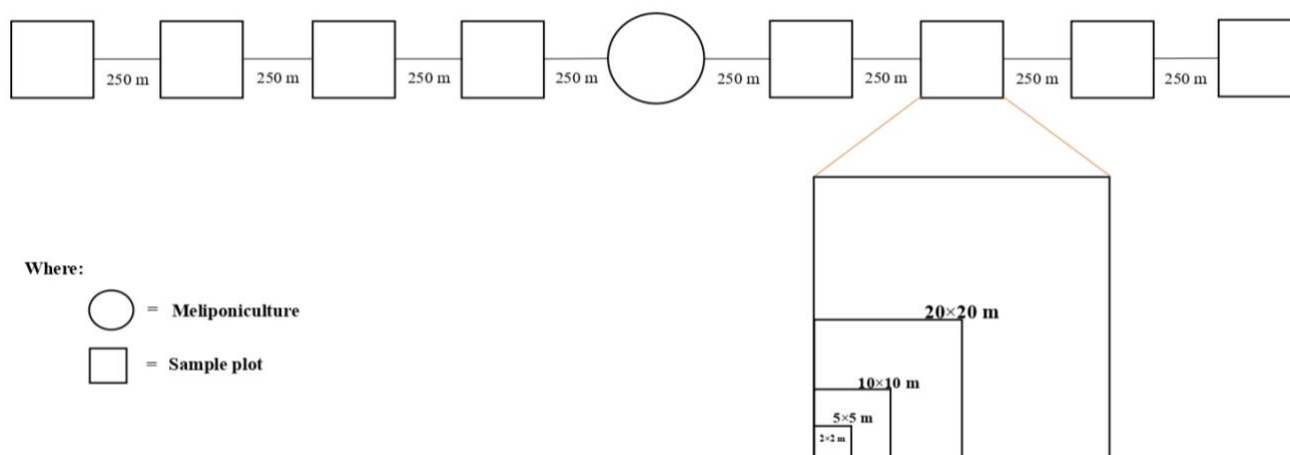
the active foraging landscape within the Tulak Tallu Village Forest. The region has a very wet climate classified as type A according to the Schmidt and Ferguson classification (Ridahwati 2021), with an average annual rainfall of around 4,316 mm/year based on data from the Makassar Class I Meteorological Station. The air temperature averages 22.68°C, ranging from 14.6°C to 31.8°C. Most residents of Tulak Tallu Village depend on gardening and small-scale farming, cultivating rice, cocoa, sugar palm, and several (13 beekeepers) residents keep stingless bees for honey production. The area experiences three distinct seasons: a rainy season (January to April), a dry season (July to November), and a short transition period between May and June.

### Sampling design

This study employed the vegetation analysis method to determine the IVI. The research used purposive selection of respondents (colony owners), each representing different observation sites. The three respondents were selected because they are the only stingless-bee keepers in the village and serve as representatives for identifying forage resources surrounding their colonies. They are the only stingless beekeepers in the village, as mentioned. For each respondent, eight observation plots were established, resulting in a total of 24 plots. Each plot measured 20×20 m (400 m<sup>2</sup>). Plots were spaced at 250 m to capture vegetation gradients within the broader foraging area, while still ensuring coverage of plants located closer to the colony. Plots were placed systematically within the bees' roaming radius of the active hive, not based on respondent preference. The combination of respondent sample selection and plot placement can be clearly defined as a two-stage sampling design. The total sampling extent followed the maximum foraging range of stingless bees up to approximately 1,000 m (Roubik and Aluja 1983). The central point of the study area was selected from one of the active stingless bee colonies (Figure 2).



**Figure 1.** Map of research location at Tulak Tallu Village Forest, Sabbang Sub-district, North Luwu District, South Sulawesi, Indonesia



**Figure 2.** Sample plots for observing bee forage sources in Tulak Tallu Village, North Luwu District, South Sulawesi

Within this area, sample plots were arranged with 250 m spacing between plots to ensure representative sampling of vegetation. Each 20×20 m plot was subdivided into smaller subplots to record vegetation at different growth stages: a 20×20 m subplot for trees (diameter ≥20 cm), a 10×10 m subplot for poles (diameter 10 to <20 cm), a 5×5 m subplot for saplings (diameter ≤10 cm, height >1.5 m), and a 2×2 m subplot for seedlings and ground cover plants (height ≤1.5 m). The survey was conducted in the field by creating plots as shown in Figure 2. Plots were measured using a tape measure and marked with raffia string, and all plots were the same size. Plant species within the plots were then identified and counted. Each plant species was measured according to criteria and grouped according to vegetation strata.

### Flowering phenology

The flowering period of bee food plants is important to understand because it is related to the annual variation in the availability of nectar and pollen used by bees. The flowering schedule of these plants was determined through interviews with respondents regarding the flowering season and supported by literature on the flowering periods of plant species found at the study site. Flowering period was determined using two data sources: interviews with local meliponiculture practitioners and published literature on flowering time, which complemented each other. Once vegetation structure data were collected, interviews were conducted, asking about the flowering schedules of several unidentified plant species. Specific questions were asked, such as: i) Are you familiar with this plant species? ii) If so, what months does this plant flower, or does it depend on the growing season?. This prioritizes local observations for location-specific times.

### Data analysis

The data analysis used in the research was descriptive, namely by recapitulating data from field observations regarding the types and number of plants. The IVI formula is the same for all strata, but differs for seedlings (IVI = KR + FR). The software used is Excel to process the data. Vegetation analysis regarding density, frequency, dominance,

and importance value index used the following formulas (Kusmana 1997):

#### Density of a species

$$\text{Density (K)} = \frac{\text{Number of individuals of a species}}{\text{Area of sample plot}}$$

$$\text{Relative density (KR)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100\%$$

#### Frequency of a species

$$\text{Frequency (F)} = \frac{\text{Number of plots where the species is found}}{\text{Total number of plot}}$$

$$\text{Relative frequency (FR)} = \frac{\text{Number of plots where the species is found}}{\text{Total number of plot}} \times 100\%$$

#### Dominance of a species

$$\text{Dominance (D)} = \frac{\text{Total basal area of a species}}{\text{Area of sample plot}} \times 100\%$$

$$\text{Dominance frequency (DR)} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \times 100\%$$

#### Importance value index

The importance value index for trees, poles, and saplings is calculated using the formula:

$$\text{Importance Value Index (IVI)} = \text{KR} + \text{FR} + \text{DR}$$

For seedlings and ground cover plants, the index is calculated based on:

$$\text{Importance Value Index (IVI)} = \text{KR} + \text{FR}$$

## RESULTS AND DISCUSSION

### Stingless bees forage

A total of 39 species from 25 plant families were flowering in the plots, including forestry plants, plantation crops, ornamental plants, and grasses (Table 1). Each type of plant has a different food source. Three plant species provide a complete food source (nectar, pollen), and resin for bees. There is also one plant species, *Thelypteris* sp., that lacks nectar, pollen, and resin.

**Table 1.** Bee forage sources in the stingless bee cultivation area of Tulak Tallu Village, North Luwu District

| Family           | Common name         | Species   | Forage |        | Resin |
|------------------|---------------------|---|--------|--------|-------|
|                  |                     |   | Nectar | Pollen |       |
| Arecaceae        | Coconut             | <i>Cocos nucifera</i> L.                          | ✓      | ✓      | -     |
| Malvaceae        | Durian              | <i>Durio zibethinus</i> L.                        | ✓      | -      | -     |
| Malvaceae        | Cocoa               | <i>Theobroma cacao</i> L.                         | ✓      | ✓      | -     |
| Sapindaceae      | Rambutan            | <i>Nephelium lappaceum</i> L.                     | ✓      | -      | -     |
| Anacardiaceae    | Mango               | <i>Mangifera indica</i> L.                        | ✓      | ✓      | ✓     |
| Lamiaceae        | Teak                | <i>Tectona grandis</i> L.f.                       | ✓      | ✓      | -     |
| Lamiaceae        | Gofasa              | <i>Vitex cofassus</i> Reinw. ex Blume             | ✓      | ✓      | -     |
| Myrtaceae        | Clove               | <i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry | ✓      | ✓      | ✓     |
| Fabaceae         | Calliandra          | <i>Calliandra calothyrsus</i> Meisn.              | ✓      | ✓      | -     |
| Meliaceae        | Langsat             | <i>Lansium domesticum</i> Corrêa                  | ✓      | ✓      | -     |
| Rutaceae         | Pomelo              | <i>Citrus maxima</i> (Burm.) Merr.                | ✓      | ✓      | -     |
| Fabaceae         | Tamarind            | <i>Tamarindus indica</i> L.                       | ✓      | -      | ✓     |
| Moraceae         | Jackfruit           | <i>Artocarpus heterophyllus</i> Lam.              | -      | ✓      | ✓     |
| Musaceae         | Banana              | <i>Musa × paradisiaca</i> L.                      | ✓      | ✓      | -     |
| Myrtaceae        | Water apple         | <i>Syzygium aqueum</i> (Burm.f.) Alston           | ✓      | -      | -     |
| Oxalidaceae      | Star fruit          | <i>Averrhoa carambola</i> L.                      | ✓      | -      | -     |
| Anacardiaceae    | Cashew              | <i>Anacardium occidentale</i> L.                  | ✓      | -      | ✓     |
| Muntingiaceae    | Jamaican cherry     | <i>Muntingia calabura</i> L.                      | ✓      | ✓      | -     |
| Myrtaceae        | Guava               | <i>Psidium guajava</i> L.                         | ✓      | ✓      | -     |
| Caricaceae       | Papaya              | <i>Carica papaya</i> L.                           | ✓      | ✓      | -     |
| Bromeliaceae     | Pineapple           | <i>Ananas comosus</i> (L.) Merr.                  | ✓      | -      | -     |
| Poaceae          | Rice                | <i>Oryza sativa</i> L.                            | -      | ✓      | -     |
| Solanaceae       | Tomato              | <i>Solanum lycopersicum</i> L.                    | ✓      | ✓      | -     |
| Solanaceae       | Eggplant            | <i>Solanum melongena</i> L.                       | ✓      | ✓      | -     |
| Cucurbitaceae    | Bitter melon        | <i>Momordica charantia</i> L.                     | ✓      | -      | -     |
| Zingiberaceae    | Galangal            | <i>Alpinia galanga</i> (L.) Willd.                | ✓      | -      | -     |
| Rutaceae         | Key lime            | <i>Citrus × aurantiifolia</i> (Christm.) Swingle  | ✓      | -      | -     |
| Poaceae          | Elephant grass      | <i>Cenchrus purpureus</i> (Schumach.) Morrone     | ✓      | -      | -     |
| Rubiaceae        | Noni                | <i>Morinda citrifolia</i> L.                      | ✓      | ✓      | -     |
| Fabaceae         | Sensitive plant     | <i>Mimosa pudica</i> L.                           | -      | ✓      | -     |
| Poaceae          | Maize               | <i>Zea mays</i> L.                                | -      | ✓      | -     |
| Rubiaceae        | Robusta coffee      | <i>Coffea canephora</i> Pierre ex A.Froehner      | ✓      | ✓      | -     |
| Cucurbitaceae    | Pumpkin             | <i>Cucurbita moschata</i> Duchesne                | -      | ✓      | -     |
| Rubiaceae        | Jungle genarium     | <i>Ixora chinensis</i> Lam.                       | ✓      | ✓      | -     |
| Solanaceae       | Chili pepper        | <i>Capsicum annuum</i> L.                         | ✓      | ✓      | -     |
| Polygonaceae     | Coral vine          | <i>Antigonon leptopus</i> Hook. & Arn.            | ✓      | -      | -     |
| Asteraceae       | Billygoat weed      | <i>Ageratum conyzoides</i> L.                     | -      | ✓      | -     |
| Melastomaceae    | Indian rhododendron | <i>Melastoma malabathricum</i> L.                 | ✓      | ✓      | -     |
| Thelypteridaceae | Marsh fern          | <i>Thelypteris</i> sp.                            | ✓      | -      | -     |

Note: ✓ plants producing nectar, pollen, and resin sources; - indicates absence of nectar, pollen, or resin sources

### Flowering the calendar of plants

Based on Table 2, various flowering plant species were recorded around the meliponiculture area. Based on the literature, species such as *C. nucifera*, *Mangifera indica*, *C. papaya*, and *P. guajava* flower almost year-round, while *Durio zibethinus*, *Nephelium lappaceum*, and *Lansium domesticum* have seasonal flowering periods. Interview results showed that food crops such as *Oryza sativa*, *Zea mays*, and *Capsicum annuum* flower according to the growing season. This combination of annual and seasonal flowering plants forms the basis for developing a livestock feed calendar, which is necessary for planning the forage of stingless bees.

### Vegetation analysis (IVI) of potential stingless bee forage plants

Based on Table 3, the vegetation analysis at the tree level shows that the plant species with the highest IVI were

*C. nucifera* (IVI = 55.20), followed by *D. zibethinus* (IVI = 52.41) and *M. indica* (IVI = 48.36). Interestingly, these species are also among the most frequently visited by bees, strengthening the link between vegetation dominance and bee visitation intensity. Species such as *Anacardium occidentale* have low IVI and contribute little to stand structure.

At the pole level (Table 4), *Artocarpus heterophyllus* dominated (IVI = 48.53), followed by *Syzygium aqueum* (IVI = 21.33) and *Musa × paradisiaca* (IVI = 21.33). Some of the dominant species in this stratum also function as food, indicating that regenerative vegetation contributes to maintaining long-term food sources.

At the sapling stage (Table 5), dominant species include *C. calothyrsus* (IVI = 53.21), *A. heterophyllus* (IVI = 52.95), and *C. Papaya* (IVI = 52.21). *D. zibethinus* in Table 5 appears because this vegetation was found in this level category. Many of these species are fruit or legume crops,

thus having high potential as food due to consistent nectar and pollen production.

At the seedling stage (Table 6), the species with the highest IVI were *A. conyzoides* (IVI = 29.79), *C. annuum*

(IVI = 24.34), and *M. pudica* (IVI = 19.44). The dominance of these fast-growing herbs indicates that ground flora is abundant.

**Table 2.** Flowering calendar of plants in Tulak Tallu Village, North Luwu District, South Sulawesi

| Species   | Flowering time: Month to |   |   |   |   |   |   |   |   |    |    |    | DPS | Sources |                              |
|---|--------------------------|---|---|---|---|---|---|---|---|----|----|----|-----|---------|------------------------------|
|   | 1                        | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |     |         |                              |
| <i>Cocos nucifera</i> L.                          | ✓                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | -  | -  | -  | -   | -       | Erwan et al. (2022)          |
| <i>Durio zibethinus</i> L.                        | -                        | - | - | - | - | - | - | - | - | -  | ✓  | ✓  | -   | -       | Arfiani 2024                 |
| <i>Theobroma cacao</i> L.                         | ✓                        | ✓ | ✓ | - | - | - | - | - | - | -  | ✓  | ✓  | -   | -       | Arfiani 2024                 |
| <i>Nephelium lappaceum</i> L.                     | -                        | - | - | - | - | - | - | - | - | ✓  | ✓  | -  | -   | -       | Rosmarlinasiah et al. 2020   |
| <i>Mangifera indica</i> L.                        | -                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | -  | -   | -       | Erwan et al. (2022)          |
| <i>Tectona grandis</i> L.f.                       | -                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | -  | -  | -  | -   | -       | Rosmarlinasiah et al. (2020) |
| <i>Vitex cofassus</i> Reinw. ex Blume             | -                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | -  | -  | -  | -   | -       | Nuraina et al. (2018)        |
| <i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry | -                        | - | - | - | - | - | ✓ | ✓ | ✓ | ✓  | -  | -  | -   | -       | Local community              |
| <i>Calliandra calothyrsus</i> Meisn.              | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Local community              |
| <i>Lansium domesticum</i> Corrêa                  | -                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓  | -  | -  | -   | -       | Local community              |
| <i>Citrus maxima</i> (Burm.) Merr.                | ✓                        | - | - | - | - | ✓ | ✓ | ✓ | ✓ | -  | -  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Tamarindus indica</i> L.                       | -                        | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | - | -  | -  | -  | -   | -       | Erwan et al. (2022)          |
| <i>Artocarpus heterophyllus</i> Lam.              | -                        | - | - | - | - | - | - | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Musa × paradisiaca</i> L.                      | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Erwan et al. (2022)          |
| <i>Syzygium aqueum</i> (Burm.f.) Alston           | -                        | - | - | - | ✓ | ✓ | ✓ | - | - | -  | -  | -  | -   | -       | Nurhalisa et al. (2023)      |
| <i>Averrhoa carambola</i> L.                      | -                        | - | - | - | ✓ | - | ✓ | - | ✓ | ✓  | ✓  | -  | -   | -       | Rosmarlinasiah et al. (2020) |
| <i>Anacardium occidentale</i> L.                  | -                        | - | - | ✓ | ✓ | ✓ | ✓ | - | - | -  | -  | -  | -   | -       | Nurhalisa et al. (2023)      |
| <i>Muntingia calabura</i> L.                      | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Rosmarlinasiah et al. (2020) |
| <i>Psidium guajava</i> L.                         | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Arfiani 2024                 |
| <i>Carica papaya</i> L.                           | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Ananas comosus</i> (L.) Merr.                  | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Local community              |
| <i>Oryza sativa</i> L.                            | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Local community              |
| <i>Solanum lycopersicum</i> L.                    | ✓                        | ✓ | ✓ | - | ✓ | ✓ | - | - | ✓ | ✓  | ✓  | ✓  | -   | -       | Nurhalisa et al. (2023)      |
| <i>Solanum melongena</i> L.                       | -                        | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | -  | -   | -       | Nurhalisa et al. (2023)      |
| <i>Momordica charantia</i> L.                     | -                        | - | - | - | - | - | - | ✓ | ✓ | ✓  | ✓  | -  | -   | -       | Nurhalisa et al. (2023)      |
| <i>Alpinia galanga</i> (L.) Willd.                | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Local community              |
| <i>Citrus ×aurantiifolia</i> (Christm.) Swingle   | -                        | - | - | - | - | - | - | - | ✓ | -  | -  | -  | -   | -       | Erwan et al. (2022)          |
| <i>Cenchrus purpureus</i> (Schumach.) Morrone     | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Agussalim et al. (2017)      |
| <i>Morinda citrifolia</i> L.                      | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Mimosa pudica</i> L.                           | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Zea mays</i> L.                                | ✓                        | ✓ | ✓ | - | - | - | ✓ | ✓ | ✓ | ✓  | ✓  | -  | -   | -       | Agussalim et al. (2017)      |
| <i>Coffea canephora</i> Pierre ex A.Froehner      | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Cucurbita moschata</i> Duchesne                | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Local community              |
| <i>Ixora coccinea</i> L.                          | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Erwan et al. (2022)          |
| <i>Capsicum annuum</i> L.                         | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | ✓   | -       | Rosmarlinasiah et al. (2020) |
| <i>Antigonon leptopus</i> Hook. & Arn.            | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Local community              |
| <i>Ageratum conyzoides</i> L.                     | ✓                        | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓  | ✓  | ✓  | -   | -       | Arfiani, 2024                |
| <i>Melastoma malabathricum</i> L.                 | ✓                        | ✓ | ✓ | - | - | - | - | - | - | ✓  | ✓  | ✓  | -   | -       | Rosmarlinasiah et al. (2020) |
| <i>Thelypteris</i> sp.                            | -                        | - | - | - | - | - | - | - | - | -  | -  | -  | -   | -       | Local community              |

Note: ✓ : flowering period; - : non-flowering period; DPS: depending on the planting season

**Table 3.** Vegetation analysis at the tree level

| Species   | KR (%) | FR (%) | DR (%) | IVI   |
|---|--------|--------|--------|-------|
| <i>Cocos nucifera</i> L.                          | 20.24  | 14.55  | 20.41  | 55.20 |
| <i>Durio zibethinus</i> L.                        | 19.05  | 16.36  | 17.00  | 52.41 |
| <i>Mangifera indica</i> L.                        | 14.29  | 18.18  | 15.89  | 48.36 |
| <i>Artocarpus heterophyllus</i> Lam.              | 9.52   | 12.73  | 6.90   | 29.15 |
| <i>Nephelium lappaceum</i> L.                     | 5.95   | 7.27   | 6.03   | 19.25 |
| <i>Calliandra calothyrsus</i> Meisn.              | 7.14   | 5.45   | 6.57   | 19.16 |
| <i>Vitex cofassus</i> Reinw. ex Blume             | 4.76   | 5.45   | 4.17   | 14.38 |
| <i>Citrus maxima</i> (Burm.) Merr.                | 3.57   | 5.45   | 3.22   | 12.24 |
| <i>Lansium domesticum</i> Corrêa                  | 3.57   | 5.45   | 2.54   | 11.56 |
| <i>Musa</i> × <i>paradisiaca</i> L.               | 2.38   | 1.82   | 1.13   | 5.33  |
| <i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry | 3.57   | 1.82   | 2.15   | 7.54  |
| <i>Tectona grandis</i> L.f.                       | 3.57   | 1.82   | 2.03   | 7.42  |
| <i>Tamarindus indica</i> L.                       | 1.19   | 1.82   | 1.24   | 4.25  |
| <i>Anacardium occidentale</i> L.                  | 1.19   | 1.82   | 0.71   | 3.72  |

**Table 4.** Vegetation analysis at the pole level

| Species                                 | KR (%) | FR (%) | DR (%) | IVI   |
|---|--------|--------|--------|-------|
| <i>Artocarpus heterophyllus</i> Lam.    | 15.85  | 17.31  | 15.37  | 48.53 |
| <i>Syzygium aqueum</i> (Burm.f.) Alston | 6.10   | 9.62   | 5.61   | 21.33 |
| <i>Musa</i> × <i>paradisiaca</i> L.     | 6.10   | 9.62   | 5.61   | 21.33 |
| <i>Lansium domesticum</i> Corrêa        | 7.32   | 7.69   | 6.31   | 21.32 |
| <i>Calliandra calothyrsus</i> Meisn.    | 7.32   | 7.69   | 6.18   | 21.19 |
| <i>Tectona grandis</i> L.f.             | 6.10   | 5.77   | 8.87   | 20.74 |
| <i>Psidium guajava</i> L.               | 4.88   | 7.69   | 2.97   | 15.54 |
| <i>Mangifera indica</i> L.              | 4.88   | 5.77   | 4.70   | 15.35 |
| <i>Citrus maxima</i> (Burm.) Merr.      | 3.66   | 5.77   | 4.63   | 14.06 |
| <i>Averrhoa carambola</i> L.            | 3.66   | 3.85   | 3.61   | 11.12 |
| <i>Muntingia calabura</i> L.            | 2.44   | 3.85   | 2.40   | 8.69  |
| <i>Anacardium occidentale</i> L.        | 2.44   | 3.85   | 1.53   | 7.82  |
| <i>Durio zibethinus</i> L.              | 2.44   | 1.92   | 2.48   | 6.84  |
| <i>Nephelium lappaceum</i> L.           | 1.22   | 1.92   | 2.13   | 5.27  |

**Table 5.** Vegetation analysis at the sapling level

| Species   | KR (%) | FR (%) | DR (%) | IVI   |
|---|--------|--------|--------|-------|
| <i>Calliandra calothyrsus</i> Meisn.                    | 20.00  | 14.04  | 19.17  | 53.21 |
| <i>Artocarpus heterophyllus</i> Lam.                    | 16.67  | 19.30  | 16.98  | 52.95 |
| <i>Carica papaya</i> L.                                 | 18.89  | 19.30  | 14.02  | 52.21 |
| <i>Theobroma cacao</i> L.                               | 15.56  | 12.28  | 13.52  | 41.36 |
| <i>Psidium guajava</i> L.                               | 7.78   | 10.53  | 5.50   | 23.81 |
| <i>Durio zibethinus</i> L.                              | 5.56   | 7.02   | 9.70   | 22.28 |
| <i>Averrhoa carambola</i> L.                            | 2.22   | 3.51   | 2.69   | 8.42  |
| <i>Durio zibethinus</i> L.                              | 2.44   | 1.92   | 2.48   | 6.84  |
| <i>Citrus</i> × <i>aurantiifolia</i> (Christm.) Swingle | 2.22   | 1.75   | 1.78   | 5.75  |
| <i>Mangifera indica</i> L.                              | 1.11   | 1.75   | 2.37   | 5.23  |
| <i>Syzygium aqueum</i> (Burm.f.) Alston                 | 1.11   | 1.75   | 1.49   | 4.35  |
| <i>Morinda citrifolia</i> L.                            | 1.11   | 1.75   | 0.78   | 3.64  |
| <i>Ananas comosus</i> (L.) Merr.                        | 1.11   | 1.75   | 0.28   | 3.14  |

**Table 6.** Vegetation analysis at the seedling level

| Species   | KR (%) | FR (%) | IVI   |
|---|--------|--------|-------|
| <i>Ageratum conyzoides</i> L.                           | 15.50  | 14.29  | 29.79 |
| <i>Capsicum annuum</i> L.                               | 13.95  | 10.39  | 24.34 |
| <i>Mimosa pudica</i> L.                                 | 7.75   | 11.69  | 19.44 |
| <i>Calliandra calothyrsus</i> Meisn.                    | 8.53   | 6.49   | 15.02 |
| <i>Cenchrus purpureus</i> (Schumach.) Morrone           | 6.98   | 7.79   | 14.77 |
| <i>Melastoma malabathricum</i> L.                       | 5.43   | 6.49   | 11.92 |
| <i>Solanum lycopersicum</i> L.                          | 4.65   | 5.19   | 9.84  |
| <i>Solanum melongena</i> L.                             | 3.10   | 3.90   | 7.00  |
| <i>Cucurbita moschata</i> Duchesne                      | 5.43   | 3.90   | 9.33  |
| <i>Thelypteris</i> sp.                                  | 3.88   | 5.19   | 9.07  |
| <i>Alpinia galanga</i> (L.) Willd.                      | 3.10   | 5.19   | 8.29  |
| <i>Momordica charantia</i> L.                           | 3.88   | 3.90   | 7.78  |
| <i>A. flavescens</i>                                    | 3.88   | 2.60   | 6.48  |
| <i>Zea mays</i> L.                                      | 3.10   | 1.30   | 4.40  |
| <i>Morinda citrifolia</i> L.                            | 1.55   | 2.60   | 4.15  |
| <i>Ananas comosus</i> (L.) Merr.                        | 1.55   | 2.60   | 4.15  |
| <i>I. grandiflora</i>                                   | 2.33   | 1.30   | 3.63  |
| <i>Oryza sativa</i> L.                                  | 2.33   | 1.30   | 3.63  |
| <i>Citrus</i> × <i>aurantiifolia</i> (Christm.) Swingle | 1.55   | 1.30   | 2.85  |
| <i>Mangifera indica</i> L.                              | 0.78   | 1.30   | 2.08  |
| <i>Artocarpus heterophyllus</i> Lam.                    | 0.78   | 1.30   | 2.08  |

## Discussion

Stingless bees at the study site showed preferences for flowers from certain plant families as primary food sources, as reflected by the dominance of Fabaceae, Myrtaceae, and Asteraceae (Table 1). This finding is consistent with studies conducted in Brazil, which reported that stingless bees consistently utilize flowers from Fabaceae, Myrtaceae, and Asteraceae despite differences in biogeographical conditions (Nascimento et al. 2015). The dominance of these families reflects the abundance of stingless food. At the research site, the presence of 39 plant species that provide nectar, pollen, and resin indicates that stingless bees depend on vegetation to meet their nutritional needs throughout the season. This abundance aligns with Vijayakumar and Jeyaraaj (2016), who reported that stingless bees habitually collect floral resources from a broad range of plant species. The dominance of vegetation from several families and species found in this study has a good role in the sustainability of stingless bees as a food source.

Differences in flowering period and the availability of resources among plant species, as shown in Table 2, also affect pollen and nectar composition. Adequate pollen and nectar are essential for a bee colony (Rodney and Purdy 2020). Species that flower seasonally, such as several fruit trees, provide pulses, whereas year-round bloomers such as *C. nucifera* should act as stabilizing resources during floral gaps. Table 3 shows that *C. nucifera* at the tree stage has the highest IVI value, indicating dominance in the meliponiculture area. When IVI values are examined together with flowering duration, dominant species such as *D. zibethinus* and *C. nucifera* emerge as key contributors to forage availability across strata and seasons. The ecological relevance of dominant species is consistent with previous findings that structurally important plants often support

ecosystem stability (Craven et al. 2018; Vezzani et al. 2018). Conversely, *A. occidentale* shows the lowest IVI, indicating limited representation within the vegetation structure.

At the pole stage (Table 4), *A. heterophyllus* recorded the highest IVI, while *N. lappaceum* had the lowest. These differences reflect variation in vegetation structure rather than direct indicators of forage preference. Its consistent presence in the landscape enhances forage stability. Meanwhile, the low IVI of *N. lappaceum*, combined with its absence at seedling and sapling stages, suggests poor regeneration. Among sapling vegetation (Table 5), *C. calothyrsus* showed the highest IVI, indicating strong ecological adaptation and dominance. In contrast, *Morinda citrifolia* L. exhibited a low IVI, suggesting limited abundance within the sapling layer. At the seedling levels (Table 6), *A. conyzoides* recorded the highest IVI, consistent with its high regeneration capacity and widespread distribution.

The availability of floral resources directly affects the survival of bee colonies. Species such as *Muntingia calabura*, *C. papaya*, and *P. guajava* were recorded as important components of year-round forage availability (Rosmarlinasiah et al. 2020; Erwan et al. 2022; Arfiani 2024). When forage is insufficient, colonies can be relocated to areas with abundant blooming species (Erwan et al. 2022; Budiawan et al. 2026). These findings support the development of site-specific forage management strategies, emphasizing the maintenance and enrichment of plant species with high IVI and extended flowering periods. Enriching bee forage plant species can be achieved through careful planning, including selecting easy-to-grow plants and introducing plants that flower year-round. This will lay the foundation for the bees' continued survival and the availability of sustainable forage sources. The main limitations of this study include the sample size, the lack of data on bee visitation to flowers, the reliance on interview-based flowering information, and the short duration of the fieldwork. Multi-season phenological monitoring is recommended for direct quantification of bee visitation levels, and comparisons between villages or different land use types.

In conclusion, this study demonstrates ecological and applied contributions by showing that the study site is supported by 39 plant species from 25 families. The flowering calendar shows an asynchronous flowering pattern, thus ensuring the availability of food throughout the year. Ecologically, these results emphasize that dominance, flowering continuity, and multi-strata vegetation collectively underpin forage reliability in agroforestry-based meliponiculture systems. From an applied perspective, meliponiculture practitioners are advised to prioritize enrichment planting of high-IVI species with year-round or complementary flowering periods. Feed enrichment with high IVI can be done gradually, where the selection of plant species that have the potential to grow well in the selected location and have sources of nectar, pollen, and resin as the main support for the sustainability of the bee colony. Vegetation across multiple growth stages within a short flight radius of colonies and use flowering calendars

as operational tools for hive placement and seasonal management. Future research should integrate quantitative visitation data, microclimate monitoring, and interspecific competition assessments to strengthen management-oriented recommendations.

## ACKNOWLEDGEMENTS

Thanks are extended to the Tree Physiology and Silviculture Laboratory, Faculty of Forestry, Universitas Hasanuddin, Indonesia. Appreciation is also given to the stingless bee farmers in Tulak Tallu Village, Sabbang Sub-district, North Luwu District, South Sulawesi, Indonesia.

## REFERENCES

- Agussalim, Agus I, Umami N, Budisatria IGS. 2017. Variasi jenis tanaman pakan lebah madu sumber nektar dan polen berdasarkan ketinggian tempat di Yogyakarta. Buletin Peternakan 41 (4): 448-460. <https://doi.org/10.21059/buletinpeternak.v41i4.13593>. [Indonesian]
- Arfiani FSP. 2024. Keanekaragaman poensi sumber pakan dari polen pada madu lebah tanpa sengat di lima daerah di Indonesia. [Skripsi]. Institut Pertanian Bogor, Bogor. [Indonesian]
- Budiawan, Prastiyo A, Sadapotto A, Muchtar AA, Nurhalizah. 2026. Potential production and feed sources for *Tetragonula biroi* bees in meliponiculture in South Sulawesi, Indonesia. J Glob Innov Agric Sci 14: 121-129. DOI: 10.22194/JGIAS/26.1684.
- Budiawan, Rahman AF, Nurhayati N, 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 (1): 144-151. <https://doi.org/10.13057/asianjfor/r090115>.
- Bueno FGB, Kendall L, Alves DA, Tamara ML, Heard T, Latty T, Gloag R. 2023. Stingless bee floral visitation in the global tropics and subtropics. Glob Ecol Conserv 43: e02454. <https://doi.org/10.1016/j.gecco.2023.e02454>.
- Craven D, Eisenhauer N, Pearse WD, Hautier Y, Isbell F, Roscher C, Bahn M, Beierkuhnlein C, Bönisch G, Buchmann N, Byun C, Catford JA, Cerabolini BEL, et al. 2018. Multiple facets of biodiversity drive the diversity-stability relationship. Nat Ecol Evol 2 (10): 1579-1587. <https://doi.org/10.1038/s41559-018-0647-7>.
- Erwan E, Purnamasari DK, Resti R, Muhsinin M. 2022. Identifikasi jenis tanaman pakan lebah madu sebagai sumber nektar dan polen. Jurnal Triton 13 (2): 206-220. <https://doi.org/10.47687/jt.v13i2.254>. [Indonesian]
- Harianja AH, Adalina Y, Pasaribu G, Winarni I, Maharani R, Fernandes A, Saragih GS, Fauzi R, Tampubolon AP, Njurumana GN, et al. 2023. Potential of beekeeping to support the livelihood, economy, society, and environment of Indonesia. Forests 14 (2): 321. <https://doi.org/10.3390/f14020321>.
- Kusmana C. 1997. Ekologi dan sumberdaya ekosistem mangrove. Makalah Pelatihan Pengelolaan Hutan Mangrove Lestari Angkatan I PKSPL. Institut Pertanian Bogor, Bogor. [Indonesian]
- Lowore J, Meaton J, Wood A. 2018. African forest honey: An overlooked NTFP with potential to support livelihoods and forests. Environ Manage 62: 15-28. <https://doi.org/10.1007/s00267-018-1015-8>.
- Machado T, Viana BF, da Silva CI, Boscolo D. 2020. How landscape composition affects pollen collection by stingless bees? Landscape Ecol 35: 747-759. <https://doi.org/10.1007/s10980-020-00977-y>.
- May-Itzá WdJ, Martínez-Fortún S, Zaragoza-Trello C, Ruiz C. 2022. Stingless bees in tropical dry forests: Global context and challenges of an integrated conservation management. J Apic Res 61 (5): 642-653. <https://doi.org/10.1080/00218839.2022.2095709>.
- Nascimento AS, Marchini LC, Carvalho CAL, Araújo DF, Silveira TA. 2015. Pollen spectrum of stingless bees honey (Hymenoptera Apidae), Parana State, Brazil. J Entomol Zool Stud 3 (2): 290-296.
- Nuraina I, Fahrizal, Prayogo H. 2018. Analisa komposisi dan keanekaragaman jenis tegakan penyusun hutan tembakang jelomuk di Desa Meta Bersatu Kecamatan Sayan Kabupaten Melawi. Jurnal Hutan Lestari 6 (1): 137-146. <https://doi.org/10.26418/jhl.v6i1.24151>. [Indonesian]

- Pérez-Morfí A, Dorantes-Euan A, Rodríguez R, Ramírez-Arriaga E, Dupuy-Rada JM, Canto A. 2024. Diversity, structure, and composition of melliferous and non-melliferous vegetation surrounding meliponaries of the Yucatan Peninsula, Mexico. *Bot Sci* 102 (4): 1109-1128. <https://doi.org/10.17129/botsci.3497>.
- Pratama IPNE, Watiniasih NL, Ginantara IK. 2018. Perbedaan ketinggian tempat terhadap jenis polen yang dikoleksi oleh lebah Trigona. *Jurnal Biologi Udayana* 22 (1): 42-48. [Indonesian]
- Ridahwati R. 2021. Changes in rainfall and climate classification in South Sulawesi. *J La Lifesci* 2 (5): 37-50. <https://doi.org/10.37899/journallalifesci.v2i5.524>.
- Rodney S, Purdy J. 2020. Dietary requirements of individual nectar foragers, and colony-level pollen and nectar consumption: A review to support pesticide exposure assessment for honey bees. *Apidologie* 51: 163-179. <https://doi.org/10.1007/s13592-019-00694-9>.
- Rosmarlinasiah R, Kabe A Usliawaty Z, Syamsul S. 2020. Potensi beeforage *Apis dorsata* binghamii di KPHP Gula Raya Tobimeita Kendari. *Celebica* 2 (1): 121-129. <https://doi.org/10.33772/JC.V11I2.16821>. [Indonesian]
- Roubik DW, Aluja M. 1983. Flight ranges of *Melipona* and *Trigona* in tropical forest. *J Kans Entomol Soc* 56 (2): 217-222.
- Rozman AS, Hashim N, Maringgal B, Abdan K. 2022. A comprehensive review of stingless bee products: Phytochemical composition and beneficial properties of honey, propolis, and pollen. *Appl Sci* 12 (13): 6370. <https://doi.org/10.3390/app12136370>.
- Suprianto S, Trianto M, Alam N, Kirana NGAGC. 2020. Karakter morfologi dan analisis daerah conserved gen elongation factor 1? (EF1?) pada *Lepidotrigona terminata*. *Metamorfosa: J Biol Sci* 7 (2): 30-39. <https://doi.org/10.24843/metamorfosa.2020.v07.i02.p05>. [Indonesian]
- Trianto M, Marisa F. 2020. Diversity of bees and wasps (Hymenoptera) in cowpea (*Vigna sinensis* L.) in agricultural area at Martapura District, Banjar Regency, South Kalimantan. *J Sci Technol* 9 (2): 29-33. <https://doi.org/10.22487/25411969.2019.v9.i2.15174>.
- Trianto M, Purwanto H. 2020. Morphological characteristics and morphometrics of stingless bees (Hymenoptera: Meliponini) in Yogyakarta, Indonesia. *Biodiversitas* 21 (6): 2619-2628. <https://doi.org/10.13057/biodiv/d210633>.
- Vezzani FM, Anderson C, Meenken E, Gillespie R, Peterson M, Beare MH. 2018. The importance of plants to development and maintenance of soil structure, microbial communities and ecosystem functions. *Soil Till Res* 175: 139-149. <https://doi.org/10.1016/j.still.2017.09.002>.
- Vijayakumar K, Jeyaraaj R. 2016. Floral sources for stingless bees in Nellithurai Village, Tamilnadu, India. *Amb Sci* 3 (2): 69-74. <https://doi.org/10.21276/ambi.2016.03.2.ra04>.