Foraging behavior of stingless bee (\textit{Geniotrigona thoracica} and \textit{Heterotrigona itama}) on star fruit trees (\textit{Averrhoa carambola} L.)

S S Asma, N A Adam*, M Y Siti Najwa, N Asilah, T S Syukri, and W N Asiah

Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang Selangor Darul Ehsan, Malaysia

*Corresponding author: nur_azura@upm.edu.my

Abstract. Star fruit produce flowers and fruits nearly the whole year round and it require cross-pollination for good fruit set and yields. An inadequate pollination rate is one of the factor that contributes to low yield. One of the effective way of increasing the pollination rate is by having insect pollinators such stingless bees in the star fruit farm. Malaysia is rich with native pollinator such as stingless bee, but there still lack of study related on their foraging behaviour. Therefore, the objectives were to study the foraging behaviour of \textit{Geniotrigona thoracica} and \textit{Heterotrigona itama} on star fruit trees. The colonies of \textit{G. thoracica} and \textit{H. itama} were selected for observation of activity foraging of stingless bee. Foraging bees was enumerated by using a manual tally counter to determine the number of individuals that flew out and into their hive within a 10 minute period each hour for each colonies. Then 10 of foragers’ \textit{G. thoracica} and \textit{H. itama} were selected randomly and marked using insect colouring on their thorax. The period for each flower that visited by \textit{G. thoracica} and \textit{H. itama} was recorded by using stopwatch. The number of flower visited by \textit{G. thoracica} and \textit{H. itama} also recorded in 3 minutes. Result showed the peak time foraging activity of both stingless bees were in between 8.00am until 10.00am. The foraging activity for each hours showed there was not significant differences, p > 0.05. Then the highest number flower visited by \textit{G. thoracica} in 3 minute is 31 flowers while the lowest number flower visited in 3 minute is 7 flowers. However, for \textit{H. itama} the highest number visited flowers are 27 and lowest number visited flowers are 8, for the longest average visited period for each flower is 14.76 seconds and the shortest period is 3.57 seconds. Meanwhile for \textit{G. thoracica} longest average visited period for each flower is 12.88 seconds and the shortest average visited period for each flower is 2.72 seconds. In conclusion, this experiment showed that stingless bees have the characteristic for effective pollinator and have the potential to be used as a pollinator for star fruit trees. However, temperature, humidity and weather gave big influence on the foraging activity of stingless bees on star fruit plant.

Keywords: stingless bee, \textit{Geniotrigona thoracica}, \textit{Heterotrigona itama}, pollination, pollinators
1. Introduction
Star fruit (Averrhoa carambola L.) belongs to the family Oxalidaceae. Star fruit’s flower is a complete flower but heterodistylyous. It is difficult to self-pollinate and needs pollinators for development of fruits. One of the effective ways is by introducing the stingless bee as pollinator. Stingless bee is a good candidate as a pollinator that is a highly diverse and abundant group of eusocial bees, originated from tropical and subtropical region [1]. Pollinators are known to provide symbiosis process with the ecosystem function. This study provided the guideline for grower to manage the population of pollinators in proper ways.

2. Materials and Method
2.1. Sampling site
The site of this experiment was in Integrated farm, Faculty of Agriculture, University Putra Malaysia with the latitude 2.9917ºN; longitude 101.7163º E.

2.2. Sampling method
2.2.1. Preparation materials
The star fruit tree was pruning 1 month before experiment started. It was to encouraged growth of buds flower. Each tree of star fruit was fertilized with NPK Blue in once 2 weeks.

2.2.2. Observation active time of foraging
The 3 colonies of G. thoracica and H. itama were selected for observation of activity foraging of stingless bee. Foraging bees was enumerated by using a manual tally counter to determine the number of individuals the fly out and in their hive within 10 minutes period each hour.

2.2.3. Observation pollination service
10 of forager’s G. thoracica and H. itama were selected randomly and marked using insect colouring on their thorax. The period for each flower that visited by stingless bees were recorded by using stopwatch. The number of flower visited by stingless bees also recorded in 3 minutes.

2.3. Data Analysis
For data analysis of number G.thoracica and H.itama, stingless bee flew out and into hive by using One way analysis of variance were used with P <0.05 to determine the difference between number stingless bee flew out and into hive and time.

3. Results and Discussion
The study on the number of stingless bee (G.thoracica and H.itama) that flew out from the hive and the number of stingless bee that flew into the hive related to the time of day is presented in Figure 1, Table 1.1 and 1.2.

![Figure 1](image-url)

Figure 1. Number of stingless bee (G.thoracica and H.itama) that flew out and into hive
The highest and lowest number for *G.thoracica* flew out from hive were 995 individuals (9.00 am) and 675 individuals (11.00 am), respectively. Furthermore, the highest and lowest number individual *G.thoracica* flew into hive were 1005 individuals (8.00 am) and 749 individuals (10.00 am), respectively. On the other hand, respectively, for *H.itama* the highest and lowest number individual flew out from hive were 535 individuals (8.00 am) and 368 individuals (12.00 noon). Also, the highest and lowest number *H.itama* flew into hive were 593 individuals (8.00 am) and 386 individuals (12.00 noon), respectively.

Table 1.1: Number of stingless bee (*G.thoracica*) that flew out and into hive

| Time (Hours) | No. of stingless bee that flew out from hive | No. of stingless bee that flew into hive |
|--------------|---------------------------------------------|-----------------------------------------|
| 0800 – 0900  | 381.67 ± 38.77*                             | 385.00 ± 40.10*                         |
| 0900 – 1000  | 270.33 ± 74.37*                             | 308.33 ± 44.39*                         |
| 1000 – 1100  | 247.33 ± 58.52*                             | 249.67 ± 49.33*                         |
| 1100 – 1200  | 225.00 ± 26.08*                             | 253.67 ± 53.49*                         |
| 1200 – 1300  | 257.33 ± 20.99*                             | 268.33 ± 48.33*                         |

Note: Value with the same letter were not significantly different (P = 0.05)

Table 1.2: Number of stingless bee (*H.itama*) that flew out and into hive

| Time (Hours) | No. of stingless bee that flew out from hive | No. of stingless bee that flew into hive |
|--------------|---------------------------------------------|-----------------------------------------|
| 0800 – 0900  | 178.33 ± 39.99*                             | 197.67 ± 58.17*                         |
| 0900 – 1000  | 166.33 ± 36.38*                             | 177.33 ± 34.46*                         |
| 1000 – 1100  | 146.00 ± 40.95*                             | 183.33 ± 30.12*                         |
| 1100 – 1200  | 123.33 ± 36.52*                             | 128.67 ± 29.24*                         |
| 1200 – 1300  | 122.67 ± 22.05*                             | 140.67 ± 28.85*                         |

Note: Value with same letter were not significantly different at P = 0.05

Based on the tables shown, there were no significant differences (p > 0.05) for number of both stingless bees that flew out from hive and the number of both stingless bees that flew into the hive between times. Thus, the range of time from 8.00 am to 1.00 pm did not influence the activity of stingless bee. The number of both stingless bees that flew into the hive and flew out from the hives is relatively decrease by time for foraging activity. However, *G.thoracica* has slight increase at 12.00 noon for individuals that flew into and flew out the hive. [6] stated that some foraging patterns do exist with a pollen-collecting peak in the early morning and a nectar-collecting peak in the late morning.

The total flowers that had been visited by *G.thoracica* were 583 flowers. Then the highest number flower visited in 3 minutes by *G.thoracica* was 31 flowers while the lowest number flower visited in 3 minute was 7 flowers. Total numbers of flowers visited by *H.itama* were 463 flowers where the lowest visited flowers were 8, while the highest numbers of flowers visited were 27. Respectively, the longest and shortest average visited period for each flower for *G.thoracica* were 12.88 and 2.72 seconds. Meanwhile, for *H.itama* the longest and shortest average visited period for each flower were 14.76 and 3.57 seconds, respectively. This mean that *H.itama* spent more time in one flower than *G.thoracica*, this might be because of the size proboscis of *H.itama* shorter than *G.thoracica*. 
Figure 2. The number of flower that visited by stingless bees G. thoracica and H. itama in 3 minute and average time taken visited for each flower.

The peak hour of stingless bees for foraging activities was around 8.00am to 10.00am. Increasing individuals flew in and out was because of the routine activity housekeeping bees such as brings out the trash or brings out the dead individuals besides foraging activities. Usually stingless bee starts their foraging activity at early morning because of favorable temperature. Temperature, light intensity, and relative humidity were the factors that most influenced the foraging activities [3].

Energy preservation and achieved nutrient are the factor that can influence the time foraging of stingless bee. Early morning is the time of highest foraging activity because of stingless bee need to fulfil their energy requirement while at mid-day temperature is increasing. The optimal level of relative humidity and temperature within between 70% to 90% and approximately 20ºC is the favorable condition for stingless bee starts their foraging activities [2].

Stingless bees remained active in the morning to collect pollen and nectar. Since starfruit flowers were almost closed between 1400 hours to 1800 hours [7]. Stingless bees tend to show flower constancy, repeated visit to the same flower. This is one of the characteristic for effective pollinator [5]. Frequency and duration of visit by pollinators to nectariferous depend on nectar production level [4, 5].

4. Conclusion
Foraging activity of this bee species highly overlapped with the opening time of the flowers. Stingless bees tend to showed flower constancy and a single flower-visit was sufficient for efficiently transferring pollen to the stigma, thus promoting pollination. Stingless bees start their foraging activity at early morning because that time has favorable temperature and prefers foraging in the hot sunny day than the rainy season due to the small size of body beside rain can be disturbing their flight.

5. References
[1] Heard, T. A. (1999). The role of stingless bees in crop pollination. Annual Review of Entomology, 44(1), 183-206.
[2] Hilário, S.D., Imperatriz-Fonseca, V.L. and Kleinert, A. M. P. (2013). Flight Activity And Colony Strength In The Stingless Bee Melipona Bicolor (Apidae, Meliponinae). Revista Brasileira de Biologia. 60(2): 299–306.
[3] Iwama, S. A., (1977), Influência de fatores climáticos na atividade externa de Tetragonisca angustula (Apidae, Meliponinae). Bol. Zool., 2:189-201.
[4] Mohd Norowi, H., Sajap, A. S., Rosliza, J., Mohd Fahimie, J., & Suri, R. (2008). Conservation and sustainable utilization of stingless bees for pollination services in agricultural ecosystems in Malaysia. Department of Agriculture, Malaysia.
[5] Putra, D. P., Dahelmi, S. S. M., & Swasti, E. (2016). Pollination in chili pepper (Capsicum annuum L.) by Trigona laeviceps and T. minangkabau (Hymenoptera, Meliponini).
[6] Roubik, D. W., (1989), Ecology and natural history of tropical bees. Cambridge Tropical Biology Series, 514p.
[7] Saúco, V. G., & Tindall, H. D. (1993). Carambola cultivation (No. 108). Food & Agriculture Org.

6. Acknowledgements
This research was funded by Fundamental Research Grant Scheme (FRGS) 07-01-16-1794FR and Trans-disciplinary Research Grant Scheme (TRGS) TRGS/1/2016/UPM/01/5/2 from Ministry of Education, Malaysia.