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Foraging Preference of Pollen by Stingless Bee at Three Types of Land Use in Lombok Island

Preferensi Polen Sumber Pakan Lebah Kelulut pada Tiga Tipe Penggunaan Lahan di Pulau Lombok

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ABSTRACT

The success of stingless beekeeping was determined by site suitability and the availability of floral sources. Bee forage was also an important requirement used to improve the qualities and quantities of its products. Information about specific forage plants in different land uses was needed to make the plants sufficient. Therefore, this study aimed to examine forage preference for stingless bees in different land use areas. The location used was categorized into three types, namely agroecosystems, forests, and settlements. The pollen samples were analyzed with acetolysis and then identified. The results showed four species of stingless bees, namely Tetragonula fuscobalteata, T. laeviceps, and T. clypearis, as well as Heterotrigona erythrogastra. T. fuscobalteata was mostly cultivated in the settlements, T. laeviceps and T. clypearis were cultivated in the agroecosystems, while H. erythrogastra was mostly found near the forest. The identification of pollen showed that the favorite feed plants of Tetragonula were Bromeliaceae and Cyperaceae, while the forage preference for H. erythrogastra was Rubiaceae. The Principal Component Analysis revealed that the bees' preference was influenced by the availability of forage sources. Based on the results, stingless bees did not have specific forage plants, but foraging was often carried out to provide an abundance of potential plants around their hives.

KATA KUNCI
kelulut, polen, preferensi, pakan

INTISARI

Keberhasilan budidaya lebah kelulut didukung oleh kesesuaian lokasi budi daya dan ketersediaan sumber pakan. Pakan lebah syarat penting menjamin kualitas dan kuantitas produk-produk kelulut. Informasi jenis tumbuhan pakan lebah di berbagai penggunaan lahan diperlukan untuk menyediakan tumbuhan pakan yang cukup. Penelitian ini bertujuan untuk mengetahui preferensi pakan lebah kelulut di beberapa penggunaan lahan yang berbeda. Lokasi penelitian dikelompokkan menjadi tiga tipe lahan yaitu agroekosistem, hutan dan permukiman. Polen dianalisis dengan metode asetolisis dan diidentifikasi. Hasil penelitian menemukan empat jenis kelulut yang teridentifikasi yaitu Tetragonula fuscobalteata, T. laeviceps, T. clypearis, dan Heterotrigona erythrogastra. T. fuscobalteata banyak dibudidayakan di wilayah permukiman, T. laeviceps dan T. clypearis banyak dibudidayakan di daerah agroekosistem, sedangkan H. erythrogastra dibudidayakan di dekat kawasan hutan. Jenis polen yang menjadi kesukaan genus Tetragonula berasal dari famili Bromeliaceae dan Cyperaceae, sedangkan untuk jenis H. erythrogastra, Rubiaceae adalah famili tanaman yang disukai sebagai sumber pakan. Hasil Principal Component Analysis memperlihatkan bahwa preferensi pakan oleh kelulut budidaya dipengaruhi oleh ketersediaan sumber pakan. Berdasarkan hasil-hasil tersebut dapat disimpulkan bahwa kelulut tidak memiliki preferensi pakan yang spesifik akan tetapi lebih memilih sumber pakan yang banyak tersedia di sekitar sarang.

Introduction

Stingless bees are a group of harmless bees with malfunctioning stings (Michener 2012), and there are 40 different species from several genera in Indonesia. Furthermore, several species have been cultivated, including *Heterotrigona itama*, *Tetragonula biroi*, and *Tetragonula laeviceps* (Harjanto et al. 2020). The success of stingless beekeeping depends on the suitability of the cultivation sites and the availability of forage in their surroundings. The locations that have sufficient water sources and forage plants have a higher chance of successful cultivation. Habitats with high density and plant species can also attract and increase the presence of bees (Creswell & Miller 2000). The availability of sufficient forage around the hives also ensures the existence of the stingless bee population in the cultivation location, while their insufficiency can cause further flight distance for foraging. Therefore, information about the distribution of forage, their potency, and the flight ability of stingless bees are very important as initial information for beekeepers to manage beekeeping activities.

Feeds are materials that can be eaten, digested, and used by living organisms (Tilman et al. 2011). They are also needed for survival, for example, insects, such as stingless bees need feed to live, grow and reproduce. The feed sources are one of the major factors that determine the production rate of beekeeping products (Rismayanti 2014). The availability of a sufficient amount can also provide economic benefits for farmers to increase their income (Yanto et al. 2016). To determine the worth of a bee product, it is necessary to know the type of forage plants consumed (Banowu 2016).

The three types of honey bees forage are nectar, sap, and pollen. Nectar is a sweet liquid that is secreted by the nectar glands of plants, which develop on the flowers, leaves, and stems (Agussalim et al. 2017), while the sap is a concentrated liquid substance obtained from sticks, fruits, and other sticky plant parts (KBBI-Kamus Besar Bahasa Indonesia 2018). Pollen is a powdery product produced by the male genitalia of plants (Agussalim et al. 2017). These types of forage are often processed by stingless bees to produce different products, such as honey, propolis, and pollen.

The ability of these insects to obtain their feed still depends on the availability of natural foods, namely plants growing without human intervention. The availability of these plants is influenced by the flowering period. Bees often experience a difficult time during the post-flowering season when only a small amount of nectar is available. Therefore, it is important to provide additional information on the types of plants that have the potential to become forage and can be planted around cultivation sites. This is expected to increase the forage supply for cultivation when natural flora is not blooming.

Pollen is a substance that is accidentally carried away by stingless bees when visiting flowers (Dahlia et al. 2019). The collection and analysis of pollen carried are often used to identify the types of plants visited and favored by the insects (Topitzhofer et al. 2021). The diversity and abundance of their sources are important to provide adequate nutrients for bee colonies (Lau et al. 2019), but there are limited studies on pollen sources for stingless bees.

At cultivation sites, the ability of these insects to visit the flowers considered as food sources is influenced by the availability of forage surrounding the hives (Pratama et al. 2018). However, when the plants are insufficient to fulfill their needs, they fly further to find forages. Smith et al. (2017) stated that the foraging ability of the stingless bee was up to 500 m from the hives, but they can fly beyond this range to meet their demands. They also use all potential plants as forage, but the types of plants with the potential to become feed on each land use area have several characteristics. For example, the agroecosystem is dominated by rice, cassava, corn, and plantation crops (Fellica et al. 2019), while forests are often dominated by woody plants, such as candlenut, rajumas, sengon, and other plants (Oktaviyani et al. 2017). Residential areas contain many ornamental plants and fruit trees planted by the community.

The information about the forages in different environments for stingless bees is needed by beekeepers to provide sufficient pollen sources as well as enhance honey production. Therefore, this study aimed to determine the types of forage plants or flowers visited by stingless bees and the pollen carried into their hives. The results can serve as information for farmers to enrich the types of forage around their cultivation locations.

Methods

Materials

The tools used in this study were GPS, Eppendorf tube, plastic, camera, and stationary, while the materials were stingless bees, pollen, and alcohol.

Locations

This study was carried out in four districts on Lombok Island, namely North Lombok, West Lombok, East Lombok and Central Lombok, from November 2017 to March 2018. The samples were identified at the Laboratory of Biological Control, Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University.

Lombok Island has an area of 7,707.25 km^2 and was divided into four regencies and one city, namely North Lombok, West Lombok, East Lombok and Central Lombok, as well as Mataram City. However, this study was only carried out in the four regencies. The locations of beekeeping in Mataram City were not sampled because the cultivated colonies were not found. The study sites selected were the stingless beekeeping areas, which were located within a radius of five meters from the agro-ecosystem, forest, and settlement land. The classification of land-use types was observed through satellite images at a radius of 500 m, and they were categorized as follows:

a. Agroecosystems were dominated by lands modified by humans to increase economic income. The criteria for these areas was 45% to 50% of land cover consisting of paddy fields or plantations with non-forest vegetation.
b. Forests were the areas containing many plants with a diameter > 50 cm, a wide canopy, and periodic flowering periods. When viewed from the satellite images, the criteria for these areas were dark green color. The lands were categorized as forests when 70% of the appearance of the satellite image was covered with tree canopies.
c. Settlements were the urban and rural areas, which served as the residential areas and places of public activities. The criteria were approximately 45% of the land was dominated by houses and small areas of trees.

Sampling of Study Location

The sampling locations consisted of three land use types, namely agroecosystems, forests, and settlements, which were determined using the snowball information method. Furthermore, this method looked for one source of information and finding others based on the information obtained from the initial source. The coordinated sampling locations were recorded and mapped using a GPS (Global Positioning System), type Garmin GPSMAP 76CSx. The sampling locations were then divided into nine agroecosystems, seven forests, and 10 settlement areas.

Sampling of Pollen

The pollen samples were collected from artificial hives in November 2017 and February 2018. This process was carried out to obtain data on plants visited by the stingless bees. The samples were directly taken from the hive using tweezers and then placed in a labeled Eppendorf tube, as shown in Figure 1.

Figure 1. The samples of pollen were taken from the artificial hives

Stingless bee Identification

Identification of stingless bees was carried out based on the method proposed by Jalil and Shuib (2012). The first step was to examine the cuticle tesselation, when the dorsal part does not contain yellow scales, proceed to the second step. The mandible of the samples was also examined, and when it contained one tooth, it was included in the Genus Heterotrigona. However, when two teeth were observed, the third step was performed. The next step was identification by observing the teeth or denticles. The samples were identified by examining the wing membrane, wing hamuli, scutellum, malar space, propodeum, rear tibia hairs, and hind basitarsis.

Pollen Identification

The technique used for pollen identification was adopted from Huang (1972), namely palynology using the acetolysis method. The pollen samples were placed in cuspidal tubes, followed by the addition of one ml of 10% KOH. This was carried out to remove the organic matter on samples as well as to make the walls visible. Subsequently, they were centrifuged for 10 min at 3,500 rpm. The KOH liquid was then discarded and the samples were washed using distilled water. They were washed by centrifuging using distilled water for 10 min at 3,500 rpm with two replications.

A total of one ml glacial acetic acid was added to the pollen, and then centrifuged for 10 min at 3,500 rpm. The supernatant solution obtained was removed and one ml mixture of 100% acetic anhydrous and 100% acetic acid (H_2SO_4) in a ratio of 9:1 was added. The solution was heated at a temperature of 90°C to 95°C for five minutes and centrifuged for 10 minutes at 3,500 rpm. The supernatant was removed and one ml of glacial acetic acid was added, followed by centrifugation for 10 min at 3,500 rpm. The sediment was washed with distilled water two to three times with centrifugation for 10 min at 3,500 rpm. Subsequently, the supernatant solution was removed and the samples were prepared by adding 30% glycerin jelly. The preparations obtained were then examined under a light microscope. The parameters observed were the shape and the plant family of the pollen samples (Huang 1972). The observation results were identified using the Pollen Atlas (Willard et al. 2004) and others identification articles.

Data Analysis

The pollen families at each location were identified and presented in a graphical form, after which it was analyzed descriptively. The relationship between stingless bee forage preference and land use type was analyzed with the Principal Component Analysis (PCA) using XLSTAT.

Results and Discussion

Land Type and Species of Stingless Bee

The identification results of stingless bee samples on Lombok Island showed that there were four species, namely *Heterotrigona erythrogastra*, as well as *Tetragonula clypearis*, *T. fuscobalteata,* and *T. laeviceps*. These four species were found in the hives and cultivated in three types of ecosystems in Lombok. A previous study identified *T. clypearis* as a cultivated stingless bee in Lombok (Wahyuni et al. 2020), but this present study found two species of *Tetragonula* and one species of *Heterotrigona* in the same area. These findings could be used as additional information about the cultivated stingless bees on the island. In the agroecosystem lands, three species had the potential to be cultivated, namely *T. clypearis, T. fuscobalteata*, and *T. laeviceps*. Meanwhile, all types of stingless bees were identified in the forests and settlement areas.

H. erythrogastra was cultivated in the areas around forests and settlements but was absent in the agroecosystems. This might be because it had a high sensitivity to the surrounding environment after the use of pesticides. This finding was consistent with Boff et al. (2018) that the application of pesticides at certain doses interfered with the navigation system of worker bees. This species was dominant in cultivation areas around forests, while some hives were found in settlements. There were limited reports on *H. erythrogastra,* and previous studies revealed that it was only found in Kalimantan (Kahono et al. 2018). Tuksitha et al. (2018) also stated that the species was native to Borneo and only found in East Lombok Regency. *H. erythrogastra* has a mandible with one tooth, and seven hamuli on the wings. Furthermore, the wing membrane has a bright orange color, and the abdomen was reddish with thin borders on each segment (Jalil & Ibrahim 2012).

Tetragonula clypearis has a bicolorous body, the thorax was black, while its abdomen has a yellowish to brownish color (Smith et al. 2017). This species of stingless bee was widely cultivated in areas close to the agroecosystem, as shown in Figure 2. This was consistent with Sulistia et al. (2016) that *T. clypearis* was commonly found in agroforestry areas, due to the presence of sufficient forage that supported its colony survival.

Tetragonula fuscobalteata was usually cultivated in sites surrounding settlement areas. This species of stingless bee was the smallest among others (Sakagami 1978), and it adapted to human activities.

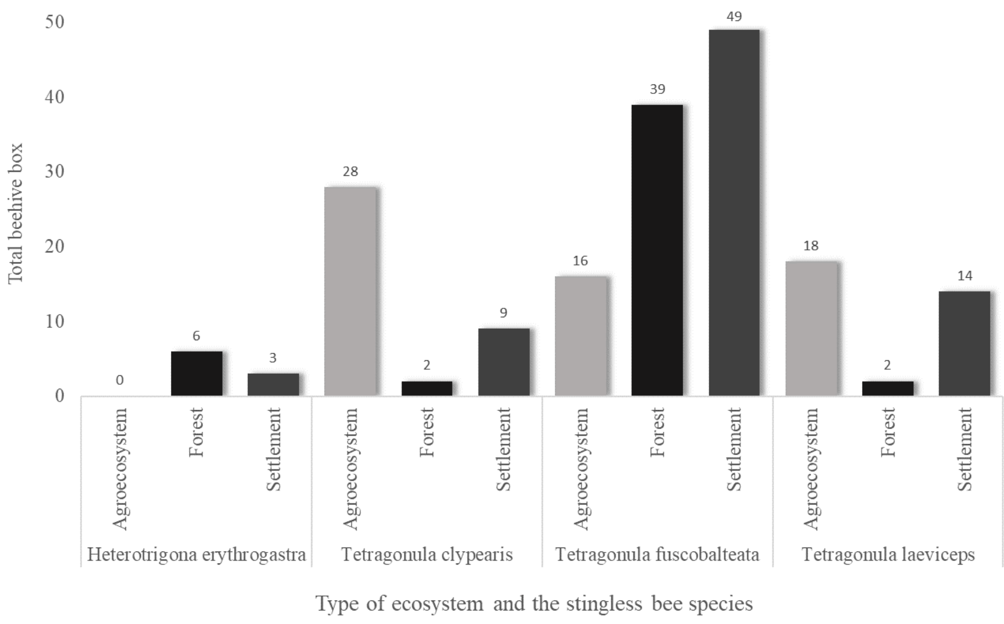

Figure 2. Total beehive box of four species of cultivated stingless bee in three types of ecosystem

The majority of the cultivated colonies were transplanted from the artificial hives, which were placed near the house doors and foundations as well as bamboo house supports. Furthermore, the availability of abundant forage plants, which were planted by humans was a factor that influenced their survival in this area. Suriawanto (2017) stated that *T. fuscobalteata* was the most common species in the rural areas of Sulawesi. This is in line with a recent study, where it was cultivated on Lombok Island.

Tetragonula laeviceps was a species of stingless bees widely cultivated in Java. Furthermore, it was often used for the production of beekeeping products as well as a pollination agent (Rahmani et al. 2020). *T. laeviceps* was mostly found in the surrounding agroecosystem lands, as shown in Figure 2. The preferable type of agroecosystem for this species was the bamboo plantations (Agus et al. 2019), where its colonies were found.

The Diversity of Forage Plants in the Cultivation Area

There were three kinds of forage needed by stingless bees, namely nectar, pollen, and plant sap. These organisms often searched for plants that contain one or all the forages. Some of the plants that were identified around the cultivation location were presented in Table 1.

The data on forage plants found around the cultivation areas was the basic data used for the process of identifying the potential forage of stingless bees. Furthermore, the plants were identified by

Table 1. Diversity of stingless bee-feeding plants at a radius of 500 meters from the cultivation area

Family	Genera	Local name	Location
Amaranthaceae	*Celosiae*	*Jengger Ayam*	Ag, M
Anacardiaceae	*Dracontomelon*	*Dahu*	Ag, H, M
	Spondias	*Kedondong*	Ag, H, M
	Mangifera	*Mangga*	Ag, H, M
	Lannea	*Banten*	Ag
Annonaceae	*Annona*	*Sirsak*	M
		Srikaya	Ag, M
	Plumeria	*Kamboja*	Ag, M
Apocynaceae	*Arenga*	*Aren*	Ag, M
Arecaceae	*Cocos*	*Kelapa*	Ag, H, M
	Areca	*Pinang*	Ag, H, M
	Chrysanthemum	*Krisa*	Ag, H
Asteraceae	*Helianthus*	*Matahari*	Ag, H
	Pluchea	*Beluntas*	M
Bromeliaceae	*Neoregelia*	*Nanas-nanasan*	Ag, H, M
Cactaceae	*Hylocereus*	*Buah Naga*	Ag, H, M
Caricaceae	*Carica*	*Pepaya*	Ag, H, M
Clusiaceae	*Garcinia*	*Manggis*	Ag, H, M
Combretaceae	*Terminalia*	*Katapang*	Ag, M
Cucurbitaceae	*Sechium*	*Labu siam*	H
Euphorbiaceae	*Euphorbia*	*Euphorbia*	Ag
	Jatropa	*Jarak Pagar*	M
	Aleurites	*Kemiri*	Ag, H, M
	Antidesma	*Buni*	H
Fabaceae	*Tamarindus*	*Asam*	Ag, M
	Saraca	*Asoka*	H
	Delonix	*Flamboyan*	M
	Gliricidia	*Gamal*	Ag
	Erythrina	*Dadap*	H
	Calliandra	*Kaliandra*	Ag, H
	Lablab	*Komak*	H
	Samanea	*Trembesi*	Ag, M
	Sesbania	*Turi*	Ag
	Albizia	*Sengon*	Ag, H, M
	Leucaena	*Lamtoro*	Ag
Gnetaceae	*Gnetum*	*Melinjo*	M
Lamiaceae	*Tectona*	*Jati*	Ag, M
	Orthosiphon	*Kumis kucing*	Ag, M
Lauraceae	*Persea*	*Alpukat*	Ag, H, M

Family	Genera	Local name	Location
Malvaceae	*Theobroma*	*Coklat*	Ag, H, M
	Durio	*Durian*	Ag, H, M
	Ceiba	*Kapuk Randu*	Ag, H, M
	Hibiscus	*Kembang Sepatu*	Ag
	Sida	*Sidaguri*	Ag
Meliaceae	*Toona*	*Suren*	M
	Swietenia	*Mahoni*	Ag, H, M
	Aglaia	*Pacar Cina*	M
Moraceae	*Mutingia*	*Kersen*	Ag, H, M
	Artocarpus	*Nangka*	Ag, H, M
		Sukun	Ag, H
	Ficus	*Beringin*	Ag, M
Musaceae	*Musa*	*Pisang*	Ag, H, M
Myrtaceae	*Syzygium*	*Duwet*	Ag, M
	Eugenia	*Jambu Air*	M
	Syzygium	*Jambu Rata*	M
	Psidium	*Jambu Biji*	Ag, M
	Anacardium	*Jambu Mente*	Ag, M
Nyctaginaceae	*Bougainvillea*	*Bogenvil*	M
Oleaceae	*Jasminum*	*Melati*	M
Oxalydaceae	*Averrhoa*	*Belimbing*	Ag, M
Palmaceae	*Palma*	*Palem-paleman*	Ag, H, M
Passifloraceae	*Passiflora*	*Markisa*	M
Phyllanthaceae	*Sauropus*	*Katuk*	Ag
Piperaceae	*Capsicum*	*Cabe*	M
Poaceae	*Bambusa*	*Bambu*	M
	Oryza	*Padi*	Ag
	Zea	*Jagung*	M
Rosaceae	*Rubus*	*Arbei Hutan*	H
Rubiaceae	*Gardenia*	*Kacapiring*	M
	Coffea	*Kopi*	Ag, H, M
	Morinda	*Pace*	M
Rutaceae	*Citrus*	*Jeruk Bali*	Ag, H, M
		Jeruk Nipis	Ag, M
Sapindaceae	*Dimocarpus*	*Lengkeng*	Ag, H, M
	Nephelium	*Rambutan*	Ag, H, M
	Pometia	*Matoa*	Ag, H, M
Sapotaceae	*Mimosops*	*Tanjung*	Ag
	Manilkara	*Sawo Kecik*	Ag, H, M
Thymelaeaceae	*Aquilaria*	*Gaharu*	H
	Phaleria	*Mahkota Dewa*	Ag
Verbenaceae	*Gmelina*	*Jati Putih*	Ag, H
	Lantana	*Tembelekan*	Ag, H
	Stachytarpheta	*Pecut Kuda*	M
Family 1	-	*Sandat*	M
Family 2	-	*Minden*	H
Family 3	-	*Masangleang*	M
Family 4	-	*Bita*	Ag

Remarks :
Ag : Agroecosystem land use
H : Forest land use
M : Settlement land use

analyzing the pollen found in the hives. The results showed the presence of two pollens of the forage families that were identified as the favorite of stingless bees from the genus *Tetragonula*, namely Bromeliaceae (F6) and Cyperaceae (F9). In most *T. fuscobalteata* hives, pollen from Asteraceae (F5), Nymphaeaceae (F16), and Rubiaceae (F22) were also found. Pollen from Poaceae (F20) was found in most of the hives of *T. clypearis,* while Amaranthaceae (F1) and Euphorbiaceae (F10) were identified in most *T. laeviceps* hives. The number of *H. erythrogastra* hives which pollen of Rubiaceae (F22) found was larger compared to Bromeliaceae and Cyperaceae, as shown in Figure 3.

The species of Bromeliaceae with short corollas of flowers were usually visited by bees (Freitas et al. 2020). Previous studies showed that this family was one of the sources of pollen for the stingless bees on

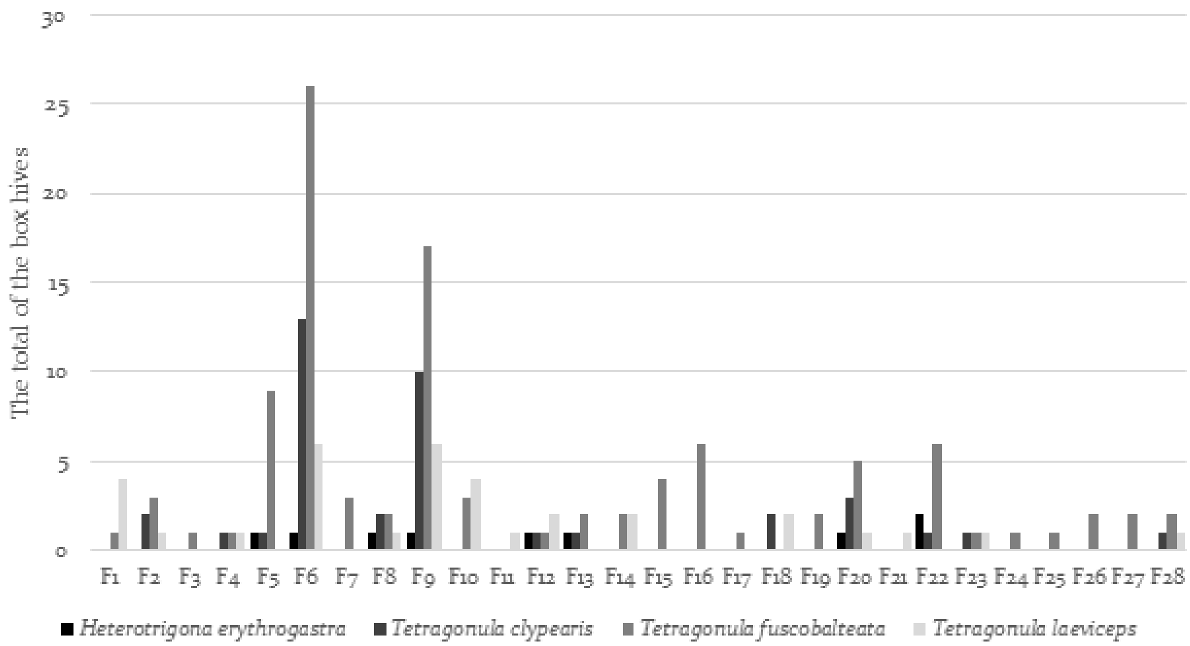

Figure 3. The number of the box hives which were found in the pollen family on each stingless bee species. Notes: F1 = Amaranthaceae, F2 = Annonaceae, F3 = Apocynaceae, F4 = Aquifoliaceae, F5 = Asteraceae, F6 = Bromeliaceae, F7 = Burmanniaceae, F8 = Commeliaceae, F9 = Cyperaceae, F10 = Euphorbiaceae, F11 = Flacourtiaceae, F12 = Lauraceae, F13 = Liliaceae, F14 = Lytharaceae, F15 = Myrtaceae, F16 = Nymphaeaceae, F17 = Osmundaceae, F18 = Oxalydaceae, F19 = Phyllanthaceae, F20 = Poaceae, F21 = Polygonaceae, F22 = Rubiaceae, F23 = Rutaceae, F24 = Theaceae, F25 = Unidentified 1, F26 = Unidentified 2, F27 = Unidentified 3, F28 = Unidentified 4.

Lombok Island. Cyperaceae was also one of the families that were often collected. This finding was consistent with a recent study that Amaranthaceae and Euphorbiaceae were two out of > 60 pollen families, which served as food sources for *T. laeviceps*. However, the predominant pollen for this species was Solanaceae, Fabaceae, Myrtaceae, Araliaceae, and Polygonaceae (Jayadi & Susandarini 2020). Rubiaceae was also found in the hives of *T. fuscobalteata* in a recent study. This finding was similar to another study on Lombok Island that presented one of the families found as secondary pollen of *Tetragonula* was Rubiaceae. Amaranthaceae, Euphorbiaceae, and Cyperaceae were also found as the food sources for this genus (Anggadhania et al. 2020).

Nagamitsu and Inoue (2005) stated that *T. fuscobalteata* and *H. erythrogastra* had different flower visitation. The canopy and gap flowers were often visited by *T. fuscobalteata*, while the deep flowers were visited by *H. erythrogastra*. A recent study also showed that Rubiaceae was the favorite pollen family for *T. fuscobalteata,* which came from the canopy and gap flowers. The result illustrated that Asteraceae, which had deep flowers was one of the favorite for *H. erythrogastra*, as shown in Figure 3. *T. clypearis* preferred Poaceae as the pollen source in this study, but this finding was inconsistent with Sulistia et al. (2016), where its sources were Caricaceae, Fabaceae, Sapindaceae, Rubiaceae, and Euphorbiaceae. Pangestika et al. (2017) reported that the pollen of Poaceae was loaded by *T. laeviceps*. This bee species had a role as a pollinator of flower plants from Brassicaceae (Wulandari et al. 2017), Solannaceae (Putra et al. 2016), and Arecaceae (Wati 2013). *T. laeviceps* also collected pollen from the plant species of Euphorbiaceae (Wati 2013), and this was in line with this study. The images of some pollens were presented in Figure 4.

Principal Component Analysis (PCA)

Principal component analysis (PCA) was used to determine the forage preferences of stingless bee

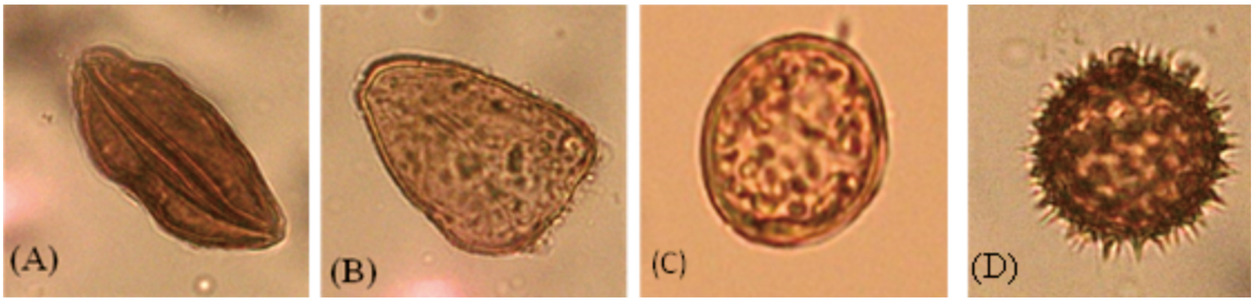

Figure 4. (A) Bromeliaceae's pollen; (B) Cyperaceae's pollen; (C) Rubiaceae's pollen; (D) Asteraceae's pollen

species based on the pollen found in the hives. It also explained the relationship between the preferences and the land types at the cultivation site. The PCA was carried out with 11 combinations of the species of stingless bee and land types. *H. erythrogastra* in the agroecosystems was not used because there was no pollen data. Based on the pollen family, the result from the main components I (32.56%), II (26.32%), and III (15.19%) explained 74.07% of the total variance.

From the data of the family, the PCA showed that several groups of stingless bee species in specific land types had different preferences for forage plants, as shown in Figure 5. From the main components I and II, *T. fuscobalteata* cultivated in the forest preferred forage from Apocynaceae (F3), Burmanniaceae (F7), Myrtaceae (F15), Phyllanthaceae (F19) as well as 3 pollens from unidentified families, namely F25, F26, and F27. The same species cultivated in settlements preferred Cyperaceae (F9), Osmundaceae (F17), and Theaceae (F24).

The main components II and III explained the feed preferences of stingless bee species from the genus *Tetragonula,* which was cultivated in the agroecosystem lands. However, the preference was not illustrated with the combination of the main components I and II. *T. laeviceps* and *T. fuscobalteata* in this type of land preferred pollen from the same plant family, including Flacourtiaceae (F11), Lauraceae (F12), Polygonaceae (F21), Rutaceae (23) as well as one unidentified family, namely F28.

The three main components of PCA did not explain the forage preferences for *H. erythrogastra* and *T. laeviceps* in forests and settlements as well as *T. clypearis* in all land types. This indicated that the types

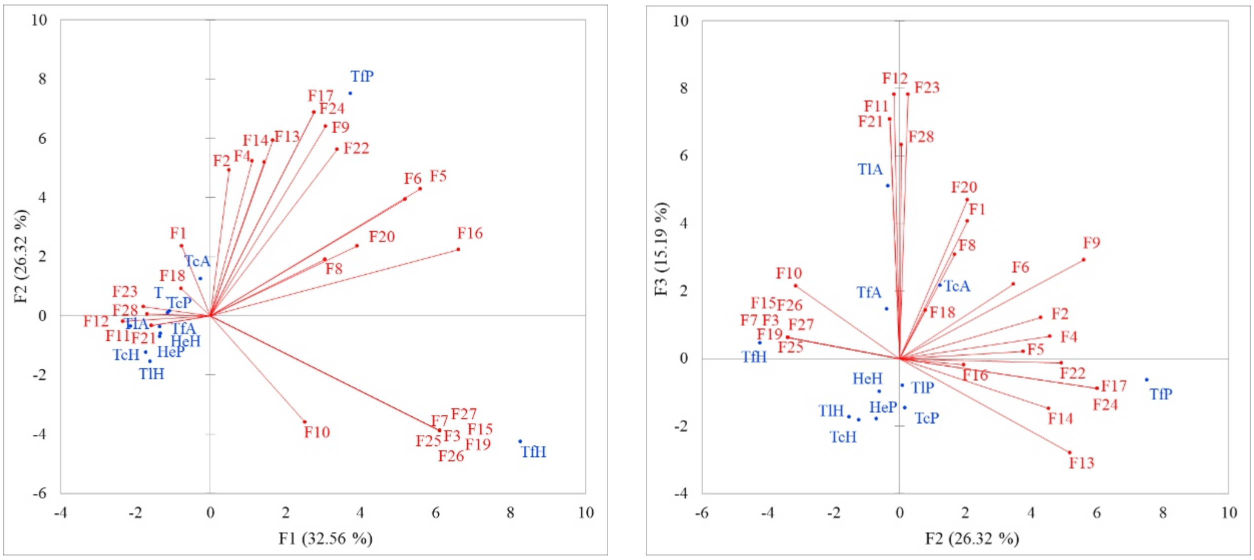

Figure 5. Principal Component Analysis (PCA) showed the relationship between forage plants (family) and stingless bee species on different land type. Note: He = *H. erythrogastra,* Tf = *T. fuscobalteata,* Tc = *T. clypearis,* Tl = *T. laeviceps,* A = agroecosystem, H = forest, P = settlement

of stingless bees in these land use areas do not have different forage sources.

The species of the cultivated bees on different land types were classified into five groups based on the similarity of forage preferences, namely the pollen family found in the hives. *H. erythrogastra* was divided into two groups, namely I and II, which were cultivated in the forests and settlements, respectively. *T. laeviceps* was also divided into two, where the stingless bees obtained in the forests and settlements were in group III. Meanwhile, others in the agroecosystem lands were placed IV. *T. fuscobalteata* and *T. clypearis* belonged to group V even though they were cultivated in different land types, as shown in Figure 6.

Based on the results of PCA and hierarchical clustering analysis, each species of stingless bee had a different preference to forage plants in different types of land. The result also showed that the same species did not have a specific forage preference. The same type of land did not affect the similarity of plants preferred by the same or different species. This was related to the availability of pollen from the diverse forage sources in each land use type.

Generally, the source of forage for stingless bees was flowering plants (Sanjaya et al. 2019). A recent study showed that most of these sources were found in areas with flowering plants, such as the guava tribe (Myrtaceae) and ferns (Osmundaceae). Based on the families found as the preference of the genus *Tetragonula* in the agroecosystem lands, some pollen were obtained from plants in agricultural lands and plantations, such as spice trees (Lauraceae) and oranges (Rutaceae). The forage preferred by *T. fuscobalteata* were usually found in the forests. There were also more diverse plants, such as trees, shrubs, and herbs in the forest. The pollen families that were identified were Myrtaceae, Apocynaceae, and Phyllanthaceae. The same species of stingless bee in the settlement areas also tended to have forage preferences for families that were common in this area, such as Ferns (Osmundaceae), flowering trees or shrubs/ornamental plants (Theaceae), and grasses (Cyperaceae).

The results showed that forage preferences were more influenced by the diversity of the sources around hives or habitat. Nagamitsu et al. (1999) stated that bees did not use specific plant taxa as their floral resources. Similar results were reported by Bisui et al. (2019), where differences in the sites did not affect

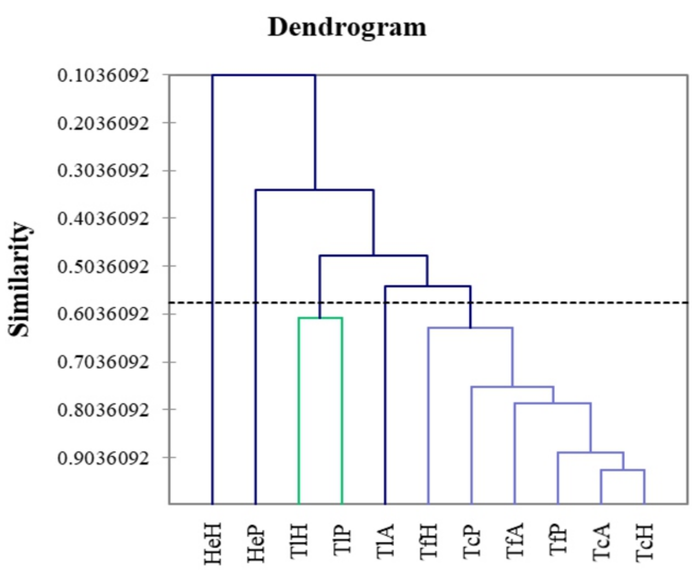

Figure 6. *Hierarchical cluster analysis* dendrogram species of stingless bees on the different land types based on the families of forage plants

their foraging activity. However, the availability of various families of these plants contributed to the pollen that was collected. The high availability of plant species in the forest areas was influenced by the higher preference of stingless bees (Prado et al. 2021).

Conclusions

A total of four species of stingless bee were identified on Lombok Island, namely *Heterotrigona erythrogastra*, as well as *Tetragonula clypearis*, *T. fuscobalteata,* and *T. laeviceps*. The preferences of forage for the *Tetragonula* genus were the plants from the family Bromeliaceae and Cyperaceae, while forage often visited by *H. erythrogastra* were from the Rubiaceae. The Principal Component Analysis showed that plants preferred by stingless bees usually grew or were found in each land type. Lauraceae and Rutaceae were the forage preferences in the agroecosystem lands; Myrtaceae, Apocynaceae, and Phyllanthaceae in the forest areas; while Osmundaceae, Theaceae, and Cyperaceae were common in settlements. In the future, the beekeeper must consider performing plant enrichment of the feed sources around the beekeeping areas to increase the bee products.

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Contribution of Authors

Both authors contributed equally to the writing of this manuscript and declared that there is no conflict of interest.

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