ABSTRACT

This study ~~aimed~~ aims to ~~observe~~ investigate the foraging behaviour of *Heterotrigona itama* in exploiting food resources ~~in~~ at a residential area, and the viability of this species to adapt to urban microclimatic conditions. *Heterotrigona itama* ~~preferred~~ prefers to forage at areas closer to their nesting site, where diverse food sources ~~were~~ are found. The marked bees of *H. itama* ~~preferred~~ to forage on various resources available at a ~~500~~ 500-metre~~s~~ radius ~~of distance~~ from the house yard. The results indicate that ~~The~~ the active foraging pattern of *H. itama* ~~was~~ is negatively correlated to the time phases of a day ($p < 0.05$). This phenomenon was contributed by the three peaks of foraging hours, which reached a peak in the early morning (6~~.~~:30 ~~am~~ to 8~~.~~:00 am), moderately peaked towards the evening (2~~.~~:30 ~~pm~~ to 3~~.~~:30 pm), and was greatest towards the afternoon (10~~.~~:30 am to 12.00 pm). The ambient temperature and relative humidity were not the ~~main~~ primary factors influencing the ~~overall~~ average number of foragers exiting from and returning to the hives (temperature~~;~~, p>0.05~~;~~) and humidity~~;~~, p>0.05). There was a difference between the variety of content resources collected by the bees (p<0.05). The nectar or water sources ~~(51.39%)~~ was the highest material (51.39%) that was brought back to the hive by foragers, followed by resin (34.73%) and pollen (13.87%). There ~~were~~ was a significant difference~~s~~ in foraging time phases by returning foragers for collecting resin (p<0.05) and nectar or water (p<0.02), but there was no significant difference in foraging time phases found for pollen (p>0.05). ~~This study has shown~~ The results indicate that *H. itama* is able to withstand urban microclimate condition~~s~~, and ~~had~~ successfully incorporated pollen, nectar or water, and resin obtained from ~~the~~ floral and non-floral resources into their diet.

Keywords: Abiotic factors, foraging behaviour, *Heterotrigona itama*, residential area, stingless bees

INTRODUCTION

Compared to honeybees, ~~the~~ stingless bees are relatively ~~easy~~ easier to handle, less aggressive as they do not have a functional stinger, and are efficient in foraging ability, thus making them ideal to be reared in residential areas. Nowadays, ~~Urban~~ urban beekeeping in residential areas ~~nowadays~~ demonstrates a rise in popularity in Malaysia (Basari et al., 2018). ~~The b~~Beehives require minimal land, and can be placed almost anywhere, ~~such as~~ including house yards and orchards. However, the foraging activity of stingless bees in an urban environment remains unclear. In the State of Sabah, beekeeping with *Heterotrigona itama* has induced a massive growth ~~of~~ in interest, particularly on the west coast where many beekeepers want to keep colonies of bees in residential areas as a hobby, income ~~opportunities~~opportunity, ~~and~~ or for their own source of authentic honey. The direct contributions of stingless beekeeping include the value of the output~~s~~ produced such as honey, beebread, and one of essential ingredients ~~for~~ in cosmetics and medicine, known as propolis (Yaacob et al., 2018). The indirect but significant contribution of beekeeping is through floral pollination in agricultural and natural environments (Roubik, 2006; Heard, 1999). The flora of the residential area ~~where~~ wherein the beehives are situated ~~tends to~~ is highly benefitted ~~benefit the area's flora~~ due to pollination activities by ~~these~~ the bees (Roubik & Buchmann, 1984).

Heterotrigona itama is a common stingless bee species found in Southeast Asia, and is ~~one of~~ among the most popular species in meliponiculture (Heard, 1999; Mustafa et al., 2018). Due to its popularity, ~~thus,~~ it has been selected as a model organism in this study. This species

can be easily identified from other commonly encountered species with similar colouration, as it has a wider and longer body (Samsudin et al., 2018). For example, the main feature of the genus ~~of~~ *Tetrigona* spp. (e.g. *T. apicalis* and *T. binghami*) is its ~~by having~~ large white-tipped wings, while the *Tetragonula* spp. (*T. laeviceps* and *T. fuscobalteata*) ~~appear to be~~ is much smaller than ~~the~~ other ~~genus~~ genera of stingless bees. ~~So~~ Thus far, the effects of climatic factors (e.g. temperature and relative humidity) towards the flight activity of *H. itama* in urban areas ~~remained~~ remains poorly understood. Temperature and relative humidity are ~~important~~ vital environmental factors that may affect the foraging activity of ~~the~~ stingless bees (Hilario et al., 2001). The climatic factors ~~had~~ have been reported to influence the flight activity of *Tetragonula carbonaria* (Heard, 1999). ~~Studies by~~ Keppner and Jarau (2016) also found that the foraging activity of *Partamona orizabaensis* escalated in weather conditions such as colder temperatures and increased relative humidity, as well as during rainfall. The climatic factors aid honeybees and bumblebees in orientating and navigating their environments, as successful orientation is vital for ~~bees'~~ foragers to return to their nest after foraging (Moore & Rankin, 1983; Stelzer et al., 2010).

Previous studies ~~had~~ have shown that eusocial bees exhibit high preference in exploiting material sources for the survival of their colonies (Moore & Rankin, 1983; Nagamitsu & Inoue, 1997; Stelzer et al., 2010). Thus, urbanisation may affect the bees' flight activities due to changes ~~of~~ in ~~resources~~ the availability of local resources~~locally and in the surrounding area~~. However, data ~~is still~~ remains limited. The bees require floral resources to survive, and therefore, private gardens, parks, and wild floral habitats within ~~the~~ urban landscapes may support food and nesting resources (Ropars et al., 2019; Udy et al., 2020). Although urban beekeeping is growing in popularity in Sabah, the bees' foraging activity in residential areas has been poorly investigated. Therefore, this study ~~aimed~~ aims to ~~observe~~