Jurnal Biologi Tropis

Original Research Paper

Behavioral Patterns and Honey Yield Between Native and Non-native Stingless Bees in Bali's Ecosystem

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Article History
Received : December 20th, 2024
Revised : January 05th, 2025
Accepted : January 10th, 2025

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Abstract: The coronavirus disease 2019 (COVID-19) pandemic has led to significant growth in honey bee cultivation in Bali, leading to the introduction of nonnative bee species alongside the indigenous *Tetragonula laeviceps*. However, the 75% failure rate of nonnative species cultivation between 2020 and 2023 necessitated a deeper understanding of species adaptability in the Bali ecosystem. This study specifically examined the behavioral adaptation and honey production of *Heterotrigona itama* compared with those of *Tetragonula laeviceps* in a shared cultivation environment. A seven-month comparative experimental study involving 30 bee colonies (15 *H. itama* introduced from Lampung and 15 local *T. laeviceps*) was conducted. Time series sampling was employed at three daily intervals (09:00, 13:00, and 16:00) for behavioral observations, while honey production was measured via nondestructive vacuum extraction. *H. itama* demonstrated superior honey production (516.3 ml average) to that of *T. laeviceps* (213.3 ml average). The species exhibited distinct foraging preferences, with *T. laeviceps* favoring *Jatropha integerrima* and *H. itama* preferring *Antigonon leptopus* and *Xanthostemon chrynsanthus*. Both species have developed different adaptive strategies for nectar–water content management, with *H. itama* utilizing sun exposure and *T. laeviceps* employing smaller storage pots. This study revealed successful coexistence between native and nonnative species through differentiated foraging behaviors and resource utilization strategies, with *H. itama* showing greater productive capacity attributed to morphological and behavioral differences.

Keywords: Apiculture, Bali, foraging behavior, interspecific competition., honey production, species adaptation.

Introduction

Before COVID-19 developed in Bali, honey bee cultivation was concentrated in the eastern region of Bali, especially in Karangasem Regency, which became the largest honey producer in Bali. This phenomenon is supported by the presence of native bee species that have adapted well to the local ecosystem, namely, *Tetragonula laeviceps* (*kele bali*) and *Apis cerana* (*nyawan bali*), which have become integral parts of regional biodiversity. Since the COVID-19 pandemic hit in 2020, honeybee farming activities involving various age groups have significantly increased. This dynamic created an urgency to increase honey production capacity, which in turn encouraged farmers to introduce various nonnative bee species, such as *H. itama*, *G. thoracica*, and *T. apicalis* from Lampung and Sumatra; *T. clypearis* from Lombok and Java; and *T. biroi* from Sulawesi (Ador et al., 2023; Nogueira et al., 2021; Putra et al., 2024; Sayusti et al., & Nagir, 2021).

Preliminary studies revealed that the 75% failure rate in nonnative beekeeping indicates a significant gap in the understanding of the adaptability of bee species to the Balinese ecosystem. Key challenges in the introduction of new species include intraspecific competition at foraging and colonization sites, differences in food source preferences, and the emergence of new predators in the local food chain. The high failure rate from 2020-2023 resulted in a decline in the number of farming communities caused by the lack of production targets and the degradation of colony populations.

The absence of quantitative data on honey demand in Bali creates a critical information gap in the beekeeping industry. Amidst this situation, local farmers have retained colonies of *T. laeviceps* that exhibit superior adaptability, albeit with lower honey production and longer production cycles (6–8 months). Therefore, this study was designed to explore the ecological balance in the context of coexistence between native and nonnative species, with a focus on behavioral adaptation, food resource utilization, and honey productivity. This study aimed to analyze the behavioral adaptations and honey production of the bee species *H. itama* and *T. laeviceps* within the same cultivation site. This study provides a comprehensive understanding of the optimal strategy for combining *H. itama* and *T. laeviceps* beekeeping to sustainably increase honey production in Bali.

Materials and Methods

This comparative experimental study was conducted at Royal Honey Sakah, a cultivation site specifically focused on the rearing of *Heterotrigona itama* and *Tetragonula laeviceps* bees, which are located in Banjar Sakah, Batuan Kaler Village, Sukawati District, Gianyar. The selection of this location was based on the representative environmental characteristics for the cultivation of both target bee species. The research period lasted for seven months, from November 2023 to May 2024. The purposive sampling approach with the research sample consisted of 30 bee colonies divided into two groups: 15 colonies of *H. itama* introduced from Lampung Province and 15 colonies of *T. laeviceps* locally cultivated by Royal Honey Sakah (Adnyana, 2021). To ensure uniformity of the initial conditions, all the colonies selected were in the productive phase but had not yet produced honey. The difference in the geographical origins of the two species provides an additional dimension in the analysis of adaptation to local food sources.

Observations of adaptive behavior were conducted via a time series sampling method at three predetermined time intervals: morning (09:00 WITA), afternoon (13:00 WITA), and evening (16:00 WITA). Behavioral documentation was conducted systematically via photo- and video-recording techniques to enable a detailed postobservation analysis. For the measurement of honey production, a nondestructive extraction method using a vacuum system with 12 volts of power was implemented to ensure the preservation of the honey pot structure and propolis. The data analysis adopted a qualitative descriptive approach with an emphasis on the scientific interpretation of the observed phenomena (Paulus et al., 2023). The analyzed variables included adaptive behavior patterns, characteristics of interspecies interactions, and honey productivity parameters, which were then integrated to provide a comprehensive understanding of the dynamics of the coexistence of the two species within the same cultivation site.

Results and Discussion

Behavioral adaptation analysis

In the context of apiculture ecology, the balance between colony size and available food resources is a critical factor for optimizing honey production. The essential nutritional components of Trigona bees include resin, nectar, and pollen. Observations revealed that *H. itama* from Lampung and *T. laeviceps* from Bali presented significant morphological and behavioral differentiation at the same cultivation location. On the basis of the environmental carrying capacity analysis, the Royal Honey Sakah site has the theoretical capacity to support 40-50 colonies, but this study was limited to 30 colonies for experimental purposes.

Preliminary findings indicate that one of the main factors for the failure of *H. itama* cultivation in Bali is related to the intraspecific aggression of *T. laeviceps*. Despite its relatively small body size, *T. laeviceps* exhibits strong competitive dominance, leading to its categorization as an invasive species in major honey-producing areas, such as Lampung Province, Sumatra, and Kalimantan, resulting in the implementation of population control programs. However, observations during the study period indicated the absence of aggressive interactions between the two species, which was attributed to the balanced distribution of nutritive resources relative to the population density.

The ecological equilibrium achieved in this culture system is manifested in the minimization of intraspecific and interspecific competition for food resources. However, territorial dynamics were observed, especially in the context of colonization, where *T. laeviceps* tended to take over *H. itama* nests during colony division. Management adaptations in the form of providing alternative colonization substrates, such as empty boxes and hollow coconut shells, have proven effective in mitigating territorial conflicts, as evidenced by the spontaneous colonization of coconut shells by *T. laeviceps* colonies undergoing division (**see Figure 1**). The preference for coconut shells as a habitat correlates with optimal thermoregulatory characteristics for brood development, with ideal temperatures of approximately 25°C. Hilario et al. (2003) confirmed that colony productivity significantly decreases at temperatures below 18°C or above 30°C.

Figure 1. New colonies of *T. laeviceps* formed from the rupture of the colony inside the coconut fruit.

Food sources and foraging behavior

In the context of apicultural nutrition, klanceng bees have three essential food requirements: resin, nectar, and pollen. Observations have shown that resin transforms into propolis, which has structural and defensive functions, especially in the construction of entrance funnels and sealants for colony protection from predators. After the formation of defensive structures, the resin was utilized for the construction of honey pots. This process is followed by nectar foraging by worker bees for honey production via fermentation in sealed pots. In parallel, pollen is collected and processed into bee pollen, which, together with honey, serves as a nutritional reserve during periods of food source scarcity (Sulaeman, Fikri, Kalsum, & Mahani, 2019).

Vegetation analysis at the Royal Honey Sakah research site has identified several plant species that provide a combination of resin, nectar, and pollen with both seasonal and continuous flowering patterns. The significant flora included *A. leptopus*, *J. integerrima*, *X. chrynsanthus*, *C. luisiana*, and *C. calothyrsus*, as well as various fruit species, such as *Musa* sp., Arecaceae, *M. indica*, *A. heterophyllus*, and *S. aqueum*. Observations revealed distinct foraging preferences between the two bee species.

T. laeviceps showed a dominant preference for *J. integerrima*, whereas *H. itama* frequented *A. leptopus* and *X. chrynsanthus*. Other flora species presented more generalized visitation patterns (**see figure 2**). Foraging activity exhibited a diurnal pattern with initiation at 08:00, reaching a peak at 11:00, followed by a gradual decline until the late afternoon. This finding is in line with Emil, Priawandiputra, Kahono, & Atmowidi (2024) and Wulandari, Atmowidi, & Kahono, (2017) study on *Brassica oleracea*, which confirmed that Trigona's optimal activity period was between 09.00 and 13.00.

The balance between food resource availability and colony density is a critical determinant of honey productivity. An imbalance in the system can trigger intraspecific and interspecific competition, which manifests as the degradation of the physical condition of the colony, such as discoloration of the inlet funnel to dullness or the appearance of fungal growth. Specific nutrient deficiencies result in distinct indicators: resin deficiency is visible in the deterioration of colony structure; nectar insufficiency is characterized by empty honey pots; and pollen deficit correlates with a slowdown in brood development. In addition, vegetation selection should consider potential competition with other pollinators, such as Lepidoptera and Vespidae, which can significantly affect production efficiency.

Figure 2. (A) *Jatropha integerrima* flowers are dominantly visited by *T. laeviceps*, and (B) bride tear flowers are dominantly visited by *H. itama*.

Analysis of Predator–Prey Interactions in Aquaculture Systems

These observations suggest that the adaptive sensitivity of *Klanceng* bees to predation pressure surpasses their response to food source limitations. In the context of ecological stress, both bee species presented greater resilience to nutrient limitation than to predation pressure, where excessive predation can induce a stress response, leading to reduced productivity and even colony relocation to more secure habitats.

An inventory of predators at the study site identified several vertebrate and invertebrate species, including Gekkonidae (geckos and lizards) and Araneae (spiders), which directly affected bee populations through active predation. However, the most significant threat comes from *Megachile* sp., a bee species with the morphological characteristic of a dorsal white band that exhibits kleptoparasitic behavior in the form of propolis theft from the entrance funnel structure. This behavior induces an acute stress response in the colony, which can trigger colony displacement within a relatively short period of time (Gouw & Gimenes, 2013; Kartikasari, Muslimin, & Putri, 2023; Schaller, Dalmazzo, Decarre, Caluva, & Galvani, 2024).

On the basis of the level of ecological and economic impact, *Megachile* sp. was identified as the most serious predator threat, indicating the urgency for the implementation of intensive monitoring strategies and the modification of colony locations to mitigate predation pressure (Alves-dos-Santos, Melo, & Alves-dos-Santos, 2003; H. A. P. Putra, Ni, & Ni, 2014; Roubik, 2020). These findings have significant implications for the development of predator management protocols for Klanceng beekeeping (see Figure 3).

Figure 3. *Megachile* sp. A type of propolis-stealing bee

Trigona Bee Honey Production

The honey production obtained during the study (6 months) was at its maximum, and *T. laeviceps* produced an average of 213.3 ml less than the production of *H. itama*, which was 516.3 ml (Table 1). Morphologically, *H. itama* bees are relatively large; therefore, more honey can be collected from the stomach. The low honey production of *T. laeviceps* bees is due to their smaller body size and fewer populations in the colony. On average, there were many pollen samples in the colony; thus, honey collection could not be performed because the characters in one colony are associated with the tasks of finding nectar, pollen, and resin. In addition, colonies with fern wood were used as the standard volume size for *T. laeviceps* breeding to obtain maximum results. Fern nests produce more honey than do the bamboo and coconut shells of *T. laeviceps.*

In contrast, *H. itama* predominantly adjusts the available food sources, on average, by looking for nectar rather than pollen, so that within three months, the honey collected in the pot was filled and harvested twice during the study. Bride's tear flowers are predominantly visited by *H. itama*, where daily flowering with abundant nectar produces more honey than *T. laeviceps does*. The same study was also conducted in which klanceng bees had eusocial way of life that was influenced by habitat, hot temperatures, types of vegetation (food), and pests. The type of *Klanceng* bee found in the bride's tearflower produces more dominant honey because it is not influenced by the season (Kartikasari et al., 2023). The high-water content in nectar causes different bee behavior adaptations. *T. laeviceps*, after obtaining nectar, are immediately placed in a smaller honey pot, and the process of reducing the water content continues to be carried out so that honey is obtained with a water content of 24%. In contrast to *H. itama*, the nectar collected from the stomach was warmed or basked on the leaves to reduce the water content. The size of the honey pot causes less than the maximum water content to be reduced in the colony so that each honey has a water content of 27–30% (Arena, Toppa, Martines, & Alves-dos-Santos, 2023; Arifiyanto, Nukmal, Pratami, & Lestari, 2022).

Table 1. Total honey production during the study (6 months)

Colonies	Total Honey Production		
	T. laeviceps	***H. itama***	
	Harvest I (ml)	**Harvest I (ml)**	**Harvest II (ml)**
1	300	350	210
2	150	200	200
3	245	250	255
4	125	260	245
5	275	235	200
6	225	375	350
7	325	400	375
8	160	265	255
9	190	325	300
10	210	300	250
11	200	210	180
12	165	215	190
13	230	235	200
14	190	240	210
15	210	255	210
Total Production	3200	4115	3630
Flat	**213,3**	**516,3**	

Figure 4. (Left) Honey in *T. laeviceps* nests, and (Right) honey in *H. itama* nests

Practical Implications

This study has several significant practical implications for beekeeping practices in Bali and similar regions. The documented success in managing both species in a shared environment provides a viable model for mixed-species cultivation, potentially increasing overall honey production while maintaining an ecological balance. The identification of specific floral preferences for each species enables effective garden planning and resource management in apiaries. The findings regarding nectar water content management strategies can inform the development of optimized honey harvesting schedules and storage techniques. Furthermore, an understanding of predator dynamics, particularly threats from *Megachile* sp., suggests the need for targeted protective measures in commercial beekeeping operations.

Limitations

This study had several notable limitations that should be considered when interpreting the findings. This research was conducted at a single location in Bali, potentially limiting the generalizability of the results across different ecological zones. The seven-month study period may not have fully captured the seasonal variations in bee behavior and honey production patterns, particularly given Bali's distinct wet and dry seasons. The sample size of 30 colonies, which is sufficient for preliminary observations, may not represent the full range of behavioral variation within each species. Additionally, this study focused primarily on behavioral adaptation and honey production, leaving aspects such as genetic adaptation, disease resistance, and long-term colony sustainability. The study also did not account for potential variations in nectar quality and composition across different floral sources, which could influence honey production and quality.

Conclusion

The two species (*H. itama* and *T. laeviceps*) at Royal Honey Sakah presented different adaptive strategies for utilizing available resources. Differentiation in foraging behavior was observed through differences in floral preferences, where *T. laeviceps* showed a dominant affinity for *Jatropha integerrima*, whereas *H. itama* more frequently exploited *Antigon leptopus* and *Xanthostemon chrynsanthus*. This temporal stratification in foraging activity contributes to the minimization of interspecific competition, allowing stable coexistence between the two species. In terms of productivity, *H. itama* demonstrated greater honey production capacity than did T. laeviceps, which can be attributed to morphological and behavioral differentiation. This significant difference is also influenced by adaptive strategies in nectar moisture management, where *H. itama* developed thermoregulatory behavior through sunlight exposure, whereas *T. laeviceps* relied on evaporation processes in smaller storage pots. Future research is needed to explore the dynamics of interactions between H. itama and T. laeviceps in the context of more extensive seasonal variations, especially those related to fluctuations in the availability of food sources and adaptive responses of both species, the development of optimal hive designs for each species, and further tests related to the quality of honey produced.

Acknowledgments

We would like to thank PT Mega Science Indonesia for assisting in proofreading and translating the manuscript so that it is suitable for publication.

Referensi

Adnyana, I. M. D. M. (2021). Populasi dan Sampel. In M. Darwin (Ed.), *Metode Penelitian Pendekatan Kuantitatif* (1st ed., pp. 103–116). Bandung: CV. Media Sains Indonesia.

Ador, K., Gobilik, J., & Benedick, S. (2023). Phylogenetic and Morphological Characteristics Reveal Cryptic Speciation in Stingless Bee, Tetragonula laeviceps s.l. Smith 1857 (Hymenoptera; Meliponinae). *Insects*, *14*(5), 438. doi: 10.3390/insects14050438

Alves-dos-Santos, I., Melo, G. A. R., & Alves-dos-Santos, I. (2003). Apoidea Neotropica: Homenagem aos 90 Anos de Jesus Santiago Moure. *Criciúma, SC: Editora UNESC.*

Arena, M. V. N., Toppa, R. H., Martines, M., & Alves-dos-Santos, I. (2023). Release experiments as an indicator of flying activities of stingless bees in urban areas. *Frontiers in Sustainable Cities*, *4*, 1103835. doi: 10.3389/frsc.2022.1103835

Arifiyanto, A., Nukmal, N., Pratami, G. D., & Lestari, E. R. (2022). Trigona Honey Bee Cultivation as a Sustainable Agricultural Alternative in Bandarsari Village, Padangratu District, Central Lampung Regency. *Abdimas Talenta: Jurnal Pengabdian Kepada Masyarakat*, *7*(2), 811–818. doi: 10.32734/abdimastalenta.v7i2.8918

Emil, M. F. P., Priawandiputra, W., Kahono, S., & Atmowidi, T. (2024). Diversity and nesting ecology of Indo-Malayan stingless bees (Hymenoptera: Apidae) in Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, *25*(10), d251023. doi: 10.13057/biodiv/d251023

Gouw, M. S., & Gimenes, M. (2013). Differences of the Daily Flight Activity Rhythm in two Neotropical Stingless Bees (Hymenoptera, Apidae). *Sociobiology*, *60*(2), 183–189. doi: 10.13102/sociobiology.v60i2.183-189

Kartikasari, D., Muslimin, M. A. I. I., & Putri, D. F. A. (2023). Budidaya lebah klanceng di peternakan azka trigona Desa Jiwut, Kabupaten Blitar. *Radikula : Jurnal Ilmu Pertanian*, *2*(2), 100–112. Retrieved from https://scholar.google.com/scholar?start=60&q=manfaat+madu+bagi+kesehatan&hl=id&as_sdt=0,5#d=gs_qabs&t=1711269306486&u=%23p%3DL_4QBNg0e6AJ

Nogueira, D. S., Rasmussen, C., & Oliveira, M. L. (2021). A New Species of Tetragona Lepeletier & Serville, 1828 from the "truncata group" and New Distribution Records of T. truncata Moure, 1971 (Hymenoptera: Apidae). *Neotropical Entomology*, *50*(1), 68–77. doi: 10.1007/s13744-020-00822-6

Paulus, A. Y., Sulaeman, Mayasari, A. C., Ayu, J. D., Musniati, N., Sari, M. P., … Adnyana, I. M. D. M. (2023). *Biostatistika Epidemiologi* (1st ed.; H. Akbar, Ed.). Bandung: CV. Media Sains Indonesia.

Putra, H. A. P., Ni, W. L., & Ni, S. M. (2014). Structure and production of stingless bee Trigona spp. in cylindrical and round nest types. *Jurnal Biologi*, *18*(2), 60–64.

Putra, R. E., Novitasari, N., Rosmiati, M., Husna, I. Z., Setiyarni, E., & Kinasih, I. (2024). Efisiensi Penyerbukan Tetragonula laeviceps Pada Budi Daya Tumpang Sari Tomat Dan Mentimun Di Greenhouse. *Al-Kauniyah: Jurnal Biologi*, *17*(2), 293–302. doi: 10.15408/kauniyah.v17i2.29769

Roubik, D. W. (2020). Nest Structure: Stingless Bees. In *Encyclopedia of Social Insects* (1st ed., pp. 1–6). Cham: Springer International Publishing. doi: 10.1007/978-3-319-90306-4_147-1

Sayusti, T., Raffiudin, R., Kahono, S., & Nagir, T. (2021). Stingless bees (Hymenoptera: Apidae) in South and West Sulawesi, Indonesia: morphology, nest structure, and molecular characteristics. *Journal of Apicultural Research*, *60*(1), 143–156. doi: 10.1080/00218839.2020.1816272

Schaller, A., Dalmazzo, M., Decarre, J., Caluva, E. C., & Galvani, G. L. (2024). Flight activity behavior of stingless bee (Apidae: Meliponini) in an urban park outside their natural range: the influence of hive temperature. *Journal of Apicultural Research*, 1–12. doi: 10.1080/00218839.2024.2380935

Sulaeman, A., Fikri, A. M., Kalsum, N., & Mahani, M. (2019). Trigona Propolis and Its Potency for Health and Healing Process. In *The Role of Functional Food Security in Global Health* (pp. 425–448). Netherlands: Elsevier B.V. doi: 10.1016/B978-0-12-813148-0.00025-6

Wulandari, A. P., Atmowidi, T., & Kahono, D. S. (2017). The Role of Trigona laeviceps (Hymenoptera: Apidae) in Seed Production of Kale (Brassica oleracea var. alboglabra). *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *45*(2), 196. doi: 10.24831/jai.v45i2.13236