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Comparison of productivity from three stingless bees: *Tetragonula sapiens, T. clypearis* and *T. biroi* managed under same feed sources for meliponiculture

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Abstract. *Erwan, Habiburrohman, Wiryawan IKG, Muhsinin M, Supeno B, Agussalim. 2023. Comparison of productivity from three stingless bees:* Tetragonula sapiens, T. clypearis *and* T. biroi *managed under same feed sources for meliponiculture. Biodiversitas 24: 2988-2994.* The productivity of stingless bee species is affected by the workers' population, especially the foragers' number, queen bee productivity, and the availability of plants as the nectar and pollen sources. The recent study aims to evaluate the productivity of three stingless bee species, *Tetragonula sapiens* (Cockerell, 1911), *Tetragonula clypearis* (Friese, 1908), and *Tetragonula biroi* (Friese, 1898), managed under the same feed sources for beekeeping in stingless bee (meliponiculture). Total of fifteen colonies and every five colonies per species of *T. sapiens, T. clypearis,* and *T. biroi,* respectively. The results showed that the different species of stingless bees highly affected the exit activities in the morning and afternoon and brood cell number ($p<0.01$). Furthermore, significant impacts on the honey pot number, production of honey and propolis ($p<0.05$) but not on the pollen pot number and the production of pot-pollen. Thus, productivity was characterized by honey pot number, brood cell number, and production of honey and propolis from the stingless bee of *T. biroi* was higher than *T. sapiens* and *T. clypearis*. However, the productivity of *T. sapiens* and *T. clypearis* was similar.

Keywords: Honey, nectar, pollen, pot-pollen, propolis

INTRODUCTION

The number of stingless bees, at least 500 species, and maybe more than 100 species have yet to be studied (Michener 2013). In Indonesia, was found 46 stingless bee species (Kahono et al. 2018) and mostly nesting in several natural habitats such as bamboo, sugar palm stalk, tree trunks or woods and in the ground (Agus et al. 2019a, 2021; Agussalim et al. 2019a, 2019b, 2020, 2021, 2022; Erwan et al. 2020, 2021b; Sabir et al. 2021; Supeno et al. 2021, 2022; Rachmawati et al. 2022; Agussalim and Agus 2022; Agussalim et al. 2023). In Indonesia, stingless bees have been meliponiculture by the beekeepers to produce honey, bee bread (pot-pollen), and propolis (Agus et al. 2019a, 2021; Agussalim et al. 2019a, 2019b, 2020, 2021, 2022; Erwan et al. 2020, 2021b; Sabir et al. 2021; Dewi et al. 2021; Supeno et al. 2021, 2022; Rachmawati et al. 2022; Agussalim and Agus 2022; Agussalim et al. 2023).

To produce honey, nectar is required from plant flowers or called floral nectar (secreted by the nectaries gland), extrafloral nectar (secreted by other parts of plants such as leaf axil and leaf stalks), and honeydew (Pacini and Nicolson 2007; Agussalim and Agus 2022). Bee bread is popular called for produced by honeybees, whilst stingless bee called pot-pollen which made from pollen that the foragers collect from plant flowers (Absy et al. 2018; Agus et al. 2019b; Agussalim and Agus 2022; Supeno et al. 2022). Propolis is made from resin as the raw material, which is obtained from plants (Agussalim and Agus 2022). However, the propolis is composed of resins (balsams) ranging from 45 to 55%, waxes and fatty acids 25 to 35%, essential oils 10%, pollen 5%, and mineral and other organic materials 5% (Cherbuliez 2013). The bees use propolis for several functions, such as the made entrance, constructing brood cells, embalming the hive's hole, to make honey and pollen pots. Another function of propolis is to protect their hive from various diseases, pests, viruses, bacteria, and fungi and to mummify killed invading animals in the hive (Bankova et al. 2000; Cherbuliez 2013; Michener 2013; Agussalim and Agus 2022).

Nowadays, beekeepers usually select the stingless bee with high productivity and the process of beekeeping the stingless bee is called meliponiculture. For example, *Tetragonula biroi* (Friese, 1898) is mainly found on Sulawesi Island or called Sulawesi endemic stingless bee (Suhri et al. 2021). However, Kahono et al. (2018) reported that *T. biroi* is also found in Papua. Suhri et al. (2021) reported that the foraging activity of *T. biroi* is significantly lower at the introduced habitat in Bantul, Purworejo, and Magelang (Java) than in Luwu and Bone (Sulawesi) which is impacts greatly decreased the honey production. The introduction of the *T. biroi* by the beekeepers in West Lombok, Indonesia, aims to obtain higher honey production and propolis to improve and increase their income. However, West

Lombok (West Nusa Tenggara) is located in the same line with Sulawesi as the origin or endemic of *T. biroi*, namely the Wallace line (Ali and Heaney 2021). This line indicates Sulawesi and West Lombok have similar environmental conditions and animal characteristics to support the optimal production of the stingless bee *T. biroi*. Moreover, *Tetragonula sapiens* (Cockerell, 1911) and *Tetragonula clypearis* (Friese, 1908) are also found in origin or endemic from Lombok Island. However, Kahono et al. (2018) reported that *T. sapiens* is also found in Ambon and Papua, whilst *T. clypearis* also found in Maluku and Papua.

The honey production of stingless bee *Tetragonula* sp., which is meliponiculture in the coffee plantation in North Batukliang Sub-district, Central Lombok District, is 5.74 g/5 months (Supeno et al. 2021), 9.18 mL/month from the bamboo hive and 18.72 mL/month from the box hive for stingless bee *Tetragonula* sp. which is meliponiculture in North Lombok (Erwan et al. 2020). However, honey production of *T. clypearis* which is meliponiculture in the yard and rice field at Lembah Sari Village (Batulayar Sub-district, West Lombok District), ranges from 153.2 to 164.2 mL/4 months (Supeno et al. 2022). Furthermore, the production of honey from *Tetragonula laeviceps* (Smith, 1857) which is meliponiculture in Sleman, Yogyakarta, ranges from 60 to 263 mL/4 months (79.2 to 328 g/4 months) (Agussalim et al. 2020; Agussalim and Agus 2022). In addition, Suhri et al. (2021) reported that the honey production of *T.* cf. *biroi* in Purworejo is 500 mL/colony/8 months, in Bantul has never been harvested started from introduced in 2018. However, in Sulawesi, the endemic of the *T.* cf. *biroi* can produce honey 2,030 mL/colony for two moths meliponiculture. Furthermore, Abduh et al. (2020) reported that propolis production from *T. laeviceps* ranges from 4.26 to 4.54 g/month, meliponiculture in Cibeusi Village (Subang, West Java). Erwan et al. (2021b) reported that propolis production from honey pots of stingless bee *Tetragonula* sp. from North Lombok is 7.40 g/hive/month for box hive, whilst in bamboo hive is 3.28 g/hive/month. Based on the previous study showed that a lack of information has been reported about the productivity of three species of stingless bees, *T. sapiens*, *T. clypearis*, and *T. biroi* especially in Batu Mekar Village as one of the meliponiculture centers in Lingsar Sub-district, West Lombok District (West Nusa Tenggara). Therefore, this study aims to evaluate the productivity of *T. sapiens*, *T. clypearis*, and *T. biroi*, managed under the same feed sources for meliponiculture.

MATERIALS AND METHODS

Study area

This study was performed in the Trigona Garden farm (8º32'37"S 116º12'08"E) in Batu Mekar Village, Lingsar Sub-district, West Lombok District, West Nusa Tenggara, Indonesia. We selected Trigona Garden farm as the location of this study because this farm is one of the meliponiculture centers in Lingsar Sub-district and was supported by various plant types as the bee feed to support the high productivity of stingless bees. We used fifteen stingless bee colonies divided into three groups: *T. sapiens*, *T. clypearis*, and *T. biroi*. Each group consisted of five stingless bees' colonies as the replications and were meliponiculture for two months to determine their productivity because the beekeepers in West Lombok were usually honey harvested for two months. The boxes were used to meliponiculture; all stingless bees were similar in size, namely length of 30 cm, width of 15 cm, and height of 12 cm. In addition, the colonies were placed in a bee house directly to feed sources on three stacked shelves (Figure 1).

Procedures

Bee forages inventory

Plant types as the nectar and pollen sources for the stingless bee's food were identified at a distance of 150 meters around the meliponiculture location. Identifying nectar and pollen was done by the method described by Agussalim et al. (2017, 2018). Briefly, one or two flower samples were taken, and the petals of the flower were removed. Afterward, checking nectar availability in the base of flowers was characterized by the presence of sweet fluid. Furthermore, plant flower pollen was checked in the anthers in the form of powder or flour and generally was a yellow color. When collecting nectar, the foragers usually visit one flower was required for 1 to 3 seconds, and after that, they move to other flowers until their honey sack (honey stomach) is full. When the foragers collect pollen, they visit flowers and repeatedly stick their bodies to flowers. Afterward, the pollen which was stuck in their body was collected by a pollen brush located in their hind legs and stored in the corbicula.

Foragers exit activity

The foragers' exit activity from the hives was counted using hand counter check at 7:00 am WITA (central Indonesian time) and at 3.00 pm WITA each for ten minutes per hive for 15 hives were used in the study. The foragers' exit activity was counted at a distance of 1.5 meters from the bee house (Agus et al. 2019b; Erwan et al. 2020, 2021b). At the time of observation, the temperature and humidity of the environment were measured using a thermo-hygrometer also were observed.

Figure 1. Bee house was used to place the stingless bees' colonies, *T. sapiens* (top rack), *T. clypearis* (middle rack) and *T. biroi* (bottom rack) in the study

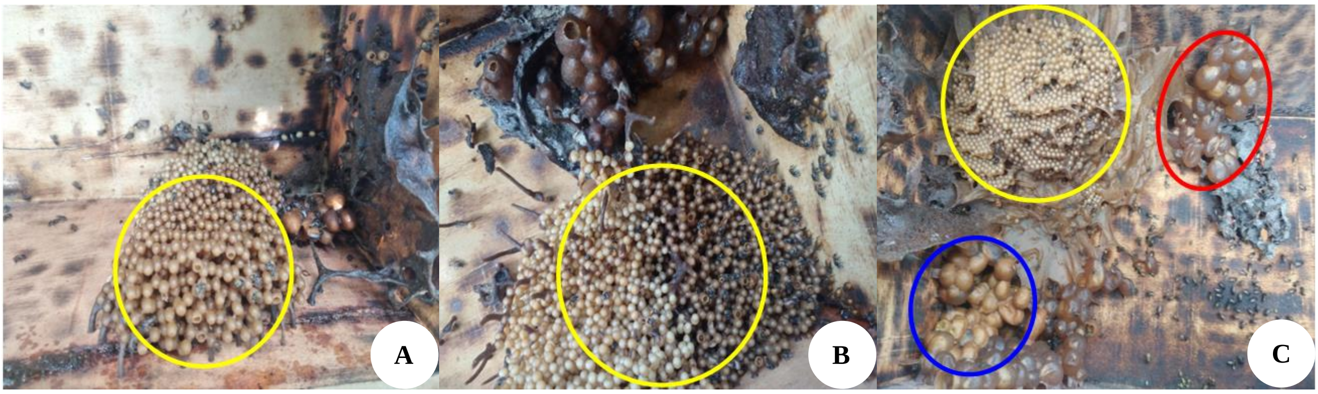

Figure 2. Colonies of stingless bees: A. *T. sapiens*, B. *T. clypearis*, and C. *T. biroi*. Yellow circles were brood cells, the red circle was honey pots, and the blue circle was pollen pots.

Honey and pollen pots number

Honey pots (Figure 2 was marked by the red circle) and pollen pots (Figure 2 was marked by the blue circle) were counted directly to the box hives by using hand counter check every two weeks.

Brood cell number

Brood cell numbers (Figure 2 was marked by yellow circles) were counted directly in the box hives by using a hand counter checks every two weeks. The counting of brood cell numbers was performed in the afternoon when the bee workers were not too aggressive. The mature brood cells were marked by cream color, and the young brood cells by brown color.

Production of honey, propolis, and pot-pollen

Honey pots were cut using a knife and stored in a plastic glass. Afterward, honey pots were squeezed to separate honey and propolis. Furthermore, the honey volume was measured by the graduated cylinder (Agussalim et al. 2020; Erwan et al. 2020). Clean propolis, which was separated from honey, was measured by digital scales with an accuracy of 0.1 g (Agussalim et al. 2020; Erwan et al. 2021b). Pollen pots were separated from propolis, and pot-pollen was measured by digital scale (Agus et al. 2019b; Supeno et al. 2022).

Data analysis

The data on foragers' activity, honey pot number, pollen pot number, brood cell number, and production (honey, propolis, and pot-pollen) were normalized by log-transformed (Log10). All data were analyzed by using one-way Analysis of Variance (ANOVA) using SPSS version 23, followed by Tukey's test. The plant types as the bee forages, temperature, and humidity, were analyzed by descriptive analysis.

RESULTS AND DISCUSSIONS

Trigona Garden farm conditions

The results showed that the temperature and humidity of Trigona Garden farm ranged from 27.50 to 29.26°C and 53.00 to 63.14%, respectively (Table 1). This results in temperature and humidity, including normal category, to support optimal growth and development colony of stingless bees (Agussalim et al. 2020). The temperature and humidity determine the quality of nectar that a bee's forager can collect. For example, the high sugar content with low moisture of nectar when high temperature and low humidity but low sugar content with high moisture when low temperature and high humidity (Agussalim et al. 2019a; Agussalim and Agus 2022). The temperature and humidity in our study differed from Agussalim et al. (2020) in that the stingless bee *T. laeviceps* can optimally produce honey and propolis at ranges from 23.4 to 35.3°C and 41.50 to 85.3%, respectively.

The high temperature impacted the decreased all bees' activities, such as foragers in the field when they collected nectar and pollen, nurse workers in the hive when carrying the queen bee and all brood cells, and also interfered activity of the bees workers when production of honey, pot-pollen, and propolis. Dantas (2016) reported that the activity of stingless bees in the hives increased when the temperature for about 36 to 40°C. Furthermore, Roubik (2006) explained that the lethal temperature for *Tetragonula carbonaria* (Smith, 1854) of 46°C and 41°C for *Scaptotrigona postica* (Latreille, 1807). In addition, Macías-Macías et al. (2011) found that the imago and pupae from three species *Melipona colimana* (Ayala, 1999), *M. Beecheii* (Bennett, 1831), and *Scaptotrigona hellwegeri* (Friese, 1900) are more deaths at low temperatures, namely under 7°C, than high temperatures 25 to 40°C. However, the three species are more tolerant, with the minimum death at temperatures 25 to 40°C. Halcroft et al. (2013a) also reported that the stingless bee *Austroplebeia australis* could survive and develop well at extreme temperatures (-0.4 to 37.6°C).

Bee forages

The recent results showed that the plant types as the bee forages in the Trigona Garden farm are divided into three groups consisting of nectar source namely *rambutan* (*Nephelium lappaceum* L.) and mango (*Mangifera indica* L.), pollen source namely sunflower (*Helianthus annuus* L.), Mexican sunflower (*Tithonia rotundifolia* (Mill.) S.F.Blake), and jackfruit (*Artocarpus heterophyllus* Lam.), both nectar and pollen namely coconut (*Cocos nucifera* L.), longan (*Dimocarpus longan* Lour.), water apple (*Syzygium* *samarangense* (Blume) Merr. & L.M.Perry), bride's tears (*Antigonon leptopus* Hook. & Arn.), xanthostemon (*Xanthostemon chrysanthus* (F.Muell.) Benth.), red Batavia flower (*Jatropha pandurifolia* Andrews), banana (*Musa paradisiaca* L.), and papaya (*Carica papaya* L.), resin source namely mango, banana, jackfruit, papaya, and mulberry (*Morus alba* L.) (Table 2). Nectar is collected by the foragers from plant flowers or sap (sugar palm plant) and used by bee workers to produce honey. Pollen is collected by the foragers from plant flowers and used to produce pollen and bee bread as the main protein source (Agussalim et al. 2017, 2018; Erwan et al. 2020, 2021a, 2022; Agussalim and Agus 2022; Erwan and Agussalim 2022; Supeno et al. 2022). Furthermore, the resin was used by the bee workers to produce propolis which was used by the stingless bees to construct the entrance, hive construction, and make honey and pollen pots. In addition, another function of propolis is to embalm all hive surfaces, especially the hole, construct brood cells, and protect the hive from viruses, bacteria, and fungi (Bankova et al. 2000; Cherbuliez 2013; Michener 2013; Agussalim et al. 2020; Erwan et al. 2021b; Agussalim and Agus 2022).

All plant types (Table 2) have different flowering times, except coconut and bride's tears can bloom and flower all year to fulfill nectar and pollen for stingless bees in the Trigona Garden farm. Coconut is one of the potential plants as the nectar and pollen sources to support the sustainable production of honey, pollen, and bee bread (Agussalim et al. 2017, 2018). The queen bee uses pollen to improve its productivity to produce more eggs as the workers, drones, and queen candidates. In addition, Lo et al. (2019) explained that the food quantity which is provided by nurse workers to the brood cells would determine whether the queen genetically can develop the full queen.

Foragers exit activity

The recent results showed that the different stingless bee species had a high effect on the exit activities in the morning and afternoon ($p<0.01$) (Table 3). The morning exit activity from the *T. biroi* was higher than *T. sapiens* and *T. clypearis*; however, the morning exit activity from *T. sapiens* and *T. clypearis* was similar. The afternoon exit activity from the *T. biroi* was the highest, followed by *T. clypearis* and the lowest was *T. sapiens* (Table 3). The exit activity of the forager bees aims to collect some materials such as nectar to produce honey, pollen to produce pot-pollen, resin to produce propolis, and water. Furthermore, these materials were brought into hives which were transferred to workers whose job was to produce honey, pot pollen, and propolis (Erwan et al. 2020, 2021b).

The foragers' activity in the field when they collect nectar, pollen, and resin depends on the environmental conditions. For example, when it rains, the forager bees do not exit the hives, and dos activities in the hives (Agussalim and Agus 2022). Furthermore, when the high temperature of the environment decreases, the bee activities require higher energy when they fly to collect food from the plant flowers compared to the normal temperature. The foragers' exit activity in our study differed from our previous studies. Erwan et al. (2021b) reported that the foragers' exit activity from the hive *Tetragonula* sp. in the morning ranges from 34.7 to 37.5 times/5 minutes and 24.9 to 25.5 times/5 minutes in the afternoon for the bamboo hive. Whilst box hive ranges from 49.2 to 51.3 times/5 minutes in the morning and 29.2 to 29.6 times/5 minutes in the afternoon.

Furthermore, Erwan et al. (2020) reported that the exit activity of foragers from the stingless bee *Tetragonula* sp. is 36.6 times/5 minutes in the morning and 25.3 times/5 minutes in the afternoon for the bamboo hive. Whilst in the box hive is 50.1 times/5 minutes in the morning and 29.3 times/5 minutes. In addition, Agus et al. (2019b) also reported that foragers of the *T. laeviceps* bring in pollen in the morning from various bee hives sizes ranging from 20.15 to 25.36 times/5 minutes and 12.19 to 12.85 times/5 minutes in the afternoon.

Brood cell number

The recent results showed that the different stingless bee species had a high effect on the brood cell number ($p<0.01$) (Table 3). The higher brood cell number was found in the *T. biroi* followed by *T. clypearis* and *T. sapiens*. However, the brood cell number from *T. clypearis* and *T. sapiens* were similar (Table 3). The higher brood cell number in *T. biroi* was supported by the higher exit activities in the morning and afternoon than that *T. clypearis* and *T. sapiens* (Table 3). The brood cell number from each colony indicates the productivity of each queen bee to produce much more eggs, whereas *T. biroi* queen is more productive in producing eggs which impacts higher brood cell number than in *T. sapiens* and *T. clypearis*. In addition, the brood cell number will be described as the number of workers in the colony, whereas the higher brood cell number will be impacted by the higher number of workers. Furthermore, the brood cells are hatches and become workers when their eggs are fertilized but drones from the unfertilized eggs (Supeno et al. 2022). The brood cells from three species of stingless bees in our study differed from the previous study. Supeno et al. (2022) reported that the brood cell number from *T. clypearis,* which is meliponiculture in the yard and rice field, ranged from 2,731 to 3,121 cells and 2,739 to 3,112 cells, respectively. The brood cell number is influenced by the availability of food in the hive, foragers number which is collect nectar and pollen as the food source, and the availability of plants as the nectar and pollen sources for the bee food (Agussalim and Agus 2022; Supeno et al. 2022).

Table 1. The Trigona Garden farm conditions, temperature, and humidity

Weeks	Temperature (°C)	Humidity (%)
1	28.43±0.45	58.86±1.76
2	27.50±0.45	60.00±1.56
3	28.36±0.44	56.43±1.70
4	29.14±0.47	56.43±2.43
5	29.26±0.39	53.00±2.44
6	28.16±0.31	58.71±1.50
7	27.77±0.48	61.71±2.73
8	27.67±0.39	63.14±2.24

Note: Data was presented in the mean±Standard Error of the Mean (SEM)

Table 2. Plant types as the bee forages in the Trigona Garden farm

Plant types	Scientific name	Feed source	Resin source
Rambutan	*Nephelium lappaceum*	Nectar	-
Coconut	*Cocos nucifera*	Nectar and pollen	-
Longan	*Dimocarpus longan*	Nectar and pollen	-
Water apple	*Syzygium samarangense*	Nectar and pollen	-
Bride's tears	*Antigonon leptopus*	Nectar and pollen	-
Xanthostemon	*Xanthostemon chrysanthus*	Nectar and pollen	-
Mango	*Mangifera indica*	Nectar	Resin
Sunflower	*Helianthus annuus*	Pollen	-
Mexican sunflower	*Tithonia rotundifolia*	Pollen	-
Red Batavia flower	*Jatropha pandurifolia*	Nectar and pollen	-
Banana	*Musa paradisiaca*	Nectar and pollen	Resin
Sugar palm	*Arenga pinnata*	Sap and pollen	-
Mulberry	*Morus alba*	-	Resin
Jackfruit	*Artocarpus heterophyllus*	Pollen	Resin
Papaya	*Carica papaya*	Nectar and pollen	Resin

Table 3. The means of forager's exit activity, number of honey pots, pollen pots, and brood cells from three species of stingless bees

Parameters	*T. sapiens*	*T. clypearis*	*T. biroi*	SEM	*p*-value
Morning exit activity (times/10 minutes)	22.85^{b}	31.70^{b}	55.00^{a}	4.44	0.005
Afternoon exit activity (times/10 minutes)	19.78^{c}	25.65^{b}	38.18^{a}	2.30	<0.001
Honey pot number (pots)	9.19^{b}	10.26^{ab}	16.88^{a}	1.30	0.022
Pollen pot number (pots)	3.88	3.68	6.15	0.52	0.229
Brood cell number (eggs)	164.92^{b}	263.68^{b}	455.20^{a}	29.25	<0.001

Note: ^{a,b,c}Different superscripts within rows indicate differences at p<0.05 and at p<0.01; SEM = Standard Error of the Mean

Honey and pollen pots number

The recent results showed that honey pot number was affected by the stingless bees' species (p<0.05) but not by pollen pot number (p>0.05). The higher honey pot number was found in the *T. biroi* than *T. sapiens*. However, the honey pot number from *T. biroi* was similar to *T. clypearis*, and also *T. clypearis* was similar to *T. sapiens* (Table 3). The higher honey pot number in *T. biroi* was supported by the higher activities exit in the morning and afternoon than *T. clypearis* and *T. sapiens* (Table 3). The placement of hives on the first to third racks has no effect on honey and pollen pot numbers (Erwan et al. 2020; Agussalim and Agus 2022; Supeno et al. 2022). The recent honey pot number from three species of stingless bees (*T*. sapiens, *T. clypearis*, and *T. biroi*) differed from the previous study. Erwan et al. (2020) reported that the honey pot number from the stingless bee *Tetragonula* sp., which was meliponiculture for one-month, is 42.17 pots from the bamboo hive and 70.7 pots from the boxes hive. The production of honey and pollen pot number from stingless bees is affected by the number of foragers which collect nectar from plant flowers, the availability and flowering period of plants as the nectar source, bee species, and the environmental conditions (temperature and humidity). In addition, resin sources from plants are available as the raw material to produce propolis to make pots to store honey and pot-pollen (Agussalim and Agus 2022).

Production of honey, propolis, and pot-pollen

The recent results showed that the production of honey and propolis was affected by stingless bees' species (p<0.05) but not the pot-pollen production (Table 4). The higher honey production was found in the *T. biroi*, followed by *T. sapiens* and *T. clypearis*. However, the production of honey *T. sapiens* and *T. clypearis* were similar (Table 4). The higher production of honey in *T. biroi* was supported by higher honey pot number, exit activities in the morning and afternoon, and brood cell number than *T. clypearis* and *T. sapiens* (Table 3). The honey production is supported by the forager's number, characterized by the brood cell number whose job is to collect nectar from various plant flowers (Table 2).

The production of honey in our study (Table 4) was different from previous studies. Honey production from *T. laeviceps* which is meliponiculture, for four months in the Faculty of Animal Science (Universitas Gadjah Mada, Yogyakarta) ranges from 60 to 263 ml or 79.2 to 328 g (Agussalim et al. 2020; Agussalim and Agus 2022). The total honey production from the *Tetragonula* sp. is 9.18 mL/month for the bamboo hives and 18.72 mL/month for the box hive (Erwan et al. 2020). In addition, Supeno et al. (2022) reported that honey production from *T. clypearis*, which is meliponiculture for four months in the yard and rice field ranges from 153.2 to 164.2 mL and 153.2 to 160.5 mL, respectively. Furthermore, honey production from *Tetragonula* sp., which is meliponiculture in coffee plantations, is 3.74 g/5 months (Supeno et al. 2021). Halcroft et al. (2013b) reported that honey production from Australian stingless bees (not specific species), which is meliponiculture by the beekeepers in Queensland and northern New South Wales, is approximately 1 kg/year/hive.

Table 4. Production of honey, pot-pollen, and propolis from three species of stingless bees

Parameters	*T. sapiens*	*T. clypearis*	*T. biroi*	SEM	*p*-value
Production of honey (mL/2 months)	29.75^{ab}	27.60^{b}	59.75^{a}	5.94	0.039
Production of pot-pollen (g/2 months)	10.50	9.60	18.60	2.59	0.543
Production of propolis (g/2 months)	12.40^{b}	12.60^{ab}	26.00^{a}	2.51	0.029

Note: ^{a,b}Different superscripts within rows indicate differences at $p<0.05$; SEM = standard error of the mean

Furthermore, Chuttong et al. (2014) also reported that honey production of stingless bees from Thailand (not specific species) is average 500 g/year/hive. Whilst honey production from six stingless bee species (*Melipona brachychaeta* (Moure, 1950), *M. grandis* (Guérin-Méneville, 1844), *Scaptotrigona depilis* (Moure, 1942), *S. polysticta* (Moure, 1950), *S.* near *xanthotricha* (Moure, 1950), and *Tetragonisca fiebrigi* (Schwarz, 1938)) in Bolivia is average 3 kg/year/hive (Ferrufino and Vit 2013). Different production of honey depends on the stingless bee species, which is related to their activity when they collect nectar and the availability of plant types as the nectar sources and flowering period of plants (Agussalim and Agus 2022).

Propolis production was higher in *T. biroi* followed by *T. clypearis* and *T. sapiens*. However, propolis production in *T. clypearis* and *T. sapiens* was similar. Propolis production is supported by the foragers number, whose job is to collect resin from the plants (Table 2). The forager numbers are characterized by the number of brood cells, whereas in *T. biroi* was higher than *T. sapiens* and *T. clypearis* (Table 3). The production of propolis was positively correlated with the production of honey because honey was wrapped by the propolis (Agussalim et al. 2020; Erwan et al. 2021b; Agussalim and Agus 2022). Production of propolis in our study (Table 4) differed from previous studies. Erwan et al. (2021b) reported that the propolis production from the *Tetragonula* sp. is 3.28 g/month for bamboo hives and 7.40 g/month for box hives. Furthermore, Abduh et al. (2020) reported production of propolis from *T. laeviceps* ranges from 4.26 to 4.54 g/month. Production of propolis from *T. laeviceps* which meliponiculture for four months ranges from 15.4 to 77.2 g (Agussalim et al. 2020). Furthermore, the production of propolis is 4 kg/year/hive, which is obtained from six stingless bee species (*M. brachychaeta*, *M. grandis*, *S. depilis*, *S. polysticta*, *S.* near *xanthotricha*, and *T. fiebrigi*) (Ferrufino and Vit 2013). Erwan et al. (2021b) reported that the production of propolis from honey pots of stingless bee *Tetragonula* sp. from North Lombok is 7.40 g/hive/month for box hive, whilst in bamboo hive is 3.28 g/hive/month. Different propolis production depends on the stingless bee species, which is related to their activity to collect resin and the availability of plants as resin sources (Agussalim and Agus 2022).

The similar production of pot-pollen from three stingless bees was also supported by the similar pollen pot number produced by three stingless bee species (Table 3). However, the exit activities in the morning and afternoon among the stingless bee species differed. Still, our study needs to differentiate between the foragers, who collect pollen with nectar and resin. Production of pot pollen in our study (Table 4) differed from previous studies. Production of pot-pollen from *T. laeviceps* meliponilculture in various boxes for two months ranges from 1.02 to 4.56 (Agus et al. 2019b). Furthermore, Supeno et al. (2022) reported the production of pot-pollen from *T. clypearis*, which was meliponiculture for four months in the yard and rice field, ranging from 43.3 to 46.7 g and 43.5 to 44.1 g, respectively. In addition, production of pot-pollen from six stingless bee species (*M. brachychaeta*, *M. grandis*, *S. depilis*, *S. polysticta*, *S.* near *xanthotricha*, and *T. fiebrigi*) is 2 kg/year/hive (Ferrufino and Vit 2013). It can be concluded that the productivity of the stingless bee *T. biroi* is higher than *T. sapiens* and *T. clypearis*. However, the productivity of *T. sapiens* and *T. clypearis* is similar.

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