FORAGING ACTIVITIES OF STINGLESS BEES, *Geniotrigona thoracica* AND *Heterotrigona itama* (APIDAE: MELIPONINI) IN RELATION TO WET AND DRY SEASONS IN SELANGOR, MALAYSIA

Wan Nur Asiah Wan Mohd Adnan[1], Syari Jamian[2*], Nur Azura Adam[2], Mohamad Shukri Tan Shilan[2], Siti Asma Samsudin[2] & Chong Leong Puan[1,3]
[1]Faculty of Forestry and Environment,
Universiti Putra Malaysia,
43400 Serdang, Selangor, Malaysia.
[2]Department of Plant Protection,
Faculty of Agriculture,
Universiti Putra Malaysia,
43400 Serdang, Selangor, Malaysia.
[3]Institute of Tropical Forestry and Forest Products (INTROP),
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.
Corresponding author: syari@upm.edu.my*

ABSTRACT

This study reports the influence of wet and dry seasons on foraging activities of *Geniotrigona thoracica* and *Heterotrigona itama* in tropical climate of Malaysia. Foraging activities of the two bee species were recorded monthly from September 2014 to August 2015. Two methods of monitoring and counting the activities of the two species of stingless bees, (1) bees hovering in and bees hovering out (FIFO), and (2) bees collecting the pollen and bees bringing the nectar to their nest were recorded using a hand manual counter about 1 m^2 from the nest entrance of each species studied. This study showed the wet season recorded the highest foraging activities for both species, with *G. thoracica* and *H. itama* incurred the highest number of flights in (FI) in January 2015 (FI *G. thoracica* = 12,303 individuals: FI *H. itama* = 12,011 individuals). This study also showed the lowest foraging activities for both species in dry season with the lowest number of flights in (FI) recorded for *G. thoracica* observed in September 2014 (4880 individuals) while *H. itama* showed in May 2015 (2168 individuals). Thus, the foraging activities of these bees might be affected by other environmental aspects such as the composition of flora species surrounding the stingless bee meliponiculture.

Keywords: Wet season, dry season, tropical climate, stingless bee, *Geniotrigona thoracica*, *Heterotrigona itama*

ABSTRAK

Kajian ini melaporkan pengaruh musim hujan dan kemarau terhadap aktiviti mencari makan *Geniotrigona thoracica* dan *Heterotrigona itama* di iklim tropika seperti Malaysia. Kelakuan lebah kelulut mencari makanan dipantau secara bulanan dari September 2014 sehingga Ogos

2015. Dua kaedah pemantauan dengan menghitung aktiviti keluar masuk (FIFO) dua spesies lebah kelulut menggunakan kaunter manual tangan pada jarak kira-kira 1 m^2 dari pintu masuk sarang setiap spesies yang dikaji. Kajian ini menunjukkan musim hujan mencatatkan aktiviti mencari makan tertinggi untuk kedua-dua spesies dengan *G. thoracica* dan *H. itama* menunjukkan jumlah penerbangan tertinggi di (FI) pada bulan Januari 2015 (FI *G. thoracica* = 12,303 individu: FI *H. itama* = 12,011 individu). Kajian ini juga menunjukkan aktiviti mencari makan untuk kedua-dua spesies pada musim kemarau dengan jumlah penerbangan terendah dicatat bagi (FI) untuk *G. thoracica* pada bulan September 2014 dengan 4880 individu lebah, sementara *H. itama* menunjukkan pada bulan Mei 2015 (2168 individu). Oleh itu, aktiviti mencari makanan bagi lebah kelulut ini mungkin dipengaruhi oleh aspek persekitaran lain seperti komposisi spesies flora yang terdapat di kawasan penternakan lebah kelulut.

Kata kunci: Musim hujan, musim kering, iklim tropika, lebah kelulut, *Genotrigona thoracica, Heterotrigona itama*

INTRODUCTION

Malaysia's climate is characterised as hot and humid throughout the year with an average temperature of 27°C. The most frequent flower visitors in tropical environments are bees, many of which belong to eusocial species within the Apidae family (including stingless bees, bumblebees, and honeybees) (Härtel & Dewenter 2014). In contrast to unsocial insects that collect food to maintain their individual offspring’s survival, foragers of social insect colonies collect food to ensure the successful rearing of the brood and to meet the energetic demands of all non-foraging adults. Therefore, the survival of a bee colony depends upon the success of the workers in collecting nectar (a source of carbohydrates) and pollen (a source of proteins and vitamins) from flowers (Michener 2007).

Two seasons, wet and dry, occur every year in Malaysia. Generally, the dry period commences from February to July when the rainfall is scarce with possible occurrence of drought. The wet period occurs from August to January with the appearance of heavy rain and flood. However, due to climate change and unpredictable rainy seasons, the demarcation of the two periods is not clear. The Malaysian Meteorological Department divided the climate of Peninsular Malaysia into dry and wet periods based on the precipitation collected. Dry period occurs when precipitation is below than 200 mm per month and precipitation of more than 200 mm per month is considered as wet period or month (Wan Nur Asiah et al. 2015).

Heterotrigona itama (Cockerell 1918) and *Geniotrigona thoracica* (Smith 1857) are two most common stingless bee species in Malaysia. They can be easily found in many places due to their wider distribution and abundance (Siti Fatimah et al. 2018). These two stingless bee species are commonly used for meliponiculture in Malaysia compared to other 35 species of stingless bees (Mohd Yusof et al. 2018; Jaapar et al. 2018, 2019). The popularity of these two species among beekeepers either to generate income or as pets is due to their relatively faster adaptation in a new environment. They can be easily kept, maintain, and propagate with high resistance against diseases and possibly climate change (Wan Nur Asiah et al. 2015).

However, the knowledge of foraging behaviours of these two bee species within tropical climates especially in Malaysia is still scarce (Wan Nur Asiah et al. 2015). Many studies have been done but not analysed, such as differences in foraging behaviours for exiting and returning bees between different species and within species. Knowledge of these foraging behaviour of stingless bees is important for beekeeper to estimate the stingless bee foraging success, detection of colonies problem and sustain the colonies in wet, dry seasons and floral resources within stingless bee's meliponiculture. This study aimed to investigate the foraging activities of two selected stingless bee species; *G. thoracica* and *H. itama* in wet and dry seasons in Selangor.

MATERIALS AND METHODS

Study Site

The study site is located at the Integrated Farm, Faculty of Agriculture, Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia. It is within the student's residential area of UPM with the latitude of 2.991686°N, longitude 101.714076°E. This farm consists of local fruit trees plot, corn plot area, rare plot of rare trees (Nadir fruits), and plot for the seedling of oil palm tree, a few plots of vegetable plants. The plot of local fruit trees was chosen for this study for a one-year study. This study site had 4661 square feet consist a variety of local fruit trees such as six trees of *Dimorcarpus longan* (longan), 30 trees of *Nephelium lappaceum* (rambutan), 32 trees of *Averrhoa carambola* (starfruit), 10 trees of *Psidium guajava* (guava), 20 trees of *Syzygium aqueum* (wax apple), 14 trees of *Mangifera indica* (mango), 7 trees of *Artocarpus heterophyllus* (nangka) and 7 trees of *Artocarpus integer* (cempedak). All fruit trees in the study site were planted at a distance of 2 m to 3 m apart. These fruit trees were about 15^{th} to 20^{th} years old.

Stingless Bee Colonies

Forty stingless bee hives were placed at a site surrounded by local fruits. Out of 40 stingless colonies available at the study site, only 6 colonies from two stingless bee species, *H. itama* and *G. thoracica*, had the highest traffic with more than 50 number of bees hovering into and out of their nests were selected for this study. Three colonies of *H. itama* and 3 colonies of *G. thoracica* were maintained for six months at the Integrated Farm of Faculty Agriculture, UPM before the experiment began. These two species were chosen based on their availability and abundance in Malaysia.

Daily Activities and Foraging Pattern of Stingless bees

Foraging activities of the two bee species were recorded monthly from September 2014 to August 2015. The sampling was conducted in the first week of each month. The activities of the bees were monitored from 0800 h to 1600 h on clear day with bright sky to examine whether the time of the day influenced the activities of both stingless bees studied. Two observant monitored and counted the activities of the two species of stingless bees, i.e. bees hovering in (FI) and bees hovering out (FO), bees collecting the pollen and bees bringing the nectar to their nest using hand manual counter about a-meter square from the nest entrance of each species studied. The number of bees hovering in (FI), bees hovering out (FO), bees with pollens and bees with nectar were recorded for 10 minutes at each hour (Fidalgo & Kleinert 2007; Macias-Macias et al. 2017). Within one hour, a total of six colonies of these stingless bees were monitored and counted (i.e. each hive required 10 minutes of observation × six colonies of stingless bees).

A total of 240 minutes of observations on the bees' activities at their entrances (10 minutes × 8 hours × 3 replicates of colony for each species) was recorded for each sampling. During this study, 2880 minutes of total observations (240 minutes × 12 months) were conducted for these two species from September 2014 to August 2015. Monthly rainfalls were also obtained using a rain gauge from the weather station located in the field.

Data Analysis

All data were subjected to Kolmogorov-Smirnov test to assess the normality distribution of the foraging activities of the bees. Based on greater *P* values ($P>0.05$) that represents normally distributed data, differences in the mean number of foraging bees for the two species were analysed using ANOVA (Zar 1999). A one-way ANOVA was employed to determine whether significant differences were present with respect to the foraging activities of these two stingless bees over different months and seasons.

RESULTS AND DISCUSSION

During this study, the dry period occurred from September to October in 2014 and May to August in 2015. The wet period began in November 2014 to April 2015 (Figure 1). Figure 2 shows the number of *G. thoracica* and *H. itama* collecting nectar and pollen within a year between September 2014 and August 2015. In general, more flight activities were recorded for *G. thoracica* each month than the foragers of *H. itama* which was likely to be related to the bigger colony size of the latter. Wide oscillations in flight activities were observed for these two species within 12 months of study. Moreover, there were uneven oscillation in flight activities in the two species with a relatively noticeable increase in the wet months recorded. During the wet season, G. *thoracica* and *H. itama* incurred the highest number of flights in January 2015 (*G. thoracica* = 12,303 individuals, *H. itama* = 12,011 individuals). Figure 2 also displays the lowest foraging activities for both species in dry season. The lowest number of flights for *G. thoracica* was observed in September 2014 with 4880 individual bees counted while *H. itama* showed the lowest activity in May 2015. Differences in the number of foraging bees was significantly different among months ($F_{G.\ thoracica}$=11.94; df=11; $P<0.05$, $F_{H.\ itama}$=19.88; df=11; $P<0.05$).

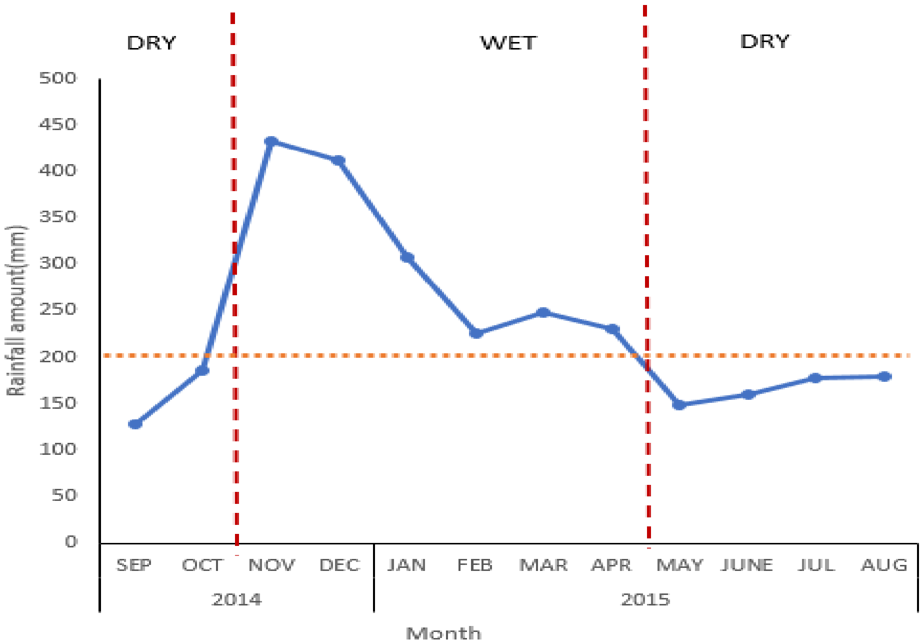

Figure 1. Amount of precipitation (rainfall) from September 2014 to August 2015 at Integrated Farm of Agriculture, UPM, Serdang. The red line indicates separation of wet from dry periods season

Source: Meteorology data Malaysia, station; Pusat Pertanian Serdang, Latitude; 3° 00'N, Longitude; 10° 42'E

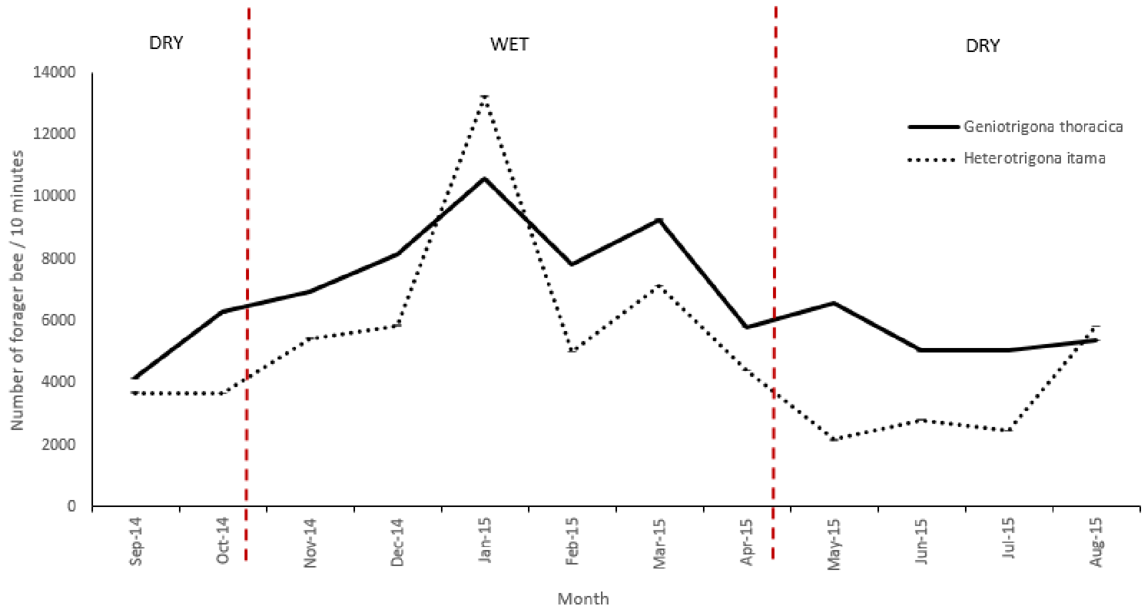

Figure 2. Abundances of foraging bees' species at their entrances of colonies within one-year

In this study, both species of stingless bee foraged actively in high abundance in the wet season (January 2015) (Figure 2). This result did not conform to findings by a couple of researchers who concluded that the abundance and distribution of stingless bees were low during the wet season (Nascimento & Nascimento 2012). However, Keppner and Jarau (2016) found that a higher flight activity of *Partamona orizabaensis* occurred during colder temperatures, higher relative humidity and even during rain. Similarly, the population of midges that pollinated cocoa flowers was higher during wet season than in dry season (Phatlane 2018; Young & Severson 1994). Another study on the native bees of the genus *Peponapis* in Mexico found that the most frequent and effective pollinators were *Cucurbita moschata* in wet season compared to in dry season (Delgado-carillo 2018). In this study, the hives of *G. thoracica* and *H. itama* were placed under the tree canopy and the bees used the shaded area as their foraging trail while foraging for food. The shade protected them from the detrimental effect of rain during the wet season and higher temperatures during the dry season. In addition, these two species of bees were more active in foraging during the day, without rain even though in wet season. Similar findings were reported by Aleixo et al. (2017) in which a high abundance of stingless bee, *Scaptotrigona aff. depilis* in wet season was associated with the mass flowering of forest trees in Brazil. Similarly, Escobedo-Kenefic et al. (2020) showed that a higher abundance of honey bees occurred in wet season associated with higher floral resources in Guatemala. In the case of midge population in the cocoa plantations, Young (1983) and Phatlane (2018) found that shaded areas provided by cocoa trees supported a higher midge population during the wet season because the shades protected them from rain. Moreover, this cocoa midge also was not tolerant to high temperatures.

The lowest abundance of foraging activities of *G. thoracica* and *H. itama* occurred in the dry season due to high ambient temperature. According to Abou-Shaara et al. (2012), a high temperature can shorten honey bees' lifespan and decrease the forager's efficiency to hunt for food because they need to use more energy to maintain their body temperature during the hot days. The ideal temperature for *H. itama* in Malaysia is 29°C to 32°C (Jaapar et al. 2018). When the temperature in their nest increases, stingless bee will slow down their foraging activities and keep fanning in the hive to cool down and sustain the temperature of the nests between 29°C to 32°C (Vollet-neto et al. 2015). Maintaining a constant temperature is critical for normal growth and development of stingless bees' larval and pupal stages (Dantas 2016). It is very likely that this factor also contributed to a low foraging activity during the dry season at the orchard in this study.

Table 1 shows the relationship between the foraging activities of these two stingless bee species with abiotic parameters during wet and dry seasons. Three abiotic parameters like humidity, luminosity and temperature were highly significant to the foraging activities of *G. thoracica* in both seasons. Meanwhile only two abiotic parameters studied which were humidity and luminosity had a highly significant correlation with *H. itama* during wet season. However, all correlation values (r) showed a weak correlation to the foraging activities for both species studied in the wet and dry season.

Table 1. Relationships between foraging bee abundance and abiotic parameters; temperature, humidity and luminosity indicate by Pearson correlation values (r)

Season	**Abiotic Factors**	**Species**	
		G. thoracica	***H. itama***
Wet	Humidity (%)	0.02	-0.11**
	Luminosity (Lux)	0.13**	0.16**
	Temperature (^{0}C)	-0.12**	-0.80
Dry	Humidity (%)	0.14**	0.09
	Luminosity (Lux)	0.10	0.07
	Temperature (^{0}C)	-0.14**	-0.09

**Correlation is significant at the 0.01 level (2 tailed)

Tropical climate showed the uniformity of all abiotic collection data (Polatto et al. 2014). Little variations in the values of the all-abiotic parameters studied did not cause any significant effects to the foraging activities for both species studied. (Table 2). A finding reported by Nascimento and Nascimento (2012) also showed that these small variations in temperature and humidity did not affect stingless bee (*Melipona asilvai* Moure) activity in tropical Northeast Brazil. Similarly, Maia-Silva et al. (2015) reported that foraging activities of *Melipona subnitida* also had weak correlation with the all-abiotic parameters studied in tropical climate. According to Hartshorn (2013), tropical climates are characterized by predictable temperature patterns and uncertain seasonal variation and precipitation regimes that are more unpredictable and highly variable from year to year. Foraging bees in the tropical region were much not affected by the abiotic factors due to the small variation range within temperature, humidity and luminosity but daily and seasonal climate probably could affect the resources available at the apiary and also affected the foraging activities of the bees (Polatto et al. 2014).

Table 2. Monthly abiotic parameters recorded during 12 months from September 2014 to August 2015 (Mean±SE)

Month	Abiotic Parameters		
	Humidity (RH)	**Luminosity(lux)**	**Temperature (^{0}C)**
Sep-14	69.88±1.12	2554.44±18.54	31.53±0.30
Oct-14	70.22±1.21	3100.86±20.17	31.30±0.36
Nov-14	73.35±1.10	1934.03±10.43	30.39±0.27
Dec-14	73.23±1.16	2013.83±14.72	31.11±0.29
Jan-15	63.55±1.14	1920.03±12.45	30.83±0.29
Feb-15	69.39±1.43	1274.22±14.43	31.39±0.38
Mar-15	63.11±1.11	2296.62±18.03	31.75±0.21
Apr-15	71.77±1.10	812.10±10.52	31.62±0.31
May-15	72.83±1.71	810.35±76.77	31.55±0.31
Jun-15	73.83±0.75	1462.22±16.41	31.44±0.20
Jul-15	72.18±0.83	1220.36±14.72	30.23±0.22
Aug-15	65.35±1.19	1941.80±19.74	32.07±0.35

CONCLUSION

As a conclusion, foraging activities of both stingless bee species significantly varied with seasons (wet and dry seasons). They were more active during the wet compared to dry season. The foraging activities of these bees might be affected by other environmental aspects such as the composition of flora species surrounding the stingless bee meliponiculture, internal colony condition and bee’s behaviours.

ACKNOWLEDGMENTS

This research was supported by Grant FRGS-5525385 from the Ministry of High Education Malaysia.

REFERENCES

Abou-Shaara, H.F., Al-Ghamdi, A.A. & Mohamed, A.A. 2012. Tolerance of two honey bee races to various temperature and relative humidity gradients. *Environmental and Experimental Biology* 10: 133–138.

Aleixo, K.P., Menezes, C. & Imperatriz Fonseca, V.L. 2017. Seasonal availability of floral resources and ambient temperature shape stingless bee foraging behavior (*Scaptotrigona aff. depilis*). *Apidologie* 48: 117–127.

Cockerell, T.D.A. 1918. Descriptions and records of bees - LXXX. *Annals and Magazine of Natural History* 2: 384–390.

Dantas, M. 2016. Thermogenesis in stingless bees: An approach with emphasis on brood's thermal contribution. *Journal of Animal Behaviour and Biometeorology* 4: 101-108.

Delgado-Carrillo, O., Marten-Rodrıguez, S., Ashworth, L., Aguilar, R., Lopezaraiza-Mikel, M. & Quesada, M. 2018. Temporal variation in pollination services to *Cucurbita moschata* is determined by bee gender and diversity. *Ecosphere* 9(11) :1-16.

Escobedo-Kenefic, N., Landaverde-González, P., & Theodorou, P. 2020. Disentangling the effects of local resources, landscape heterogeneity and climatic seasonality on bee diversity and plant-pollinator networks in tropical highlands. *Oecologia* 194: 333–344.

Fidalgo, A.O. & Kleinert, A.M.P. 2007. Foraging behavior of *Melipona rufiventris* Lepeletier (Apinae; Meliponini) in Ubatuba, SP, Brazil. *Brazilian Journal of Biology* 67(1): 133-140.

Jaapar, M.F., Nasarodin, N.S., Reward, N.F., Jajuli, R. & Idris, A.B. 2019. Notes on resin collected by stingless bees in Taman Tropika Tasik Kenyir, Terengganu, Malaysia. *Serangga* 24(2): 81-89.

Jaapar, M., Jajuli, R., Radzali, M. & Idris, A.B. 2018. Foraging behaviour of stingless bee *Heterotrigona itama* (Cockerell, 1918) (Hymenoptera: Apidae: Meliponini). *AIP Conference Proceedings* 1940: 020037.

Hartshorn, G.S. 2013. Tropical Forest Ecosystems. In Levin, A. S. (ed.). *Encyclopedia of Biodiversity.* 2nd Edition, pp. 269-279. USA: Academic Press

Härtel, S. & Dewenter, I.S. 2014. Ecology: Honey bee foraging in human-modified landscapes. *Current Biology* 24(11): 524-526.

Keppner, E. & Jarau, S. 2016. Influence of climatic factors on the flight activity of the stingless bee *Partamona orizabaensis* and its competition behaviour at food sources. *Journal of Comparative Physiology A* 202(9-10):691-699.

Macias-Macias J.O., Tapia-Gonzalez, J.M. & Contreras-Escareno, F. 2017. Foraging behaviour, environmental parameters and nests development of *Melipona colimana*

Ayala (Hymenoptera: Meliponini) in temperate climate of Jalisco, México. *Brazilian Journal of Biology* 77: 383-387.

Maia-Silva C., Hrncir, M., Silva C.I., & Imperatriz-Fonseca, V.L. (2015). Survival strategies of stingless bees (*Melipona subnitida*) in an unpredictable environment, the Brazilian tropical dry. *Apidologie* 46:631–643.

Michener, C.D. 2007. *The Bees of the World.* Baltimore: The Johns Hopkins University Press.

Mohd Yusof, N.F., Nik Rashidi, N.R., Zulkifli, N.R., Yaakop, S., Hamid, I.R. & Md- Zain, B.R. 2018. Phylogentic relationships of *Heterotrigona itama* in Malaysia based on *COI* DNA sequences. *Serangga* 23(2): 36-48.

Nascimento, D.L. & Nascimento, F.S. 2012. Extreme effects of season on the foraging activities and colony productivity of a stingless bee (*Melipona asilvai* Moure, 1971) in Northeast Brazil. *Psyche* 267361: 1-6.

Phatlane, W.M. 2018. *Pollination in Plants*. London, United Kingdom: Intech Open.

Polatto, L., Chaud-Netto, J. & Vieira, V. 2014. Influence of abiotic factors and floral resource availability on daily foraging activity of bees: Influence of abiotic and biotic factors on bees. *Journal of Insect Behavior* 27(5): 592-612.

Siti Fatimah, S., Mohd Razif, M. & Izfa, R.H. 2018. Taxanomic study on selected species of stingless bee (Hymenoptera: Apidae: Meliponini) in Peninsular Malaysia. *Serangga* 23(2): 203-258.

Smith, F. 1857. Catalogue of the hymenopterous insects collected at Sarawak, Borneo; Mount Ophir, Malacca; and at Singapore. *Journal of the Proceedings of the Linnaean Society of London Zoology* 2(6): 42–88.

Vollet-Neto, A., Menezes, C. & Imperatriz-Fonseca, V.L. 2015. Behavioural and developmental responses of a stingless bee (*Scaptotrigona depilis*) to nest overheating. *Apidologie* 46: 455-464.

Wan Nur Asiah, W.M.A., Sajap, A.S., Adam, N.R. & Hamid, M.N. 2015. Flight intensity of two species of stingless bees *Heterotrigona itama* and *Geniotrigona thoracica* and its relationships with temperature, light intensity and relative humidity. *Serangga* 20(1): 35-42.

Young, A. M. 1983. Seasonal differences in abundance and distribution of cocoa-pollinating midges in relation to flowering and fruit set between shaded and sunny habitats of the La Lola Cocoa Farm in Costa Rica. *Journal of Applied Ecology* 20(3): 801-831.

Young, A.M. & Severson, D.W. 1994. Comparative analysis of steam distilled floral oils of cacao cultivars (*Theobroma cacao* L., Sterculiaceae) and attraction of flying insect: Implications for *Theobroma* pollination syndrome. *Journal of Chemical Ecology* 20(10): 2687-2703.

Zar, J.H. 1999. *Biostatistical Analysis*. Pearson education (US): Prentice Hall.