Perennial, 2026
Vol. 22 No. 2: 53-60
p-ISSN: 1412-7784

Available Online:
https://doi.org/10.24259/perennial.v22i2.50107
e-ISSN: 2685-6859

EFFECT OF LEGUME-BASED SUBSTITUTE FEED ON THE CONSUMPTION OF *Tetragonula biroi* BEES DURING POLLEN DEFICIENCY PERIODS

Pengaruh Pakan Subtitusi Berbasis Kacang-Kacangan Terhadap Konsumsi Lebah Tetragonula biroi pada Masa Kekurangan Pakan Serbuk Sari

Budiaman[1]✉, Baharuddin[2], Muh. Anwar[1], Andi Prastiyo[1]

[1]*Study Program of Forestry, Faculty of Forestry, Universitas Hasanuddin, Makassar, Indonesia*
[2]*Study Program of Forestry Engineering, Faculty of Forestry, Universitas Hasanuddin, Makassar, Indonesia*
✉*corresponding author: budiaman@unhas.ac.id*

ABSTRACT

Limited availability of pollen during scarcity periods becomes a major constraint that reduces feed consumption in *Tetragonula biroi*. The availability of natural pollen often decreases during the dry season, thus limiting the productivity and development of stingless bee colonies. This study aims to analyze the effect of legume-based pollen substitutes on feed consumption and *T. biroi* colony development. This study was conducted on meliponiculture in Baranti Village, Sidenreng Rappang Regency, in November 2024, using a total of 12 bee colonies with an experimental duration of 9 days. This research experiment used a Completely Randomized Design (CRD) consisting of four treatments with three replications. Feed consumption and nest weight increase were analyzed using analysis of variance (ANOVA) with significance ($p<0.05$), followed by Duncan's multiple range test (DMRT). Significant differences ($p<0.05$) in feed consumption were only found in red beans compared to other substitutes (mung beans, soybeans, and control). The feed with the highest consumption value was red bean meal (2.10±0.12 g per colony every three days), as well as nest weight gain (126±5.44 g per colony every three days). These findings suggest that legume-based pollen substitutes, particularly red bean meal, can support colony development during periods of natural pollen scarcity. Practically, this feed substitute offers an additional option for managing *T. biroi* beekeeping during seasonal pollen shortages.

Keywords: Legumes; Meliponiculture; Stingless Bees; Substitute Feed; *Tetragonula biroi*

ABSTRAK

Keterbatasan ketersediaan serbuk sari pada masa paceklik menjadi kendala utama yang menurunkan konsumsi pakan lebah *Tetragonula biroi*. Ketersediaan serbuk sari alami sering menurun selama musim kemarau, sehingga membatasi produktivitas dan perkembangan koloni lebah tanpa sengat. Penelitian ini bertujuan untuk menganalisis pengaruh pengganti serbuk sari berbasis kacang-kacangan terhadap konsumsi pakan dan perkembangan koloni *T. biroi*. Penelitian ini dilakukan pada meliponikultur di Kelurahan Baranti, Kabupaten Sidenreng Rappang, pada November 2024, menggunakan total 12 koloni lebah dengan durasi 9 hari. Percobaan penelitian ini menggunakan Rancangan Acak Lengkap (RAL) yang terdiri dari empat perlakuan dengan tiga ulangan. Konsumsi pakan dan peningkatan berat sarang dianalisis menggunakan analisis varians (ANOVA) dengan signifikansi ($p<0,05$), diikuti oleh uji rentang berganda Duncan (DMRT). Perbedaan signifikan ($p<0,05$) pada konsumsi pakan hanya terdapat pada kacang merah dibandingkan dengan pengganti lainnya (kacang hijau, kedelai, dan kontrol). Pakan yang memiliki nilai tertinggi pada tingkat konsumsi terdapat pada tepung kacang merah (2,10±0,12 g per koloni setiap tiga hari), begitupun dengan pertambahan berat sarang (126±5,44 g per koloni setiap tiga hari). Temuan ini menunjukkan bahwa pengganti serbuk sari berbasis kacang-kacangan, terutama tepung kacang merah, dapat mendukung perkembangan koloni selama periode kelangkaan serbuk sari alami. Secara praktis, substitusi pakan ini menawarkan pilihan tambahan untuk pengelolaan budidaya lebah *T. biroi* selama kekurangan serbuk sari musiman.

Kata Kunci: Kacang-Kacangan; Lebah Tanpa Sengat; Meliponikultur; Pakan Subtitusi; *Tetragonula biroi*

Submitted: 27 February 2026; Accepted: 11 May 2026

A. INTRODUCTION

Seasonal pollen scarcity represents a critical constraint in stingless bee (Meliponini) beekeeping, as colony growth and survival depend heavily on continuous pollen availability. Stingless bee (Meliponini) colonies are receiving increasing attention in managed beekeeping systems due to their role as pollination agents and their contribution to crop productivity. The maintenance of healthy colonies relies heavily on the availability of pollen as the primary source of proteins, lipids, vitamins, and minerals (Brys & Strachecka 2024) needed for larval development, royal jelly production, and overall colony strength (Razali *et al*. 2021). However, fluctuations in pollen availability, particularly during dearth periods, can directly limit brood development and weaken colony stability, highlighting a key constraint that remains insufficiently addressed in stingless bee management. In addition to its ecological function, the sustainability of stingless bee colonies is also linked to the socio-economic livelihoods of small-scale farmers (Duangphakdee *et al*. 2024), particularly in tropical regions that depend on pollination services for food security and income diversification.

In Indonesia, stingless beekeeping has increasingly developed in the last decade, supported by both local knowledge and increasing commercial demand for honey, propolis, and bee bread. In total, 52 native stingless bee species have been recorded in the country, with several already domesticated at small to medium scale levels (Trianto *et al*. 2023). However, management practices, hive design, and feeding strategies still vary widely among regions and are largely based on empirical experience rather than standardized scientific guidelines. In Sulawesi, meliponiculture is gaining momentum, especially with species such as *Tetragonula biroi*, *T. laeviceps*, and *Wallacetrigona incisa*, which are increasingly integrated into agroforestry systems and smallholder farms (Prastiyo *et al*. 2024b; Prastiyo *et al*. 2025). Despite this development, limited attention has been given to feeding management during periods of pollen scarcity, which may constrain colony productivity. Therefore, the lack of standardized and evidence-based feeding strategies represents a critical knowledge gap in supporting sustainable meliponiculture in the region.

The natural availability of pollen is not constant throughout the year. Urbanization, habitat fragmentation, and landscape alteration have reduced the diversity of flowering plants that serve as the main forage source for bees (Hulsmann *et al*. 2015). During floral dearth periods, declining pollen availability can reduce foraging activity (Requier *et al*. 2017), inhibit brood development, induce colony stress, and, in severe cases, lead to colony collapse. Several studies report that even when nectar remains available, managed bees may still experience protein deficiency due to limited floral access and intensified resource competition in degraded environments (Wojcik *et al*. 2018). In stingless bees, pollen deficit is more critical because pollen is the primary protein source stored in pollen pots and is used directly for larval development. In tropical regions such as Indonesia, including South Sulawesi, fluctuations in the availability of flowers may reduce pollen intake and directly impact colony productivity.

Efforts to address pollen shortages during dearth seasons have been widely studied in honey bees (*Apis* spp.). Protein supplements, pollen patties, and artificial diets have been shown to increase brood population, enhance colony immunity, and improve colony survival rates (Lamontagne-Drolet *et al*. 2019). However, these findings cannot be directly generalized to stingless bees due to fundamental differences in physiology, smaller body size, distinct foraging behavior, and different pollen storage systems (bee bread vs. pot-pollen). Despite the development of artificial diets for *Apis*, studies on substitute feeding in Meliponini remain limited and fragmented, with little empirical evidence on their effectiveness under tropical pollen-deficit conditions. Thus, the current limitation of existing studies lies in the lack of species-specific evaluation of substitute diets for stingless bees, highlighting a clear knowledge gap that necessitates targeted investigation.

One potential substitute feed ingredient is legume-based plant material, which is known for its high protein content, relatively complete amino acid profile, ease of cultivation, and low production cost. In honey bees, legume flours such as soybean, mung bean, or chickpea have been reported to sustain brood area and increase colony survival during periods of low natural pollen (Dagnaw *et al*. 2023). However, biological differences between honey bees (*Apis* spp.) and stingless bees (*T. biroi*), particularly in pollen storage and colony feeding behavior, require careful consideration when applying these findings. Therefore, this study focuses on evaluating the effect of legume-based pollen substitutes on feed consumption and colony performance of *T. biroi* under pollen-deficit conditions, as an initial step to assess their suitability in meliponiculture systems.

To address this gap, the present study aims to evaluate the effectiveness of legume-based substitute feeds as an alternative to natural pollen in maintaining the performance of stingless bee colonies during periods of pollen deficit. It is hypothesized that legume-based pollen substitutes may influence feed consumption and colony development compared to natural bee bread under pollen-deficit conditions. This study contributes to the limited body of knowledge on the use of locally available legume resources as pollen substitutes in meliponiculture systems, particularly under tropical conditions. By addressing the lack of standardized feeding strategies during periods of natural pollen scarcity, this research provides practical and scientific insights for improving stingless bee (*T. biroi*) management.

B. METHODS

Research Study

This research was conducted over a 9-day observation period in November 2024, in Baranti Subdistrict, Baranti District, Sidenreng Rappang Regency, South Sulawesi. Microclimate data were recorded using a digital thermo-hygrometer placed at the study site, with measurements taken three times daily, morning (07:00–09:00), afternoon (11:00 –13:00), and evening (15:00–17:00) to capture temporal variation. During the study period, the average microclimate conditions recorded were a temperature of 27.51 °C and a humidity of 78.25%, with daily temperatures ranging from 26.8 to 28.3 °C and relative humidity ranging from 75.6% to 81.2%.

Observation and Data Collection

This study used a Completely Randomized Design (CRD) with four treatments and three replications, resulting in a total of 12 colonies of *T. biroi* as experimental units (Figure 1). The sample size (12 colonies) was determined based on resource availability and preliminary experimental considerations, and provides sufficient degrees of freedom for detecting treatment effects in a controlled CRD design. The transferred colonies had the same initial weight (500 g). In addition to initial weight, colonies were standardized based on similar population size (estimated from adult bee density), presence of an active queen, and comparable brood composition (larvae and pupae proportion) to reduce biological variability. Colony age was restricted to a narrower range (1-1.5 years) to ensure more uniform colony development.

Treatment allocation to colonies was performed using a randomization procedure, in which colonies were randomly assigned to each treatment group using a random number generator to avoid selection bias. The four treatments included three formulated pollen substitute diets and one control group. The control treatment used natural bee bread powder collected from *T. biroi* colonies without any additional processing, representing the bees' natural diet. The bee bread used as control was collected from multiple colonies, homogenized, and standardized to minimize variability. The formulated diets were air-dried at a controlled temperature of 27 ± 1°C for 24 hours before feeding. Each feed type was placed in a small feeding tray inside the colony and provided every three days based on preliminary observations indicating this interval maintains feed freshness while minimizing spoilage and microbial growth.

Nest weight measurements were taken every three days at night when all bees were inside; the hive box (stup) plus bees were weighed using a calibrated analytical balance with a precision of ±0.1 g, and the initial empty hive box weight was subtracted to yield net colony weight, with the same hive boxes and procedures applied to all treatments to maintain consistency. It is acknowledged that total colony weight represents a composite measure (including brood, honey, and pollen stores), and therefore serves as an indirect indicator of colony growth rather than a partitioned biomass measurement. Feed consumption data were collected from each colony according to the assigned treatments to obtain the average consumption per replication. Feed consumption was calculated as the difference between the initial and remaining feed weight, with corrections applied for moisture loss using control samples placed outside the colonies under similar environmental conditions to account for evaporation and contamination effects.



Figure 1. A: Transfer of the bee colony into the research hive; B: Meliponiculture (research area)

Identification of Forage Sources and Flowering Calendar Development

Identification of forage plants was conducted by inventorying all flowering vegetation (Nuraeni *et al*. 2025). Identification of feed potential is based on studies of literature sources, as well as determining the flowering calendar. Each plant species was recorded based on morphological characteristics, local name, and its potential as a forage source for stingless bees, as reported in the literature, without direct observation of bee visitation. Supporting information on the

presence of nectar, pollen, or resin in each species was obtained through scientific literature and relevant botanical databases. Subsequently, a flowering calendar was developed using phenological data from tropical plant references and local sources, providing an overview of flower availability throughout the year in the study area. This calendar served to illustrate the potential availability of natural forage sources as contextual information for interpreting the consumption of artificial feed by *T. biroi* colonies.

Data Analysis

The data were analyzed using Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD) to evaluate the effect of treatments on feed consumption and hive weight gain of *T. biroi*. Prior to analysis, the assumptions of normality and homogeneity of variances were tested using the Shapiro-Wilk test. If the data did not meet ANOVA assumptions, data transformation was applied until the assumptions were satisfied. Data were analyzed based on the mean values per colony over the observation period. ANOVA was performed at a significance level of 0.05. When significant differences among treatments were detected, a post-hoc analysis using Duncan's Multiple Range Test (DMRT) was conducted to compare treatment means. The selection of DMRT was based on its sensitivity in detecting differences among means. All statistical analyses were performed using SPSS Statistics version 24. Results are presented as mean ± standard deviation. In addition, effect size was calculated to determine the magnitude of treatment effects on the observed variables.

C. RESULTS AND DISCUSSION

Substitute Feed Consumption

The average consumption of legume-based pollen substitutes (Figure 2) by stingless bee colonies the significant different ($p<0.05$) only red bean with other substitutes (mung bean, soybean, and control), with the highest intake observed in the red bean treatment (2.10±0.12 g per colony every three days), which was significantly greater than the other substitutes. In contrast, mung bean (1.77±0.06 g per colony every three days) showed the lowest consumption, while soybean (1.87±0.02 g per colony every three days) and bee bread (1.80±0.05 g per colony every three days) did not differ significantly from each other or from mung bean, as indicated by the shared letter grouping.

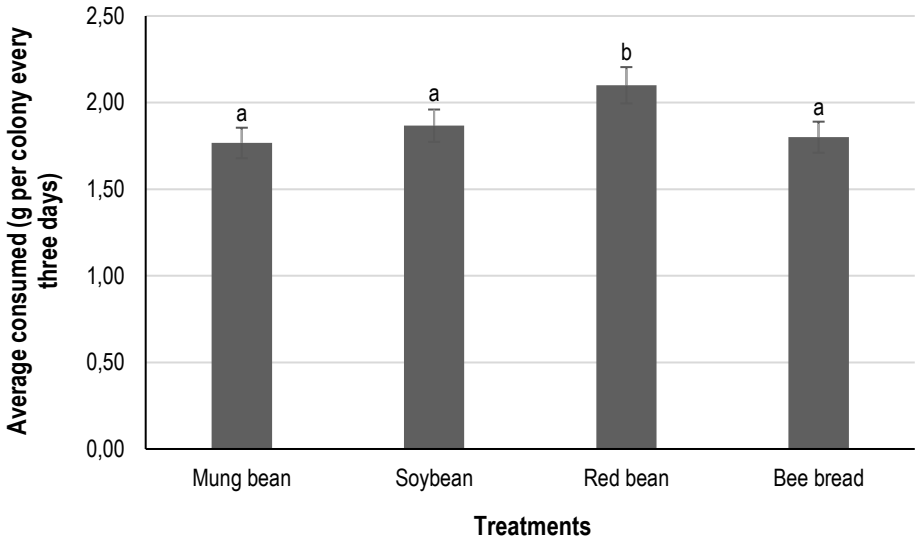


Figure 2. Consumption of legume-based pollen substitute. Significant differences in the DMRT test were only in the red bean treatment, while in the green beans, soybeans, and control, they were the same

Legume-based pollen substitutes show great potential as an alternative nutritional source for stingless bee colonies, particularly during periods of natural pollen scarcity. Legumes are known to be rich in plant-based compounds that support larval development in social bees (Vegh & Csoka 2024). Thus, legumes not only serve as a substitute for natural pollen but also act as an energy-rich feed capable of maintaining colony physiological stability during food-deficient periods. However, the observed increase in nest weight may also be influenced by additional factors such as colony age, internal colony dynamics, and foraging behavior, which were not specifically controlled in this study. These factors could interact with feed consumption and contribute to differences in colony growth responses.

Nest Weight of *T. biroi* Bee

The increase in colony nest weight (Figure 3) soybean and red bean differ significant with mung bean and bee bread ($p<0.05$), with red bean producing the highest weight gain (126±5.44 g per colony every three days), followed by soybean (113±2.92 g per colony every three days). In contrast, mung bean (85±1.57 g per colony every three days) and bee bread (78±4.11 g per colony every three days) resulted in considerably lower weight increases.

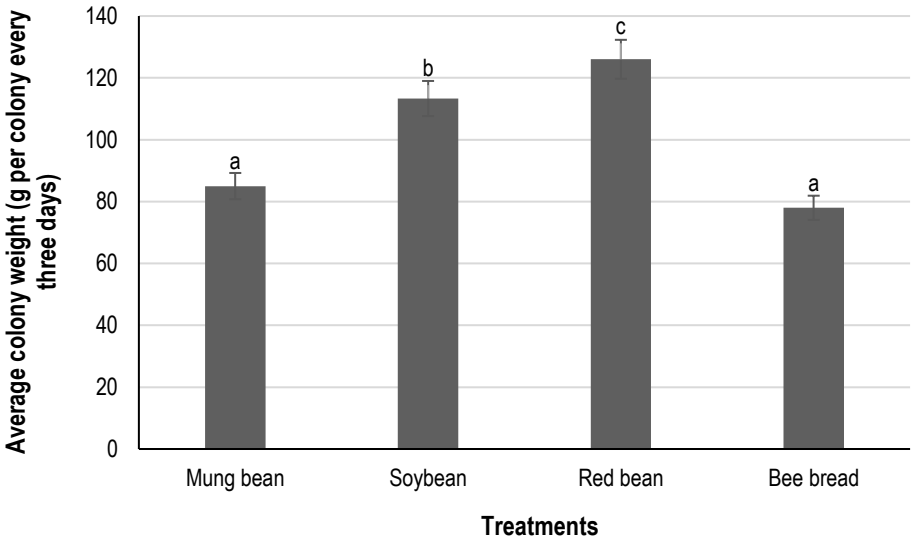


Figure 3. Increase in the weight of stingless bee colonies. The differences were found in red beans and soybeans, while the differences were the same in green beans and the control

The significant increase in nest weight among colonies fed with red bean and soybean-based substitutes. According to Lopes *et al*. (2020), increased nest mass is directly correlated with reproductive success and generational turnover within the colony. However, this study did not include a biochemical analysis of the substitute diets, such as protein levels, amino acid profiles, or lipid content, that could more clearly explain why red bean resulted in the highest consumption and nest weight gain. Comparable results have also been reported in honey bee studies, such as those by Islam *et al*. (2020), where colonies of *A. mellifera ligustica* fed with soybean-based diets exhibited higher brood area, greater colony strength, and increased honey yield compared to control groups. However, unlike *Apis* species, stingless bees possess smaller foraging ranges and distinct pollen storage mechanisms, which may influence how efficiently they utilize legume-based diets.

Potential Forage and Plant Calendar Around Meliponiculture

A total of 17 plant species from 14 botanical families were identified as potential forage sources around the meliponiculture site, providing nectar, pollen, and, in some cases, resin for stingless bee colonies (Table 2). Flowering patterns varied among species, with several key plants, such as *Muntingia calabura*, *Musa paradisiaca*, *Cocos nucifera*, *Syzygium aqueum*, *Carica papaya*, and *Theobroma cacao*, blooming throughout the year, thereby ensuring continuous forage availability to support colony development. Seasonal flowering species, including *Mangifera indica* (June-September), *Antidesma bunius* (March-May), and *Nephelium lappaceum* (October-November), provided additional peaks in floral resources that may enhance foraging activity during periods of intense blooming. Several plant species, such as *Moringa oleifera* and *Solanum melongena,* exhibited two flowering phases, functioning as supplementary forage sources during transitional seasons. In addition, pollen-dominant plants such as *Zea mays* and *Ageratum conyzoides* supported larval nutrition and colony growth during critical reproductive periods. Overall, the diversity of forage species and their staggered flowering phenology formed a continuous forage calendar, maintaining stable foraging activity and sustaining nutritional supply for stingless bee colonies within the meliponiculture landscape in Baranti Village.

The availability of flowering plants surrounding meliponiculture sites plays an essential role in ensuring the sustainability of pollen substitute application (Budiaman *et al*. 2025a). The diversity of natural forage sources, such as *M. calabura*, *M. paradisiaca*, *C. nucifera*, and *T. cacao*, offers a continuous nectar and pollen supply throughout the year, which can be complemented with legume substitutes to prevent nutritional deficiencies. This integrative strategy aligns with agroecological principles that emphasize landscape diversification to maintain colony health and honey productivity (Aldasoro *et al*. 2023, Budiaman *et al*. 2025c). Therefore, combining natural floral resources with legume-based supplements can serve as an effective solution to cope with seasonal fluctuations in pollen availability.

Table 2. Types of plants with potential for bee feed in the meliponiculture area in Baranti Village, Sidenreng Rappang Regency

Family	Species	Forages	Flowering Calendar	Sources
Anacardiaceae	*Mangifera indica*	Nectar, pollen, resin	June-September	Nuraeni *et al*. 2025
Muntingiaceae	*Muntingia calabura*	Nectar, pollen	January-December	Wahyuningsih *et al*. 2022t
Musaceae	*Musa paradisiaca*	Nectar, pollen	January-December	Erwan *et al*. 2022
Arecaceae	*Cocos nucifera*	Nectar, pollen	January-December	Nuraeni *et al*. 2025
Phyllanthaceae	*Antidesma bunius*	Nectar, pollen	March-May	Cacatian 2016
Arecaceae	*Areca catechu*	Nectar, pollen	January-December	Cacatian 2016
Myrtaceae	*Syzygium aqueum*	Nectar, pollen	January-December	Ahsani *et al*. 2023
Moringaceae	*Moringa oleifera*	Nectar, pollen	October-December; March-May	Divekar *et al*. 2023
Oxalidaceae	*Averrhoa bilimbi*	Nectar, pollen	January-March	Cacatian 2016
Annonaceae	*Annona muricata*	Nectar, pollen	March-May	Cacatian 2016
Lauraceae	*Persea americana*	Nectar, pollen	December-February	Wahyuningsih *et al*. 2022
Solanaceae	*Solanum melongena*	Pollen	March-June; September-December	Divekar *et al*. 2023
Caricaceae	*Carica papaya*	Nectar, pollen	January-December	Nuraeni *et al*. 2025
Sapindaceae	*Nephelium lappaceum*	Nectar, pollen	October-November	Wahyuningsih *et al*. 2022
Poaceae	*Zea mays*	Pollen	June-November	Arega & Gemechu 2023
Malvaceae	*Theobroma cacao*	Nectar, pollen	January-December	Cacatian 2016
Asteraceae	*Ageratum conyzoides*	Pollen	December-May	Divekar *et al*. 2023

Practically, these findings demonstrate the potential of legume pollen substitutes to improve the efficiency of stingless bee farming systems in tropical regions, where dry seasons often lead to pollen deficits. Food sources in meliponiculture areas that do not alternate flowering seasons can disrupt the development of *T. biroi* bee colonies (Budiaman *et al*. 2025b; Prastiyo *et al*. 2025b). Legume-based formulations are affordable, locally available, and easy to produce, supporting the advancement of sustainable meliponiculture (Sanchez *et al*. 2021). Their application can also reduce exploitation pressure on natural floral resources, promote ecological balance, and improve colony adaptability to climate variability (Asmawi & Ahmed 2022). Therefore, legume pollen substitutes have not only nutritional value but also ecological and economic significance for the sustainable management of stingless bee colonies in tropical ecosystems.

D. CONLUSION

Based on the research results, legume-based pollen substitutes significantly affected feed consumption and nest weight gain of *T. biroi* colonies ($p<0.05$). Red bean flour showed the highest feed consumption (2.10±0.12 g per colony per 3 days) and the greatest nest weight gain (126±5.44 g per colony per 3 days). These results indicate that red bean-based feed was more effective compared to other tested diets under the conditions of this study. The term colony performance in this study is represented by feed consumption and nest weight gain as measured parameters. Therefore, legume-based pollen substitutes, particularly red bean flour, have potential as supplementary feed during periods of pollen shortage, although their application is limited to the measured variables and experimental conditions. Seventeen plant species from 14 families have been identified as food sources for stingless bees around meliponiculture areas. This potential for food, coupled with year-round flowering patterns, ensures a continuous supply of nectar, pollen, and resin to support colony development.

ACKNOWLEDGEMENT

Thank you to the beekeepers in Baranti Village, Baranti District, Sidenreng Rappang Regency, who granted permission for the researchers to conduct research at the site. Thanks to the Faculty of Forestry, Universitas Hasanuddin.

AUTHOR'S DECLARATION

- Conflicts of Interest: None.
- We here by confirm that all the Figures and Tables in the manuscript are ours.

- No animal studies are present in the manuscript. The study focused exclusively on the stingless bee *T. biroi* under managed beekeeping conditions.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

REFERENCES

Ahsani, F.A., Bintoro, A., Asmarahman, C., & Duryat, D. (2023). Identifikasi jenis tumbuhan sumber pakan lebah madu (*Apis cerana*) di kebun lebah Desa Buana Sakti, Kecamatan Batang Hari, Lampung Timur. *Journal of People, Forest and Environment*, *3*(2), 11-20. https://doi.org/10.23960/jopfe.v3i2.7515.

Aldasoro Maya, E.M., Rodríguez Robles, U., Martínez Gutiérrez, M.L., Chan Mutul, G.A., Avilez López, T., Morales, H., Ferguson, B.G., & Mérida Rivas, J.A. (2023). Stingless bee keeping: Biocultural conservation and agroecological education. *Frontiers in Sustainable Food Systems*, 6, 1-16, https://doi.org/10.3389/fsufs.2022.1081400.

Aleixo, K.P., Menezes, C., Imperatriz-Fonseca, V.L., & da Silva, C.I. (2017). Seasonal availability of floral resources and ambient temperature shape stingless bee foraging behavior (*Scaptotrigona aff. depilis*). *Apidologie*, *48*(1), 117-127, https://doi.org/10.1007/s13592-016-0456-4.

Arega, A., & Gemechu, T. (2023). Establishing honey bee floral calendar in East Wollega Zone, Western Oromia, Ethiopia. *International Journal of Advanced Research in Biological Sciences*, *10*(6), 72-88, https://doi.org/10.22192/ijarbs.2023.10.06.007.

Asmawi, I., & Ahmed, A.O. (2022). A conspectus of strategies towards sustainable floral resources in the context of environmental and socio-economic stability. *South Asian Journal of Social Review*, *1*(2), 80-88, https://doi.org/10.57044/SAJSR.2022.1.2.2212.

Budiaman, B., Prastiyo, A., Nuraeni, S., Lestari, D.A., Wahyuni, W., Chairil, C., Arty, B., Sirimorok, N., & Nurdin, P.F. (2025a). Teknik panen ramah lingkungan dan berkelanjutan melalui tikung lebah hutan *Apis binghamii* pada kelompok tani hutan. *Surya Abdimas*, *9*(3), 392-399, https://doi.org/10.37729/abdimas.v9i3.5752.

Budiaman, B., Prastiyo, A., Sadapotto, A., Muchtar, A.A., & Nurhalizah. (2025b). Potential production and feed sources for *Tetragonula biroi* bees in meliponiculture in South Sulawesi, Indonesia. *Journal of Global Innovations in Agricultural Sciences*, *14*(1), 121-129, https://doi.org/10.22194/JGIAS/26.1684.

Budiaman, B., Rahman, A.F., Nurhayati, N., Jumadi, N.H., Khatima, K., & Prastiyo, A. (2025c). Analysis of productivity from four stingless bees (Apidae: Meliponini) and forages in urban forest, South Sulawesi, Indonesia. *Asian Journal of Forestry*, *9*(1), 144-151, https://doi.org/10.13057/asianjfor/r090115.

Brys, M.S., & Strachecka, A. (2024). The key role of amino acids in pollen quality and honey bee physiology - a review. *Molecules*, *29*(11), 1-15, https://doi.org/10.3390/molecules29112605.

Cacatian, S.B. (2016). Melliferous resources for bee forage. *Recoletos Multidisciplinary Research Journal*, *4*(1), 15-33, https://doi.org/10.32871/rmrj1604.01.02.

Dagnaw, D., Malede, E., Fekade, B., Abay, Z., Bihonegn, A., Worku, G., & Zerihun, M. (2023). Evaluation of germinated pulse flours as a dearth-period supplementary feed for honeybees. *In G. Zelleke & M. Lakew (Eds.), Proceedings of the 14th Annual Regional Conference on Completed Livestock Research Activities (Vol. I, pp. 463-469). Bahir Dar, Ethiopia: Amhara Agricultural Research Institute*.

Divekar, P.A., Singh, K., Verma, C.K., Rai, A.B., Singh, B., Yadav, S., & Karkute, S.G. (2023). Assessment of bee flora and development of a floral calendar in relation to pharmaceutical potential of honey and bee pollen in Eastern Uttar Pradesh, India. *Annals of Phytomedicine*, *12*(1), 844-855, https://doi.org/10.54085/ap.2023.12.1.55.

Duangphakdee, O., Baroga-Barbecho, J., Rod-Im, P., Attasopa, K., Locsin, A., & Cervancia, C. (2024). Economic feasibility and income security of stingless beekeeping for small-holder farmers in Southeast Asia. *Cham: Springer International Publishing*, https://doi.org/10.1007/978-3-031-43274-3_1.

Erwan, E., Purnamasari, D.K., 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.

Hrncir, M., Maia-Silva, C., Teixeira-Souza, V.H.S., & Imperatriz-Fonseca, V.L. (2019). Stingless bees and their adaptations to extreme environments. *Journal of Comparative Physiology A*, *205*(3), 415-426, https://doi.org/10.1007/s00359-019-01327-3.

Hulsmann, M., von Wehrden, H., Klein, A.M., & Leonhardt, S.D. (2015). Plant diversity and composition compensate for negative effects of urbanization on foraging bumble bees. *Apidologie*, *46*(6), 760-770, https://doi.org/10.1007/s13592-015-0366-x.

Islam, N., Mahmood, R., Sarwar, G., Ahmad, S., & Abid, S. (2020). Development of pollen substitute diets for Apis mellifera ligustica colonies and their impact on brood development and honey production. *Pakistan Journal of Agricultural Research*, *33*(2), 381-388, https://doi.org/10.17582/journal.pjar/2020/33.2.381.388.

Lamontagne-Drolet, M., Samson-Robert, O., Giovenazzo, P., & Fournier, V. (2019). The impacts of two protein supplements on commercial honey bee (*Apis mellifera* L.) colonies. *Journal of Apicultural Research*, *58*(5), 800-813, https://doi.org/10.1080/00218839.2019.1644938.

Lopes, B.D.S.C., Campbell, A.J., & Contrera, F.A.L. (2020). Queen loss changes behavior and increases longevity in a stingless bee. *Behavioral Ecology and Sociobiology*, *74*(3), 35, https://doi.org/10.1007/s00265-020-2811-8.

Maurice-Lira, J.V., Romero-Nápoles, J., Ferrera-Cerrato, R., Flores-Maldonado, K.Y., Pérez-Moreno, J., Guzmán-Franco, A.W., & González-Hernández, H. (2024). The microbiota of stingless bees: adaptive advantages in their development, feeding, and protection. *Entomologia Generalis*, 44, 779-795, https://doi.org/10.1127/entomologia/2024/2360.

Nuraeni, S., Tiwi, A.A., & Prastiyo, A. (2025). Pollen foraging preference based on floral resource distance in Tetragonula biroi. *Asian Journal of Agriculture*, *9*(2), 423-432, https://doi.org/10.13057/asianjagric/g090209.

Prastiyo, A. (2024a). Analisis morfometrik, polen dan kualitas madu lebah *Tetragonula biroi* pada ketinggian tempat yang berbeda di Sulawesi Selatan. *Thesis*, Universitas Hasanuddin Makassar.

Prastiyo, A., Rajab, M., Irfan, M., & Rahman, A. (2025). Nesting preferences and their morphometric stingless bees in Luwu Regency, South Sulawesi, Indonesia. *Perennial*, *21*(2), 71-80, https://doi.org/10.24259/perennial.v21i2.45554.

Prastiyo, A., Nuraeni, S., & Budiaman, B. (2024b). Morphology and morphometric of *Tetragonula biroi* bees at three different altitudes in South Sulawesi, Indonesia. *Biodiversitas*, *25*(5), 1993-2002, https://doi.org/10.13057/biodiv/d250516.

Razali, N.I., Razak, S.B.A., Hashim, F., Othman, N.W., & Azmi, W.A. (2021). Effect of larval food amount on in vitro rearing of Indo-Malayan stingless bee queen *Heterotrigona itama* (Hymenoptera: Apidae; Meliponini). *Sains Malaysiana*, *50*(10), 2859-2867, https://doi.org/10.17576/jsm-2021-5010-01.

Requier, F., Odoux, J.F., Henry, M., & Bretagnolle, V. (2017). The carry-over effects of pollen shortage decrease the survival of honeybee colonies in farmlands. *Journal of Applied Ecology*, *54*(4), 1161-1170, https://doi.org/10.1111/1365-2664.12836.

Sanchez, M.E.N., Cardoso Arango, J.A., & Burkart, S. (2021). Promoting forage legume-pollinator interactions: integrating crop pollination management, native beekeeping and silvopastoral systems in tropical Latin America. *Frontiers in Sustainable Food Systems*, 5, 1-10, https://doi.org/10.3389/fsufs.2021.725981.

Trianto, M., Arisuryanti, T., Purwanto, H., & Ubaidillah, R. (2023). Updated species checklist of the Indonesian stingless bees (Hymenoptera, Apidae, Apinae, Meliponini). *Journal of Tropical Biodiversity and Biotechnology*, *8*(2), 1-24, https://doi.org/10.22146/jtbb.77160.

Vegh, R., & Csoka, M. (2024). Amino acids, peptides, and proteins of pollen. *Cham: Springer International Publishing*, https://doi.org/10.1007/978-3-031-47563-4_2.

Wahyuningsih, E., Syaputra, M., Suparyana, P.K., Maya, I.P.A.T., & Lestari, A.T. (2022). Identifikasi diversitas sumber pakan lebah berbasis lahan pekarangan pada meliponikultur. *Jurnal Penelitian Hutan Tanaman*, *19*(1), 29-44, https://doi.org/10.59465/jpht.v19i1.781.

Wojcik, V.A., Morandin, L.A., Davies Adams, L., & Rourke, K.E. (2018). Floral resource competition between honey bees and wild bees: is there clear evidence and can we guide management and conservation?. *Environmental Entomology*, *47*(4), 822-833, https://doi.org/10.1093/ee/nvy077.