Productivity of Introduced *Trigona* Bees in The Green Open Space of Universitas Sumatera Utara

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Abstract.
Trigona spp. is one of the social insects that can be cultivated in open spaces, urban areas, or through a practice known as meliponiculture. Introduced colonies rely on surrounding vegetation for nectar, pollen, and resin, which are essential for supporting the queen, colony, and larvae to maintain overall colony health. Green open spaces are often underutilized, serving primarily as areas for human activities. This study aims to evaluate the success of introducing Trigona spp. bees and assess the potential of the green open space at the Universitas Sumatera Utara campus as a small-scale honey production industry. The results indicated that foraging activities continued despite the rainy season (October, November) during the two-month observation period. A total of 18 ornamental and shade plants were identified as nectar and pollen sources, with two key species namely Mangosteen (Garcinia mangostana: Clusiaceae) and Mango (Mangifera indica: Anacardiaceae), serving multifunctional roles in colony establishment. Productivity, as measured by the number of nest structures such as brood cells, pollen pots, and honey pots, reached 284, 46, and 85 units, respectively, with an average honey volume of 42.6 mL. Stepwise regression analysis yielded an equation indicating that total honey production was related to the combined activity of outgoing bees and incoming bees carrying pollen. These findings support the integration of Trigona spp. colonies into campus green spaces as a viable honey production industry, aligning with the university's vision to create lush environments for academic and research activities.
Keywords: *Foraging activity, honey, melliponiculture, pollen, stingless bee and urban area.*

I. INTRODUCTION

Bees are a diverse group of insects with considerable ecological and economic importance. Several bee species produce honey, a complex natural product widely valued for its nutritional and potential health-promoting properties [1]. Bees belong to the order Hymenoptera, a name referring to their membranous wings. Although many bee species are solitary, stingless bees belonging to the tribe Meliponini are highly social insects that live in permanent colonies. In Indonesia, stingless bees are known by various regional names, including *lanceng*, *klanceng*, *kelulut*, and *galo-galo*. Many Indonesian stingless bee species are relatively small and dark-colored compared with honey bees of the genus *Apis*. Colony size and organization may vary according to species, colony age, nest capacity, resource availability, and environmental conditions, including temperature, relative humidity, and elevation. These factors can influence foraging performance, colony productivity, and pollination activity [2].

Within Universitas Sumatera Utara, FMIPA Park (approximately 60 × 40 m) functions as a campus green open space that supports biodiversity, education, and ecological research. Its vegetation provides potential nectar, pollen, and resin resources for stingless bees, whose floral visits may facilitate pollen transfer and support plant reproduction [3]. Their activity can be evaluated at the nest entrance by recording workers entering and leaving the colony, including individuals carrying visible pollen or resin loads, because these movements reflect foraging and other colony activities, such as nest guarding and waste removal [4].

As a green open space within Universitas Sumatera Utara, FMIPA Park provides flowering vegetation and localized environmental conditions that may support stingless bee foraging. Urban parks and gardens can sustain pollinators by providing floral and nesting resources within developed landscapes [5]. Nest-entrance activity can be assessed by counting workers entering and leaving the colony, including individuals carrying visible pollen or resin loads [6, 7]. Foraging activity generally increases during the morning and declines later in the day, although its pattern varies with species, resource availability, and colony condition [8, 9]. Air temperature, relative humidity, light intensity, wind speed, and rainfall may also influence flight frequency, with rainfall commonly restricting bee movement and access to floral resources. Therefore, this study aimed to characterize the daily foraging activity of stingless bees in FMIPA Park by recording nest-entry and nest-exit frequencies and examining their relationships with local environmental factors.

II. METHODS

The study was conducted in the green zones of the Universitas Sumatera Utara campus, located among the gardens of the Faculty of Mathematics and Natural Sciences, North Sumatra, Indonesia (**Fig. 1**). The research was initiated in October 2023, with the introduction of five colonies of *Trigona* sp. to allow for an acclimation period. A plant inventory was conducted using an exploratory method, recording the plant species within a 100-meter radius of the colony sites and identified by plant taxonomists in Herbarium Medanense, North Sumatra, Indonesia. Descriptive analysis was performed on the collected data to assess the availability of bee forage types (nectar, pollen, and resin) produced by the surrounding plants. Observations of bee activity were conducted on the five colonies, located at a height of 3.5 meters above ground, along the connecting corridor between building units 4 and 5. Bee activities, including leaving the nest, entering the nest without carrying, entering the nest carrying pollen, and entering the nest carrying resin, were recorded at 10-minute intervals from 08:00 WIB to 16:00 WIB using a hand tally counter.

Fig. 1. Location of green open space area, FMIPA Park in the campus of Universitas Sumatera Utara, North Sumatra.

Data were documented on a tally sheet, compiled monthly, and observed over a two-month period (November–December 2023). Local environmental variables, such as minimum-maximum temperature (°C), relative humidity (%), sunlight duration (hours), and rainfall (mm), were measured using standardized instruments and cross-verified with data from the Regional Office of Meteorology, Climatology, and Geophysics, Region I, North Sumatra, Indonesia. The data were analyzed and presented as mean and SEM, with graphical representations generated using GraphPad Prism version 8.0.2. Pearson's correlation coefficient matrix and stepwise multiple regression analysis were conducted using Minitab version 19.0.

III. RESULT AND DISCUSSION

The environmental conditions in the green open space of the USU campus were characterized by temperatures ranging from 24.2 ± 0.53°C to 31.6 ± 1.72°C, with an average temperature of 28.6 ± 1.20°C. The relative humidity was recorded at 81 ± 5%, with an average sunlight duration of 2.5 ± 2 hours per day, and total monthly rainfall ranging between 187 mm and 287 mm during the 4-week observation period. The dynamics of environmental conditions are depicted in **Fig. 2**. The observation period was conducted during wet or monsoon season, marked by high rainfall and diminished sunlight.

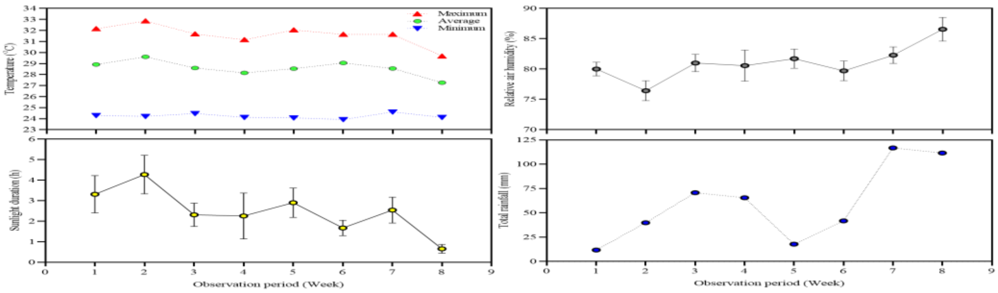

Fig. 2. Weekly basis of four environmental conditions (air temperature, rainfall, relative humidity, and sunlight duration) in the green open space of USU campus. Note: Error bars represent standard error of mean (N = 7 days).

According to the Köppen climate classification, a wet season month in tropical climates is defined as one in which the average precipitation exceeds 60 mm, a condition that occurred during the course of this study. The wet season promotes lush vegetation growth, creating a favorable environment for pollinators, such as stingless bees. However, the reduced sunlight duration and frequent rainfall may temporarily limit the availability and accessibility of floral resources, presenting challenges for bee foraging. Temperature and humidity are factors that determine the quality of nectar collected by bee foragers. High temperatures and low humidity lead to nectar with high sugar content and low moisture, while low temperatures and high humidity result in nectar with low sugar content and high moisture [10]. Temperature and solar radiation positively altered foraging activity, whereas relative humidity and dew point posed negative effects [11]. A negative correlation was observed between minimum temperature and foraging activity, while relative humidity showed mixed effects on foraging behavior [12]. Therefore, the presence of perennial blooming plant species and ongoing vegetation growth throughout this season ensures a continuous and reliable supply of diverse floral resources, thereby supporting the long-term foraging needs of pollinators, which will be monitored in the current observations. The foraging behavior of *Trigona* bees demonstrated a versatility to a wide range of plant species across multiple families in the green open space area. **Table 1** provides a list of forage plants utilized by *Trigona* bees for nectar, pollen, and resin collection around their colonies.

Table 1. Species list of forage plants visited by *Trigona* bees in the green open space of USU campus.

Forage species	**Family**	**Plant components ('+' = documented)**		
		Nectar	**Pollen**	**Resin**
Allamanda cathartica L.	Apocynaceae	+		
Antigonon leptopus Hook. & Arn.	Polygonaceae	+	+	
Artocarpus heterophyllus Lam.	Moraceae		+	+
Bougainvillea glabra Choisy	Nyctaginaceae		+	
Cocos nucifera L.	Arecaceae	+	+	
Coleus scutellarioides (L.) Benth.	Lamiaceae		+	
Dimocarpus longan Lour.	Sapindaceae	+	+	
Durio zibethinus L.	Malvaceae	+	+	
Garcinia mangostana L.	Clusiaceae	+	+	+
Ixora chinensis Lam.	Rubiaceae	+		
Mangifera indica L.	Anacardiaceae	+	+	+
Mimosa pudica L.	Fabaceae	+	+	
Ricinus communis L.	Euphorbiaceae	+	+	
Samanea saman (Jacq.) Merr.	Fabaceae	+		
Swietenia mahagoni (L.) Jacq.	Meliaceae	+		
Syzygium cumini (L.) Skeels	Myrtaceae	+	+	
Syzygium myrtifolium Walp.	Myrtaceae	+	+	
Tectona grandis L.f.	Lamiaceae	+	+	

Mangosteen (*Garcinia mangostana*: *Clusiaceae*) and mango (*Mangifera indica*: *Anacardiaceae*), serve as critical sources for all three components, i.e. nectar, pollen, and resin, demonstrating their pivotal role in supporting *Trigona* colonies. Mangosteen (*G. mangostana*) was a primary feed or forage plant for stingless bees, which served as the main pollinators in Malaysia, as documented through field surveys and metabarcoding [13]. At the local level in Dairi Regency, North Sumatra, mangosteen has also been noted as a forage plant for the development of melliponiculture to produce honey as part of the utilization of non-timber forest products [14]. Mango (*M. indica*) was documented as one of the most attractive plants for stingless bee species in Tropical Mixed Fruit Orchards, Thailand [15]. This plant species has also been reported as a source of nectar and resin for *Tetragonula biroi*, *Tetragonula clypearis*, and *Tetragonula sapiens* in Lombok, West Nusa Tenggara, Indonesia [16]. In West Bengal, India, mango was also recorded as one of the forage plants, although less frequently visited by stingless bees, with peak visitation occurring during the morning and noon [17]. *Cocos nucifera* (*Arecaceae*) and *Durio zibethinus* (*Malvaceae*) provide both nectar and pollen to the dietary needs of *Trigona*. In the morning, *Cocos nucifera* was one of the primary contributors of pollen, owing to the early blooming of its flowers and flowering throughout the year [17, 18].

Coconut (*C. nucifera*) also showed the highest dominance in the pollen spectra of honey samples from North and Central Lombok [19]. Coconut is a beneficial plant species that serves as a valuable source of nectar and pollen, supporting the sustainable production of honey, pollen, and bee bread [20, 21]. Resin collection is evident in species like *Artocarpus heterophyllus* (*Moraceae*) and *Mangifera indica* (*Anacardiaceae*). The dependence on resin-rich plants is crucial for supporting nest construction, providing antimicrobial properties to nest materials, and enhancing defense mechanisms against predators and parasites [22]. Both nectar and pollen were collected from a wide array of plants. *Trigona* bees often specialize in collecting either pollen or nectar, rarely gathering large amounts of both during a single foraging trip. When collecting pollen, workers transport highly concentrated nectar from the nest, which may facilitate pollen adhesion and provide energy during foraging [23].

Pollen is gathered by foragers from floral resources and is used to produce pollen reserves and bee bread, serving as the primary protein source for the colony [24]. Species with yellow and white flowers were the most frequently visited by stingless bees within the green open spaces of the USU campus. This observation is consistent with findings from a study on *Trigona iridipennis* in West Bengal, India [25]. It should be noted that the introduction of *Trigona* bees occurred after the establishment of green open spaces and urban reforestation efforts, which were not specifically designed to support stingless bees. *Trigona* bees demonstrated consistent flower visits, with 77% of repeated visits directed toward the same flower type, particularly when the flowers differed in color or odor [26]. This behavior suggests the adaptability of *Trigona* bees, allowing them to familiarize with local plants, prefer year-round bloomers, and adjust to varying floral abundances. Their ability to utilize multiple resources from a single species minimizes energy expenditure and boosts colony productivity, especially in resource-limited settings.

From November to December, the range of outgoing bee activity was between 1,350 and 8,638 bees, incoming activity ranged from 1,078 to 4,656 bees, pollen-carrying foragers ranged from 89 to 1,130 bees, and resin-carrying foragers ranged from 215 to 910 bees. When converted, the average foraging activity per 10 minutes was as follows: 4–16 bees for outgoing, 6–15 bees for incoming, and 1–2 bees for pollen- and resin-carrying foragers. The average activity of each colony from five *Trigona* nests and their dynamics are shown in **Fig. 3**. The productivity of the five *Trigona* nests was assessed two months after observing foraging behavior, resulting in the formation of distinctive structures within the more complex colony (**Fig. 4**). Brood cells, pollen pots, and honey pots are key components of the nesting structure and functionality of stingless bees, particularly in the context of meliponiculture. Brood cells are specialized structures within the nest where the queen lays eggs and the larvae develop. These cells are typically constructed from a mixture of wax and resin, offering a protective environment for the developing bees [27].

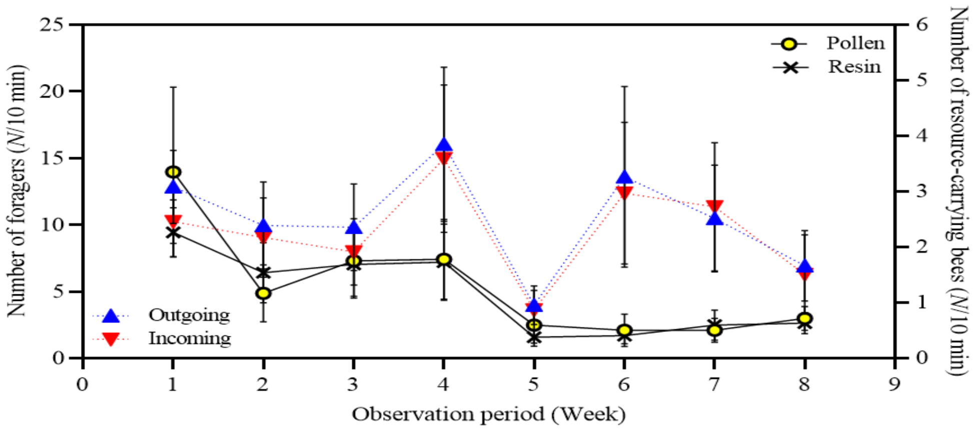

Fig. 3. Weekly basis of average foraging activity by *Trigona* bees in the green open space of USU campus. Note: Error bars represent standard error of mean (N = 5 hives).

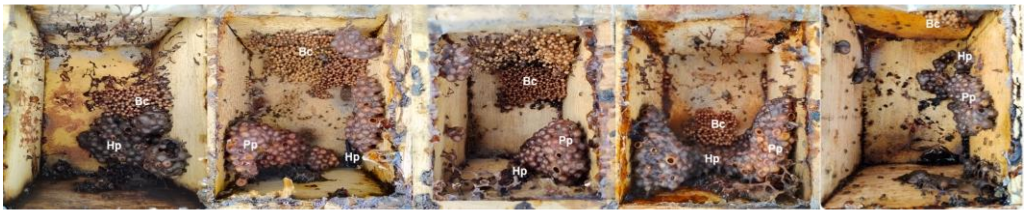

Fig. 4. Colonies of *Trigona* bees after observation period (8th week) showing the components of the nests: Bc = Brood cells, Hp = Honey pots. Pp = Pollen pots.

Pollen pots are storage structures used by stingless bees to store pollen, a vital protein source for the colony. These pots, usually made from cerumen (a mixture of wax and plant resins), are often located adjacent to brood cells within the nest [28]. Honey pots are storage vessels where stingless bees store honey, often referred to as "pot-honey" due to their unique storage method, in contrast to the traditional honeycomb structure seen in other bee species [29]. Honey pots not only serve as a food reserve for the colony but also contribute to the colony's overall productivity and economic value in meliponiculture [30]. The productivity resulting from the introduction of *Trigona* bees into open green spaces, in terms of the number of nest structures and the final honey yield, is shown in **Table 2**. The total honey produced, calculated by multiplying the volume of average honey per pot, is the main parameter for evaluating productivity. Through the introduced five nests (hives), the results were considered successful at the outset, as honey was still harvested despite the observations being conducted during the rainy season.

Table 2. Productivity of introduced *Trigona* bees (N = 5 hives) after two months in the green open space of USU campus. Average honey volume per pot was taken at least 10 pots from each hive. Note: Min. = Minimum, Max. = Maximum, Avr. = Average, SEM = Standard error of mean.

Parameters	Min.	Max.	Avr.	SEM
Brood cells (*n*)	60	625	284	108.32
Honey pots (*n*)	34	61	46	4.48
Pollen pots (*n*)	14	180	85	30.28
Honey/pot (mL)	0.78	1.20	0.91	0.08
Total honey/hive (mL)	30.6	73.2	42.6	7.80

Table 3. Pearson's correlation coefficient (r) of between productivity and foraging activities of *Trigona* bees in the green open space of USU campus. Note: Total-OUT = Total of outgoing bees over two months, Total-IN = Total of incoming bees over two months, Total-POLLEN = Total of incoming pollen-carrying bees over two months, Total-RESIN = Total of incoming resin-carrying bees over two months. Data for foraging activities were log-transformed prior to analysis.

	Brood cells	**Honey pots**	**Pollen pots**	**Honey volume**	**Total-OUT**	**Total-IN**	**Total-POLLEN**	**Total-RESIN**
Brood cells								
Honey pots	0.368							
Pollen pots	0.575	0.784						
Honey volume	0.048	0.929	0.705					
Total-OUT	-0.397	-0.704	-0.641	-0.711				
Total-IN	-0.791	-0.045	-0.576	0.127	0.311			
Total-POLLEN	0.030	0.434	0.517	0.611	-0.864	-0.247		
Total-RESIN	0.633	-0.387	-0.255	-0.685	0.222	-0.463	-0.491	

Affandi et al. [31] reported that the average honey production of *Heterotrigona itama* bees was 187.06 mL/hive/month, while *Geniotrigona thoracica* bees produced an average of 97.03 mL/hive/month, both of which significantly exceed the results of this study. Honey production among three stingless bee species (*T. biroi*, *T. clypearis*, and *T. sapiens*) was reported to range from 27.6 to 59.75 mL over a two-month period [16]. In *T. laeviceps* meliponiculture at the Faculty of Animal Science, UGM (Yogyakarta, Indonesia), honey production was found to range from 60 to 263 mL per colony (79.2 to 328 g), with an average of 176 mL

(223 g) after four months [10]. A honey yield of 49.20 to 66.60 mL per colony after two months was also reported for *Tetragonula* sp. in Gunungkidul (Yogyakarta) [32]. Moderate-to-strong correlations were observed between nest components and foraging activities (**Table 3**).

Table 4. Summary of multiple linear regression analysis assessing the relationship between honey production and selected foraging variables of *Trigona* bees in the green open space of USU Campus.

Term	**Coef.**	**SE Coef.**	***T***	***P***	**VIF**
Total-OUT	0.00756	0.00333	2.27	0.108	1.03
Total-POLLEN	0.00627	0.00180	3.48	0.040	1.03
ANOVA	**Df**	**Adj. SS**	**Adj. MS**	***F***	***P***
Regression	2	8977	4488.3	10.40	0.045
Total-OUT	1	2222	2221.6	5.15	0.108
Total-POLLEN	1	5236	5236.4	12.13	0.040
Error	3	1295	431.6		
Total	5	10271			

Brood cells showed a positive relationship with pollen pots (r = 0.575) and honey pots (r = 0.368), while honey pots and pollen pots were strongly correlated (r = 0.784). In terms of foraging, the number of outgoing bees (Total-OUT) negatively correlated with nest components, especially honey pots (r = -0.704) and pollen pots (r = -0.641), suggesting that increased foraging activity corresponds to fewer resources stored. Incoming bees (Total-IN) showed a moderate positive correlation with honey volume (r = 0.311). Pollen foragers (Total-POLLEN) had moderate positive correlations with pollen pots (r = 0.517) and honey pots (r = 0.434), while resin foragers (Total-RESIN) exhibited a strong negative correlation with honey pots (r = -0.387) and pollen pots (r = -0.255). The relationship between total honey production by *Trigona* bees and four foraging activities was evaluated using stepwise multiple regression analysis (**Table 4**). Two predictors were only included in the model: the total number of outgoing foragers (Total-OUT) and the total number of pollen-carrying incoming foragers (Total-POLLEN). The model equation shows that for every unit increase in Total-OUT, honey production increases by 0.00756 units, while every unit increase in Total-POLLEN adds 0.00627 units to honey production (**Eq. 1**).

$$Total\ honey\ (mL) = (0.00756 \times Total\ OUT) + (0.00627 \times Total\ POLLEN) \qquad \textbf{Eq. 1}$$

The model explains 87.39% of the variability in honey production (R^2), with an adjusted R^2 of 78.99%, reflecting a strong fit. The predictive capability of the model is moderate, as indicated by a predicted R^2 of 52.35%. Table 4 presents the coefficients of the regression analysis, revealing that the effect of Total-OUT on honey production was positive but not statistically significant. In contrast, Total-POLLEN demonstrated a significant positive relationship with honey production. The overall regression model was found to be statistically significant (P = 0.045, F = 10.40), indicating that the predictors collectively account for a significant portion of the variability in honey production. When examined individually, Total-OUT variable was not statistical significant (P = 0.108), whereas Total-POLLEN emerged as a significant predictor (P = 0.040). Collinearity diagnostics showed no issues, with Variance Inflation Factor (VIF) values of 1.03 for both predictors. Regression analysis and its variants have been utilized to develop models that predict the relationships between variables in melliponiculture, particularly concerning foraging activity, productivity, and environmental effects. In this study, stepwise multiple linear regression analysis was employed to derive an equation, and the results were found to be significant. Multiple regression equations were used to predict the number of incoming and outgoing *T. iridipennis* bees based on the relationship among five environmental variables, i.e. maximum and minimum temperature, relative humidity, rainfall, and wind velocity, with an R^2 ranging from 0.42 to 0.83 [12]. However, it is important to note that the data collected in this study were gathered during the rainy season. To develop a more robust model, further comparisons with a larger sample size and observations during other months, including the dry season, are necessary.

IV. CONCLUSION

During the two-month rainy-season observation, the five introduced stingless bee colonies remained active and used at least 18 plant species as potential nectar, pollen, or resin sources within FMIPA Park. The colonies produced an average of 284 brood cells, 46 honey pots, 85 pollen pots, and 42.6 mL of honey per hive. These findings indicate that the campus green open space can provide resources that support short-term colony establishment and limited honey production under wet-season conditions. However, they are insufficient to establish year-round productivity or commercial feasibility. The positive association between pollen-carrying return activity and honey production should also be interpreted cautiously because it was derived from a small number of colonies. Future studies should include more colonies, confirmed species identification, repeated observations across wet and dry seasons, measurements of floral abundance and phenology, and independent validation of the productivity model.

V. ACKNOWLEDGMENTS

This project was fully-funded through TALENTA research grant under scheme "Penelitian Terapan 2023" by Universitas Sumatera Utara with the contract number: No. 215/UN5.2.3.1/PPM/KP-TALENTA/R/2023.

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