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# An Overview of Global Meliponiculture with a Special Focus to Kerala, India

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## Abstract

Stingless bees are highly social insects which populated the tropical earth 65 million years ago longer than honey bees. They are limited to tropics and subtropics lacking venom apparatus and cannot sting. Impacts of anthropogenic influences on honey bees were already reported. Recent studies also showed that the nesting behaviour of *Trigona* (*Tetragonula*) *iridipennis* Smith in natural habitat also vary due to interaction, pheromones and environmental stimulus. *Trigona iridipennis* Smith shows great diversity in plant selection for dietary as well as resin sources. The shift towards ornamental plants for foraging may be an adaptation evolved in response to human modification of the environment. The bees collect resin from a variety of sources for building nest, its maintenance and also for defence. Bee traffic is found to be related to time, season, and strength of the colony. The study also highlights the various food sources of *Trigona iridipennis* Smith in Kerala which can be further explored for flourishing meliponiculture.

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*Tetragonula iridipennis*; Urban and peri-urban agriculture, Urbanization, Terrace gardens, Meliponiculture

## Introduction

Honey bees dominated the earth very long before the emergence of human beings. Stingless bees have emerged much before the evolution of true honey bees (*Apis cerenaindica*); which is used for the mass production honey. Stingless bees evolved around 80 million years before which is estimated by calculating the age of amber trapped stingless bees discovered from New Jersey in United States. It is assumed that stingless bees first emerged in African continent and later spread across the rest of the world (Crane, 1992; Wilie, 1983).Fossil record of stingless bees have been found inside pieces of amber 80 million years old (Baker and Chmielewski, 2003). These little bees developed before the continental drift. Stingless bees belong a large and diverse taxon comprising some than 60 genera (Rasmussen and Cameron, 2010). The meliponine crown clade is assumed to have approximately 80 million yeas (late Gondwanan origin). In the New World, major diversifications occurred approximately 30–40 million years ago (Rasmussen and Cameron, 2010; Biluca *et al.*, 2016).

Around the globe, it is estimated that there are more than 600 described species in approximately 61 genera. Approximate numbers of species so far identified are 50 in Africa, 300 species in the Americas, 60 in Asia, 10 in Australia and four in Madagascar. However, several studies over the last two decades using morphological characters (Michener 1990; Camargo and Pedro, 1992) and a single mitochondrial DNA gene fragment with limited (34 species) taxon sampling (Costa *et al.*, 2003) resulted in phylogenies. Rasmussen and Cameron (2007) published a four-gene phylogeny of 64 meliponine taxa belonging to 22 of 25 Old World genera and 15 taxa belonging to 13 of 36 New World genera.Around six hundred stingless bees' species are recorded and they are classified into five genera: Melipona, Trigona, Meliponula, Dectylurina and Lestrimelitta and some of them like Trigona and Melipona are the honey producing bees which are used commercially. Australian stingless (*Teragonula carbonaria*) bees produce less than 1 kg honey per year and considered as a medicine in many communities. The different species are diverse: their size ranges from 2 mm (the tiny sweet bees) to stingless bees slightly bigger than the European honeybee (*Apis mellifera*).

Even though there exist a diversity among Stingless bees behaviour, they are highly eusocial (Vazhacharickal and Jose, 2016a; Vazhacharickal and Jose, 2016b; Vazhacharickal and Jose, 2018). They belong to the tribe of Meliponini (family Apidae), and closely related to the common honeybees and found in most tropical or subtropical regions of the world.

Stingless bee species that produce honey belong to four main genus Austroplebeia, Trigona, Melipona and Tetragonisca. Austroplebeia are warm-loving species of stingless bees with cream coloured markings at the base of their thorax. It's hard to distinguish them apart from *T. carbonaria*, without looking inside at the different nest shape they have, but they often build a tunnel-like entrance into the hive, and make an intricate, lacy curtain of cerumen each night as a barrier across their doorway. The other distinguishing behavioural difference is that Trigona crawl over the intruder, into eyes, ears, mouth while the hive is being opened while Austroplebeia is non aggressive. Trigona build a hexagonal brood cell, in a flat layer spiralling outwards (horizontally) while Austroplebeia do not build in a discernable regular pattern (Gupta, 2014). The Austroplebeia queen has a light brown appearance, in contrast to the dark brown Trigona queen. There are nine species described so far viz *Austroplebeia australis* (Friese, 1898), *A. cassiae* (Cockerell, 1910), *A. cincta* (Mocsáry, 1898), *Austroplebeia cockerelli* (Rayment, 1930), *Austroplebeia essingtoni* (Cockerell, 1905), *Austroplebeia ornata* (Rayment, 1932), *Austroplebeia percincta* (Cockerell, 1929), *Austroplebeia symei* (Rayment, 1932, *Austroplebeia websteri* (Rayment, 1932).

Trigona is the largest genus of stingless bees, there are approximately 150 species presently included in the genus, in 11 subgenera. Trigona species occur throughout the Neotropical region, and also throughout the Indo-Australian region; as presently defined, with no record of occurrence in Africa. It is a genus of the Meliponini tribe which is found extensively in tropical regions which extends from Mexico to Argentina, India, Sri Lanka to Taiwan, the Solomon Islands, South Indonesia and New Guinea. Many species exists in different parts of world viz., *Trigona barrocoloralensis*, *T. branneri*, *T. carbonaria*, *T. chanchamayoensis*, *T. collina*, *T. Iridipennis*, *T. fuscipennis*, *T. hockingsi*, *T. hyalinata*, *T. minangkabau*, *T. recursa*, *T. spinipes*. Two species (*Trigona binghami* and *Trigona minor*) are newly added to the list of 30 species recorded earlier by Schwarz (1939), and Michener and Boongird (2004) making a total of 32 stingless bees of Trigona species currently recorded under two genera (Trigona and Hypotrigona) in Thailand (Gupta, 2014).

Prominent among them were *Trigona apicalis* Smith, *T. melanoleuca* Cockerell, *T. atripes* Smith, *T. canifrons* Smith, *T. thoracica* Smith, *T. terminata* Smith, *T. ventralis* Smith, *T. flavibasis* Cockerell, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *T. iridipennis*, *Hypotrigona scintillans*, *H. pendleburyi* and *H. klossi*. The diversity of Trigona and their resin and gum collecting behaviour depended on environmental, geographical, genetical and availability of plant resources. The bees prefer to collect resin and gum from 16 plant families including Anacardiceae, Dipterocarpaceae, Euphobiaceae, Hypericaceae, Meliaceae and Moraceae. The *T. apicalis* collect resin and gum to make the largest number of propolis compared with the other bee species. *Trigona* (*Tetragona*) *iridipennis* is the most common dammar bee found all over India. Other species were reported during 1940s and 1950s in general or from some parts of the country. Besides *Trigona iridipennis*, three other species occur in the Khasi hills, Meghalaya (Pugh, 1947). Neto (1949) recorded a total of three species from India:*Tetragona iridipennis*, *T. ruficornis* and *T.* (*Lepidotrigona*) *arcifera*. *T. ruficornis* occurs in Haldwani, Uttar Pradesh (Gupta, 2014).

Species of Trigona live in hives, and can be found in cavities in trees, mud/stone walls or underground. The various species prefer different cavity dimensions and most species have characteristic nesting sites; the nests of *Trigona fulviventris* most often are found at the foot of a tree. The entrance of the nest is most often very small, decorated with debris including cow dung, and other resinous materials of mainly plant origin. The small entrance protect them against other bees, phorid flies, lizards, spiders and ants. The entrance can be a tubular structure, with circular, oval or irregular shape extending into the open air. Some entrance tube opening pointing upwards while in others they point downwards. The queen is the fertile female with reproductive capacity while the workers are underdeveloped females. The workers do all the nest maintenance, bring home food, and nurse the developing bees. Males are only produced at a certain time of year and season, when new queens are produced. After mating the virgin queen (gyne) mate with males and the mated queens start their own hive with some workers near to the parent colony.

Nowadays, Trigona species considered as important pollinators for wild plants and agricultural crops especially in the tropics. They are key pollinators of macadamia, coconut, mango, and chayote. These bees also play a smaller role in pollination of coffee, avocados, and guava.

Trigona is the largest genus of stingless bees and have many subgenera, commonly known as dammar bees. These bees are quite small in size and look like mosquitoes or flies with distribution in tropics and sub-tropics, and even in temperate regions. They build their nests in dark enclosures like cavities in branches or trunks of trees, ant hills, termite tunnels in the ground, wall crevices or any abandoned receptacle like logs, pots and tins (Figure 1). The brood of Trigona, unlike those of Apis, are clusters of small uniform globular cells of wax. These pots are the cells in which the young are reared. The pots are closely stacked touching each other or separated each cell or cluster of cells being connected with others by girders or pillars of wax. Pollen and honey are stored in conspicuously large oval cells that are constructed close to the brood cell clusters or at their periphery quite apart from the with no clear separation. Due to this reason, the honey collected from dammar bees amalgamate with pollen that gets into it from pollen pots interspersed among the honey pots which affect the shelf life due to fermentation. Honey yields from dammar bees are very low; often a few grams to some 500 g. however, from forest areas up to 2 kg of honey are collected from each nest of well grown colonies. The honey yield is determined various factors especially climate, foraging plants, geographic locations, colony strength and the genetic makeup of the bees. Stingless bee honey looks dark amber in colour, shows highly positive polarization. The peculiar chemical composition and physical properties of the honey are attributed to the characteristic floral range where stingless bee forages.

Stingless bees are not active all year round; they are less active in cooler weather/rainy seasons. Unlike other eusocial bees, they do not sting but will defend by biting and making irritations by entering in sensitive parts of the enemies, if their nest is disturbed. Most of them make nests in hollow trunks, tree branches, underground cavities, or rock crevices or even adapted to various anthropogenic habitats (Vazhacharickal and Jose, 2016a; Vazhacharickal and Jose, 2016b; Vazhacharickal and Jose, 2018).

## Stingless bees (*Trigona iridipennis*)

Usually stingless bees were seen in building foundations, mud walls, stone walls and tree cervices. They prefer tropical climate. Also seen in tropical places especially Mexico to Argentina and Indo-Australian regions especially India, Sri Lanka and Taiwan (Sakagami, 1982; Wille *et al.*, 1983).

The most prominent stingless bees seen in India is *Trigona iridipennis* species (Swaminathan, 2000). Before they were known as *Melipona iridipennis*. Now the species located in India and Sri Lanka belong to Trigona genus and this classification is widely accepted (Michener, 1974; Sakagami, 1978). These bees got the name *Trigona iridipennis* due to triangular abdomen and iridescent wings. For building nest, they collect resins from trees which makes them called as Dammer bees. In India especially villages and among tribal people of Kerala, stingless bees were domesticated but not much importance and attention were for the management of these bees. Much importance are given to the large scale production of *Apis indica* and *Apis mellifera* in Kerala. Very little scientific studies were conducted in stingless bees in Kerala. Stingless bees were much far ahead of medicinal properties of honey, and plant pollination when compared to other honey bees (Garedew *et al.*, 2004). Even though the stingless bee produce less quantity of honey (400-600 ml), due to high medicinal property of their honey, smooth taste and fragrance make them superior than other types of honey. The importance of stingless bee pollination is much higher than the value of their honey produced. There are lot of small plant that depend only on stingless bees for their pollination (Heard, 1999). The body of the stingless bees were designed to collect pollen and nectar from very small flowers. The stingless bee travel only around 800 m radius for collecting pollen and nectar which make them suitable for controlled pollination. Stingless bees could be effectively used for green houses, poly houses and controlled farming techniques. The small bees do not get much appreciation and preferences for their valuable services. For house yard honey culture these small bees could be effectively utilized due to their special features and biodiversity in Kerala.

## Features of stingless bees

1) They do not abscond their nest easily
2) Unlike the Apis species, they do not sting. So they could handle much easily
3) They can collect honey and pollen from very small flowers (spinach, Thulsi; Holy basil)
4) Effective pollinator in ornamental plants and vegetables
5) High availability of resins for making the stingless bee hive from various trees (mango trees, jack tree)
6) Effective control of enemies and seal the hive except the portion of entrance tube which are guarded heavily by guard bees
7) Low cost and easily available materials for hive and growing stingless bees (earthen pot, bamboo pole, log wood, wooden boxes, coconut shell and mud pots)
8) Hives could be places hanging on the sunshades of houses, or open porches, or in farm using bee hive stands.
9) Hives could be placed very close to each other and require very limited space
10) Shifting and transportations of the hives very easy.

## Taxonomical classification (Stingless bees)

Kingdom: Animalia
Class: Insecta
Subclass: Dileniidae
Order: Hymenoptera
Family: Apidae
Genus: Trigona
Species: *Trigona iridipennis*

## General characteristics

Like Apis genus honey bees, stingless bees are also social insects with well-defined caste system. A colony consist of queen, workers, and drones. In a colony there is normally single queen. Majority of the bees will be workers and have less workers. Even though, They have some similarities with Apis but differ widely.

1) Apis genus queen mate with more than one male but stingless be mate with a single male

2) Apis genus honey bees collect the wax produced from their bodies, while stingless bee make their nest with wax and resin collected from trees

3) In stingless bees during swarming, the newly hatched virgin queen moves to new nest with half of the workers. While in Apis genus, the new queen stays in the old nest and it is the old queen moves to a new nest.

4) In Apis genus, there is no connection between the old hive and new hive, but in stingless bees there is good connection with the parent and daughter colonies. Daughter colonies collect resin, pollen and honey from mother colonies.

5) Unlike the Apis honey bees, the fully grownup queen cannot fly

6) In Apis species, the egg hatched larvae get food provided by worker bees (progressive provisioning) while in stingless bee there is only a one time provision of food (Mass provisioning). So before the queen lays egg, the complete food for the development of egg will be provided and after the queen lays egg, the workers seal the chamber (Roubik, 2006).

7) Stingless bee drones feed on individually collected honey and pollen, while Apis genus drones cannot do this.

8) Unlike the Apis honey bees, stingless bee do not have a sting for stinging or poison gland. But as a part of the their defence, they bite, enter into eyes, nose, ears, and hair to irritate the enemies and defend their nest.

9) Apis honey bees make the com with wax secreted from their body while stingless bee make the brood, pollen and honey chamber with wax collected from their body and resin collected from plants and mixed together known as cerumen.

Regarding the medicinal properties, stingless bee honey is far ahead that all the other types of honey (Garedew *et al.,* 2004; Torres *et al.,* 2004). Due to the scarcity of stingless bee honey, other types of honey were used in various ayurvedic formulations in Kerala. Stingless bee honey can be directly used as medicines while sometimes mixed with other herbal formulations. Stingless bee honey successfully used as an effective ingredient for eye infections, lung diseases, allergy, asthma, skin diseases, varicose vein, ulcer, piles and even cancer. The stingless bee honey is used in folk, tribal, local and unani medical treatments. Despite of all these, still not much attention is given for the production of stingless bee honey. Only a few people prefer meliponiculture as a part of their hobby, extra income or self-production of honey. But still the honey production is limited in Kerala.

Stingless bee hives could be seen in many house across the villages in Kerala. They are seen hanging in walls of house, shed, cow shed or in backyards as on stands. In olden times, colonies seen in tree trunks were cut as such using axe and saw and kept hanging near the houses. But now a days people transfer the colonies to bamboo poles, earthen pots, wooden boxes which is widely practiced now (Vazhacharickal and Jose, 2016a; Vazhacharickal and Jose, 2016b; Vazhacharickal and Jose, 2018). This kind of domestication need much more refinement and knowledge about their biological behaviour lifestyle, and special characters.

In reality, stingless bees are not tamed to our habitat, instead we are arranging habitat according to their biology and rearing them. Cultivation of the bees for the production of honey, wax, pollen and pollination among plant is known as bee keeping or apiculture.

The art of rearing stingless bees is known as meliponiculture. Countries like Australia and brazil gives much attention and importance for meliponicuture, but India still not much popularity is gained for meliponiculture. Even though the honey yield from the stingless bees are less compared to other honey bees, the honey medicinal properties, pollination role they are much ahead. They could be easily handled by kids, ladies and even old people.

Farmers who practice meliponiculture, lack scientific knowledge about their lifecycle, foraging characteristics, swarming, nest construction, mating, colony division, honey extraction, and honey processing. Limited publication regarding these factors also make the theme much more complex.

Traditional and heard knowledge were the possible solutions and resources for the farmers. Lack of colonies for the newly entering people to this filed is also an existing problem. Despite of all these factors, still we can ascertain that there are enough colonies around our neighbouring vicinity.

## Origin of meliponiculture

Ancient Mayan people kept stingless bees and considered as an integral part of social and religious life. At that time also, it provide a small scale economy by providing honey, wax and resins. The cultural importance of a single central species, called Xunan-Kab (*Melipona beecheii*), was recorded in documents written with ideograms by the Maya, recorded in their codices. Only three of these codices have survived and one, the Tro Codex, contains most data on bees and their meaning to society. The honey produced by Xunan-Kab was considered sacred by the Maya and was also traded. Lopes de Gomara (1552) wrote that stingless bee honey occurred in different colors, flavours, and texture, and indicated that it was an important medicinal product and used to pay taxes to the Aztecs, and Inca (Roubik, 2000; Cortopassi-Laurino *et al.*, 2006).

In Mexico honey god is there and honey as well as cerumen used in religious ceremony and offering to God. In the modern society despite of cultural changes, the stingless bees, especially the Xunan-Kab, possess a widely acknowledged status as a cultural, ecological and economic icon. However, beekeeping with stingless bees has sharply declined in the last half century which may due to popularization of other honey bees or the low honey yield of stingless bees (Cortopassi-Laurino *et al.*, 2006).

In Brazil, stingless bees play an important role in the ethnobiology of the Kayapó (Posey and Camargo, 1985; Camargo and Posey,1990). 34 species of stingless bees, of which 9 were considered managed or semi-domesticated. Resin and cerumen were used in their artifacts and as medicine. Kayapo tribe people knows much information about bee behaviour, distribution, nest types and ecological zones. All knowledge on bees was passed orally through generations. The traditional way of finding nests by the noise made by worker bees during nest ventilation is still a method used by many native people from different communities in Eastern Amazon (Cortopassi-Laurino *et al.*, 2006).

The Kayapó exploit stingless bee nests, when they open natural nests to collect food, some brood, pollen and honey is left for the spirit “Bepkororoti” and this allows recovery of the colony. The Kayapó seem to be aware of the role of stingless bees as crop pollinators (Slaa *et al.*, 2006); they tend to plant bee plants near their crops to attract the bees (Cortopassi-Laurino *et al.*, 2006).

In Africa, Byarugaba (2004) discussed the Abayandas pygmy indigenous knowledge on stingless bees in the Bwindi forest reserve, Uganda. Due to special nature of the forest, the species diversity is higher when compared to other parts. These tribal use honey as medicine especially to alleviate constipation. India collection of stingless bee honey from the forest is a part of tribal people. The stingless bee honey is an integral part of Indian Ayurverdic and folk medicine preparations. In Kerala, traditional small scale rearing of stingless bees in mud pots exist many centuries before.

## Stingless bee hive structure

Stingless bees are naturally seen in tree cervices or mud/stone walls. These naturally occurring colonies are called feral colonies. More than 10 colonies were seen close together and they are called as nest aggregations.Stingless bees make their hive using resin collected from trees, secreted wax from worker bees. Wax and resin mixed mixture is generally termed a cerumen. The major parts of the hive include entrance tube, entrance, internal tunnels, resin dump, waste dump, brood, honey pots, pillars and connectives. Like Apis genus, worker, queen and drone caste differentiation also seen.

## Nest architecture and characteristics

The nest is the central place from which stingless bees mate, forage and pass through life stages. Nests are immobile fixtures and potentially long live (Michener, 1974; Roubik, 1989). Wall cavities and tree cavities are the major nesting sites for *Trigona iridipennis* Smith. They also make their nests in switch boards, telephone posts, discarded pipes etc. Though rare they were also found construct their nest on lorry cabin and also in scooter engine box. One colony even made their nest in a rain coat which was hanged in the car-porch in the off season. They are highly anthropophilous and more active in vicinity of human surroundings. A conspicuous entrance tube is found in front of the nest.

## Entrance tube

The stingless bee nest is always characterized by a nest cavity, typically provided with a very narrow opening facilitating defence (Kolmes and Sommeijer, 1992). The simplest stingless bee nest entrance protrudes slightly from the base of the entrance hole. Nest entrance is related to defence and foraging (Biesmeijer *et al.,* 2005; Biesmeijer and Seeley, 2005). It is made up of cerumen, a mixture of wax and resin. In addition to wax and resin foreign materials like grease, smoke particles, fibres, mud, dust particles etc may be seen on the entrance tube. In few colonies workers found to deposit particles of “Oil Mace” on the entrance tube. The length and width of the tube vary according to the strength of the colony and the location of the nest. There is no direct relation between the length of the tube and the age of the colony. The length of the entrance tube varies from 1.2 to 11 cm. The diameter of the entrance tube ranges from 0.7 to 2.4 cm. The wall of the tube is thin and fragile. The entrance tubes are usually directed downwards, but at our surprise one of the entrance tube was found directed upwards. The number of guard bees at the entrance varies according to the strength of the colony.

Entrance tube were absent in some colonies. The number of guard bees at entrance varies from two to sixteen. The shape of the entrance may be slit like, circular, oval or funnel like. Around the entrance tube resin deposit is found in some colonies. This deposit may be in definite patterns like concentric rings or may be irregular. The shape, size and direction of the entrance tube vary according to the nest site conditions. Outer surface of the entrance tube is usually rough and the inner surface is smooth. The recently built apical part of the entrance tube is softer and usually slightly sticky. Usually a single entrance is present at the tip of the entrance tube. Though rare in some cases more than one entrance is seen on the same entrance tube. In some nests two separate functional entrance tube were observed. Instead of opening directly into the nest the entrance tube opens into the nest through some tunnels called internal tunnel.

## Entrance

The entrance tube opens to the hive and known as entrance. Usually a single entrance can be seen in stingless bee hive. Through the entrance, the bees leave and enter the hive.

## Internal tunnel

Internal tunnel are usually branched and are made of soft cerumen. The long internal tunnel helps the stingless bees to effectively defend the colony against intruders.

## Resin dumb

The top The nests of stingless bees are made up of cerumen, a mixture of resin and wax which remains soft for an extended time and is more pliable than beeswax

(Wille, 1983; Hepburn and Kurstjens, 1984). In addition to being used for constructing nest forms, cerumen may also be used for repairing nest damage. The resin is collected from resinous plants like Jack fruit, mango tree etc. and wax is secreted by the young worker bees. The chemistry of propolis depends on the diversity of plants from which the bees collect it (Pereira *et al.,* 2003).

The resin is deposited in the nest at different places especially near the entrance. Guard bees use this resin to prevent invaders (Wille, 1983). In addition to being used for constructing nest forms, cerumen may be taken to make an emergency repair of natural enemy damage (Roubik, 2006). Cerumen is normally made freshly to construct brood cells, involucrum, nest entrance tubes, or storage pots. The wax is taken from a pure wax deposit and mixes it with fresh resin taken from a resin deposit. These may be in several positions near the nest entrance and brood cells; workers mix the materials with their mandibles (Sakagami, 1982). Melipona are keenly interested in returning to a damaged nest and collect resin from resin deposits, and also cerumen and honey, as do many stingless bee genera (Roubik, 2006). Inside the nest resin deposit can be seen at different places especially at the entrance. Three to eight deposits were seen in different nests. Nests with weak wall contain more resin deposit. In pot nest covered with cloth worker bees deposit large quantity of resin.

## Waste dump

An important feature of the nest architecture of stingless bee is the occurrence of distinct waste deposits (Kolmes and Sommeijer, 1992). In stingless bees resin and waste materials are found heaped on the nest floor (Vazhacharickal and Jose, 2016a; Vazhacharickal and Jose, 2016b; Vazhacharickal and Jose, 2018). In Apis bees the workers defecate outside the nest. In stingless bees latrines are maintained within the nests, where several symbionts live. Adult defecations in the nest are gathered at small latrines; most are consumed by symbiotic organisms (Roubik, 2006). Drainage outlets are maintained in the nests of subterranean stingless bees, such as Meliponula and Plebeiana, and in tree nesting species including Trigona and Tetragona (Sakagami, 1982; Camargo and Roubik, 1991).Waste is deposited in the nest at different places. They are mainly in the form of granules. These deposits contain dead bees, broken wings, discarded cocoons etc. A maximum of six waste dumps were observed in some colonies. Worker bees carry these waste particles with their mandible and deposit it on the floor of the nest at definite places. Worker bees carry this waste on their mandibles and throw away at distant places at day time.

## Food storage

Food storage consists of pollen pots and honey pots. Honey and pollen pots are oval and same sized (Drumond *et al.,* 1998). Honey and pollen are stored in separate pots. Usually these pots are intermixed. In some colonies they were found stored separately. Honey and pollen pots are made up of cerumen a mixture of wax secreted by the worker bees and resin collected from plants. They are usually oval in shape, chocolate in colour and are almost similar in size. The cell openings always directed upwards. A large number of pollen pots are usually placed near the entrance and near the brood cluster. The honey and pollen pots are found either separate or intermixed. The height of the pollen pot ranges from 0.7 to 1.2 cm and the diameter from 0.8 to 1.0 cm. The height of the honey pots varies from 0.6 cm to1.1cm and the diameter from 0.7 to 1.2 cm.

The temperature of hives were raised and water content of the honey lowered to 18-22% and stored in honey pots. Stingless bees collect nectar and pollen from even small flowers. The sucked nectar from flowers filled in the stomach of the bees mixed with digestive enzymes. This process is also supposed to be the fragrance and medical properties of stingless bee honey. Worker bees carry, pollen and resin on the pollen basket of their hind legs.

## Brood

The brood area forms the thermal core of a stingless bee nest, where heat may be kept in (or out) by concentric involucra (Roubik, 2006). In cluster type bees, involucrum surrounding the brood is absent (Sommeijer, 1984). The cells and cocoons are cluster type. The advancing front of new cells is roughly horizontal and progress upward through the brood chamber, and all new cells open upwards. In nests having adequate space and a more or less cylindrical cell cluster, the advancing front of cells is somewhat concave (Michener, 1961). In stingless bee nest most of the species arrange brood cells in horizontal combs. In other species the brood cells are positioned in clusters; few species arrange their brood cells in intermediate arrangements (Sommeijer *et al.,* 1982).

The number of brood cells produced per day varies from about 10 in Melipona colonies up to several hundred in

Trigona species. In Melipona species, all bees are born from identical cells, while in most other genera, queen cells are larger than those that produce workers and males (Sakagami, 1982).

Brood cells are spherical or ovoid cells cluster together in group. Cells always open upwards. Egg cups are made of soft cerumen. The newly constructed brood cells are brown in colour which contains egg or larvae. In the pupal stage the worker bees scrap away the cerumen from the brood (Michener, 1974) and the brood looks white or cream in colour. The cerumen scraped from the brood is reused for the brood cell construction. The old cells from which bees had emerged is replaced by new cells (Sommeijer *et al.,* 1984).

The worker and drone eggs look similar. Queens develop in larger cells that are generally, built around the borders of the brood. Queen brood cells differ among the stingless bees. In the genus Melipona, queens are produced in comb cells of the same size and shape as those that give rise to workers and males (Ribeiro *et al.*, 2006). In Trigona and related genera, queen cells are larger, in length and width, than those of workers and males (Engels and Imperatriz-Fonsaca, 1990). Sometimes the queen cells are found amidst the worker/drone brood. The number of eggs laid per day varies considerably according to the situations of the colony, especially the availability of the food, climatic conditions etc.

Each brood cell is built by several young wax secreting workers. Complete cells have a rim of wax, called a collar, which is used for sealing it after oviposition. The number of cells produced per day varies about 10 in Melipona colonies up to several hundred in Trigona species. In Melipona species, all bees are born from identical cells, while in most other genera, queen cells are larger than those that produce workers and, males (Sakagami, 1982). The height of the worker/drone brood cell is 3.72 to 3.98 mm and the diameter is 2.92-3.31 mm. Height of the queen cells is 7.12-7.43 mm and diameter is 4.03-4.27 mm. Usually one advancing front is present, in few colonies two advancing fronts detected.

## Pillars and connectives

Inside the nest the brood cells and food pots are fixed on definite pillars made up of cerumen. This gives enough space for the worker bees to move between the brood and food pots. The perpendicular structures are called pillars and the horizontal structures are called connectives, which fixes the brood and food pots to the floor and wall of the nest (Wille, 1983). It also attaches brood and food pots among themselves with enough bee spaces between them. The brood cluster is connected to the hive wall by means of pillars which are thicker than those interconnecting the brood cells (Sommeijer *et al.,* 1984).

## Nest envelops

If the cavities are extra-large stingless bees construct partition walls with special plates called batumen which is made of hard cerumen. The wall of the nest cavity is usually lined with a layer of cerumen called lining batumen (Michener, 1964). A single or multi-layered cerumen called involucrum may surround the brood nest. Very rarely an involucrum is seen inside the nest of *Trigona iridipennis*. They usually construct an involucrum if the nest is extra-large and also when the lid of the nest slide off. This envelope protects the colony from enemies and also helps to maintain proper temperature and humidity inside the nest.

## Pollen and nectar sources for stingless bees

Stingless bees collect nectar and pollen from a variety of plant species especially woody trees, fruit trees, ornamental and medical plants, weed plants and vegetable crops. Some of the plants supply nectar and pollen through-out the year while others are only seasonal. Due to the small size, the stingless bees can collect nectar and pollen from very small flowers where other honey bee species fail to do.

## Regional accounts of meliponiculture

## Meliponiculture in Mexico

The stingless bee keeping in Mexico is considered as historical and sustainable. Nevertheless, the situation has changed in recent years, mainly concerning beekeeping with *Melipona beecheii* (Villanueva *et al.*, 2005). The genera Melipona (which includes the largest stingless bees), Scaptotrigona and Cephalotrigona occur throughout tropical America (Cortopassi-Laurino *et al.*, 2006).

In Mexico, modern meliponiculture is almost entirely depend *Melipona beecheii* and occasionally to *M. solani* (lowlands), and include *M. fasciata* and *M. colimana* (highland). Colonies of *Scaptotrigona mexicana* are maintained in clay jars in part of Mexico. *Cephalo* *trigona*, lesser in size than Melipona consist of three species in Mexico. Log hives of *C. zexmeniae* are kept by Mayan people in the Yucatan peninsula (Cortopassi-Laurino *et al.,* 2006).

Scaptotrigona have the most numerous colonies of any stingless bee species with a relatively large body and colony size. Furthermore, colonies of Melipona have far fewer workers, perhaps 70–80% less, than Scaptotrigona. However, regarding honey stores in the nest, both genera can have several liters at any one time. It can be ascertained that Scaptotrigona and Melipona, Cephalotrigona, and Tetragona are the only Neotropical stingless bees that store so much honey.

One of the techniques used in Mexico for colony propagation is the use of log hives, and the ends are closed with a plate of lime stone with cracks sealed with mud. The stone plugs are a unique asset, which require only a short time to produce from limestone rocks scattered on the surface of the entire Yucatan peninsula. Another unique asset of meliponiculture with Melipona is that the colonies continuously produce queens. A newly divided colony can thus usually possess a laying queen soon after it has been made by the beekeeper. The basic trial-and-error development of rearing techniques had the best chances for success using the native Melipona thatwere readily hived and whose colonies were divided successfully using a minimum of technology or scientific knowledge. Although stingless bee beekeeping has progressed since the ancient Maya worked out some basic principles, many of the current techniques remain essentially unchanged.

## Meliponiculture in Costa Rica

Stingless beekeeping in Central America originated among the Maya of the Yucatan Peninsula and spread to other Central American Indian cultures (Kent, 1984). Before the discovery and the conquest of American continent by Europeans (indigenous peoples immigrated across the Bering Strait at least 15 000 years ago), rearing stingless bees was an important part of the commercial and alimentary customs of many indigenous cultures of America. The honey obtained from stingless bees plays an important role in their culture and used for food as well as medicine and preparation of products based on cerumen. As in other Mesoamerican areas, stingless beekeepingin Costa Rica did not play an important role in the religion of indigenous cultures.

The practice of the stingless bee beekeeping in Pacific Costa Rica (Nicoya) was considered popular (Kent, 1984). Nowadays, the practice of the meliponiculture in that region is less prevalent. Other areas belonging to Puntarenas and Guanacaste provinces (Santa Cruz, Hojancha, Filadelfia, and Miramar) are known for traditional meliponiculture. In other regions of Costa Rica meliponiculture is less common, compared with Guanacaste and Puntarenas.

The farmers keep the stingless bees colonies in log hives, kept hanging under the roof of their house or a specially built space away from their house. The farmers that do not have land or a higher educational degree constitute the main social group involved in meliponiculture. Stingless bee beekeeping in Costa Rica has been practiced at a low technical level, almost without equipment, and the type of hive used is mainly a hollow log. The main species reared are “jicote gato” (*M. beecheii*), “jicote barcino” (*M. fasciata*) (*Melipona costaricensis*), “mariquita o mariola” (*Tetragonisca angustula*), “soncuano” (*Scaptotrigona pectoralis*) and “tacanique” (*Scaptotrigona luteipennis*) (Ruano Iraheta *et al.,* 2015).

Arce *et al.,* (1994) reported from a survey of 40 stingless bee beekeepers (GuanacasteProvince) a total of 9 different domesticated species: *M. beecheii*, *M. fasciata* (*M. costaricensis*), *M. fuliginosa*, *Tetragonisca angustula*, *Scaptotrigona pectoralis*, *Cephalotrigona capitata*, *Nannotrigona perilampoides*, Trigonisca, Frieseomelitta, *Oxytrigona mellicolor*, and Tetragona. Some farmers obtained production of up to 6 liters and, in the case of *M. beecheii*, the production average was 2.63 liters per hive. According to van Veen *et al.,* (1990), meliponiculture in Costa Rica is practiced basically in two ways: (1) maintaining the nests in tree trunks, from which the honey, by a lateral opening, is extracted, generally used for *M. beecheii*; and (2) maintaining the colonies in small boxes, pieces of bamboo or hollow gourds, ordinarily with *T. angustula*. Even though the meliponiculture is practiced throughout Costa Rica even in urban areas, the reproductive biology of the bees were not studied well which prevent farmers in dividing the nest (Aguilar *et al.,* 2013).

In relation with the design and dimensions of hive boxes, van Veen *et al.,* (1993) recommended for *M. beecheii* a hive with a volume of 10 liters with internal dimensions of 15 cm height, 15 cm width and 45 cm length. For *T. angustula* the recommended box measures 15 cm × 15 cm × 20 cm long, which gives a volume of 4.5 liters. In its application we have observed that the stingless beekeepers modify the dimensions of hives according to the species and the size of the colony.

Various farmers collective initiate and self-supporting groups were active different location which ensure the market and constant income generation for bee keepers. They also conduct various trainings and workshop to introduce scientific outlook of stingless bee keeping as well as value addition of the products.

Research carried out by Tropical Beekeeping Research Center (CINAT) confirmed the importance of *Nannotrigona perilampoides* and *Tetragonisca angustula* as pollinators of the ornamental plant *Salvia farinacea* (Slaa *et al.,* 2000). This stingless bee can be considered an alternative to honey bees for commercial crop pollination. It is well known that stinglessbee species richness declines dramatically above 1000 m in Central America. They are more abundant at 200–500 m and rare at 700–1000m. van Veen *et al.,* (2004) studied in Costa Rica the production of queens and drones for *M. beecheii* in relation to food storage, brood and adult populations. They found that the colonies grow at the end of the rainy season, which is a period characterized by poor foraging conditions. On the other hand they found a significant correlation between the amount of pollen stored and the production of queens and drones. More importance should be given to the biology, pollination services, management and biodiversity conservation of stingless bees in Costa Rica.

## Meliponiculture in Brazil

Meliponiculture in Brazil was studied and summarized by Nogueira-Neto (2002) and Kerr *et al.,* (1996), who promoted development of this activity. In breeding programmes were common in Brazil, to improve productivity and loss of colonies. Studies also evaluated how long a queen lived in some species, by marking physogastric queens with a dot of permanent paint. Most colonies changed queens every year.

The experiments continue, and it is clear that we need more research on the genetics of stingless bee populations. Phorid flies are controlled with the use of vinegar traps, first constructed by Imperatriz-Fonseca. These are often very effective in control. Nowadays they can be used inside the nest, as well as outside. In older times, beekeepers collected stingless bee nests in nature. Now a days farmers are learning how to divide the colonies, as well as become more conscious of environmental concerns. In Brazil, with few exceptions, beekeepers maintain a low technical level, almost without equipment. The harvest of honey is often made by shaking the hives upside-down, thereby destroying young larvae that fall from their provisions, and also attracting phorid flies that damage and parasitize the nest.

Honey, new colonies and nuclei (small incipient colonies) are the main products of Brazilian meliponiculture. Stingless bee beekeeping as a hobby and for educational purposes is another strong reason to keep these bees in urban or rural areas. Studies in Brazil showed that meliponiculture is growing rapidly as a part of secondary economic activity. Most of farmers are increasing the number of colonies they possess using new division techniques and modified boxes. The way a stingless bee beekeeper divides and propagates colonies varies according to species and husbandry knowledge.

Most Brazilian stingless bee beekeepers are members of associations and cooperatives, and some of them have their own homepages. Blogs or discussion websites are also available for stingless bee beekeepers, generally used for beginners, which facilitates the spread of general beekeeping techniques.

In Brazil, a dozen beekeepers started rearing stingless bees as part of social and governmental projects. The largest is Iraquara Project in Amazonas state, which produced 3 tons of honey in 2004. The Brazilian Agricultural Research Company (EMBRAPA) has trained more than 450 rural workers, students, and technicians in meliponiculture in North eastern Amazon. All these efforts leads to increase the colony possession by the farmers, commercialization of colony divisions and help to spread the meliponiculture practice.

## Meliponiculture in Africa

According to the revised taxonomy of stingless bee by Eardley (2005), there are over 20 stingless bee species in Africa. African stingless bee honey is mostly collected by harvesting from feral colonies, which subsequently destroys them. A few communitiesuse hollow logs or clay pots as hives, and they harvest the honey in a more sustainableway. In at least Tanzania, and Angola, meliponiculture exists and an interest to develop meliponiculture has been identified in Ghana, Kenya, Botswana and South Africa. In Angola, *Meliponula bocandei*, the largest stingless bee, produces 10–15 kg of honey in a season (Armor, 2005).

**Table.1** Internal structure of the nest of *Trigona iridipennis* Smith

| Parameters | Brood cells | | Pollen pots | Honey pots |
|---|---|---|---|---|
| | Worker/drone | queen | | |
| Dimensions<br>a) Height<br>b) Diameter | <br>3.72-3.98 mm<br>2.92-3.31 mm | <br>7.12-7.43 mm<br>4.03-4.27 mm | <br>0.7-1.2 cm<br>0.8-1.1 cm | <br>0.6-1.1 cm<br>0.7-1.2 cm |
| Shape | Oval | Oval | Oval | Oval |
| Colour | Brown to cream | Brown to cream | Dark brown | Dark brown |

**Table.2** Trees harboring nests of *Trigona iridipennis* Smith in Kerala

| **Sl.No** | **Common Name** | **Scientific name** | **Family** |
|---|---|---|---|
| 1 | Teak | *Tectona grandis* Linn. | Verbanaceae |
| 2 | Maruthu* | *Terminalia paniculata* | Combretaceae |
| 3 | Poovarasu* | *Hopea glabra* | Dipterocarpaceae |
| 4 | Kanjiram* | *Strychnox nuxvomica* | Loganiaceae |
| 5 | Neer mathalam* | *Crateva religiosa* | Capparidaceae |
| 6 | Jack fruit tree | *Artocarpus integrifolius* | Moraceae |
| 7 | Mango | *Mangifera indica* L | Caesalpiniaceae |
| 8 | Tamarind | *Tamarindus indica* L | Caesalpiniaceae |
| 9 | Manja vaka* | *Albizia lebbeck* | Fabaceae |
| 10 | Manjium | *Acacia manjium* | Fabaceae |
| 11 | Gul mohr | *Poincinia regia (Delonix regia)* | Caesalpiniaceae |
| 12 | Neem | *Melia azedirachta* | Meliaceae |
| 13 | Rain tree | *Albizia saman* | Fabaceae |
| 14 | Silver oak | *Grevillea robusta* | Proteaceae |
| 15 | Red wood | *Adenanthera pavonia* | Mimoceae |
| 16 | Coconut | *Cocos nucifera* L | Palmae |
| 17 | Arecanut | *Areca catechu* Linn. | Palmae |
| 18 | Wild jack fruit tree | *Artocarpus hirsutus* Lam. | Moraceae |

***** Name in local language (Malayalam)

**Table.3** Plantation crops as source of nectar and pollen for *Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Coconut | *Cocos nucifera* L. | Palmae | NP |
| 2 | Arecanut | *Areca catechu* Linn. | Palmae | P |
| 3 | Tea | *Camellia sinensis* | Camelliaceae | P |
| 4 | Cashew | *Anacardium occidentale* | Anacardaceae | NP |
| 5 | Coffee | *Coffea arabica* L. | Rubiaceae | N |
| 6 | Rubber | *Hevea brasiliensis* | Euphorbiaceae | N |
| 7 | Oil palm | *Elacis guineensis* | Aracaceae | P |
| 8 | Eucalyptus | *Eucalyptus sp*. | Myrtaceae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.4** Medicinal plants as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Touch-me-not | *Mimosa pudica* | Mimosaceae | P |
| 2 | Thulsi | *Osmium sanctum* | Laminaceae | N |
| 3 | Puliyarila | *Oxalis carniculata* | Oxalidaceae | N |
| 4 | Ixora | *Ixora coccinea* | Rubiaceae | NP |
| 5 | Henna | *Lowsonia alba* | Lythraceae | P |
| 6 | Castor . | *Ricinus communis* | Euphorbiaceae | N |
| 7 | Neem | *Azadirachta indica* | Meliaceae | N |
| 8 | Nagadandi | *Baliospermum monatanum* | Euphorbiaceae | N |
| 9 | Thazhuthama | *Boerhavia diffusa* | Nyctaginaceae | N |
| 10 | Parijathum | *Nyctanthes arbortristis* | Oleaceae | N |
| 11 | Phyllanthus | *Phyllanthus niruri* | Euphorbaceae | N |
| 12 | Periwinkle | *Vinca rosea* | Apocynaceae | N |
| 13 | Tridax | *Tridax procumbens* | Compositae | NP |
| 14 | 'Kallurukky' | *Scoparias dulce* | Scrophulariaceae | N |
| 15 | Sesbania | *Sesbania rostrata* | Papilionaceae | N |
| 16 | 'Neela amari' | *Indigofera tinctoria* | Fabaceae | P |
| 17 | Trumpet plant | Brugmansia suaveolens | Solanaceae | P |
| 18 | Javanese wool plant | *Aerva lanata* | Amaranthaceae | N |
| 19 | Kurumthotti | *Sida cordiflorus* | Malvaceae | NP |
| 20 | Gladiolus | *Gladiolus grandiflorus* | Iridaceae | NP |
| 21 | Thumba | *Leucas aspera* | Lamiaceae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.5** Ornamental plants as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Rose | *Rosa sinensis* L. | Rosaceae | P |
| 2 | Anthurium | *Anthurium andreanum* | Arecaceae | P |
| 3 | Marigold | *Tagetes erecta* | Compositae | N |
| 4 | Gladiolus | *Gladiolus grandiflorus* | Iridaceae | N |
| 5 | Euphorbia | *Euphorbia milii* | Euphorbiaceae | P |
| 6 | Honey tree | *Pittosporum sp* | Pittosporaceae | N |
| 7 | Garden palm | *Cyrtostachys renda* | Arecaceae | N |
| 8 | Lilly | *Pancratium sp* | Amaryllidaceae | P |
| 9 | Lotus | *Nelumbo nucifera* | Nelumbonaceae | N |
| 10 | Manja vaka | *Albizia lebbeck* | Fabaceae | P |
| 11 | Canna | *Canna indica* | Cannaceae | N |
| 12 | Hamelia | *Hamelia patens* | Rubiaceae | N |
| 13 | Balsum | *Impatiens balsaminae* | Balsaminaceae | N |
| 14 | Ball lilly | *Haemanthus cinnabarinus* | Amaryllidaceae | P |
| 15 | Bird of paradise | *Helicona rostrata* | Zingiberaceae | N |
| 16 | Bottle brush | *Callistemon speciosus* DC. | Myrtaceae | NP |
| 17 | Coral vine | *Antigonum leptopus* | Polygonaceae | NP |
| 18 | Dragon plant | *Dracaena fragrans* | Agavaceae | NP |
| 19 | Orchid | *Spathoglottis plicata* | Orchidaceae | P |

| | | | | |
|---|---|---|---|---|
| 20 | Gerbera | *Gerbera sp.* | Asteraceae | N |
| 21 | Bauhinia | *Bauhinta racemosa* | Caesalpiniaceae | NP |
| 22 | Ross-moss | *Portulaca grandiflora* | portulacaceae | P |
| 23 | Cosmos | *Cosmos bipinnatus* | Asteraceae | N |
| 24 | 'Venthi' | *Tagetus erectus* | Asteraceae | N |
| 25 | Carnation | *Dianthus caryophyllaceus* | Caryophyllaceae | N |
| 26 | Ixora | *Ixora coccinea* | Rubiaceae | N |
| 27 | Sunflower | *Helianthus annuum* | Asteraceae | N |
| 28 | Aerva | *Aerva lanata* | Amarantheceae | NP |
| 29 | Nymphea | *Nymphea stellata* | Nympheaceae | P |
| 30 | Peacock plant | *Caesalpinia pulcherima* | Caesalpiniaceae | NP |
| 31 | Golden dewdrop | *Canna indica* | Cannaceae | N |
| 32 | Poinsettia | *Euphorbia pulcherima* | Euphorbiaceae | N |
| 33 | Cosmos | *Cosmos sulfureus* | Asteraceae | NP |
| 34 | Yesterday-today | *Brunfelria calycinae* | Solanaceae | N |
| 35 | Lonicera | *Lonicera elaeagnoidea* | Caprifoliaceae | P |
| 36 | Celosia | *Celosia cristata* | Ameranthaceae | N |
| 37 | Murraya | *Murraya exotica* | Rutaceae | P |
| 38 | Blue | *Petria volubilis* | Verbenaceae | N |
| 39 | Euphorbia | *Euphorbia heterophylla* | Euphorbiaceae | N |
| 40 | Trumpet plant | *Brugmansia suaveolens* | Solanaceae | N |
| 41 | Portulaca | *Portulaca oleraceae* | Portulacaceae | NP |
| 42 | Duranta | *Duranta goldiana* | Verbinaceae | N |
| 43 | Gold spot | *Duranta plumieri* | Verbinaceae | N |
| 44 | Golden rod | *Solidago canadensis* | Compositae | P |
| 45 | Sage | *Salvia splendens* | Labiatae | P |
| 46 | Jamanthi | *Chrysanthemum sp.* | Asteraceae | NP |
| 47 | Coleostephus | *Coleostephus sp.* | Asteraceae | P |
| 48 | Celosia | *Celosia spicata* | Amaranthaceae | P |
| 49 | Hibiscus | *Hibiscus rosa-sinensis* | Malvaceae | P |
| 50 | Tristellateia | *Tristellateria australis* | Malpighiaceae | NP |
| 51 | Turnera | *Turnera subulata* | Turneraceae | NP |
| 52 | Gardenia | *Gardenta jasminoides* | Rubiaceae | NP |
| 53 | Murraya | *Murraya paniculata* | Rutaceae | NP |
| 54 | Ehretia | *Ehretia buxifolia* | Myrsinaceae | P |
| 55 | Pureria | *Pureria sp.* | Papilliionaceae | NP |
| 56 | Aster | *Celeosteplnus myconis* | Asteraceae | NP |
| 57 | Mimosa | *Mimosa sp.* | Mimosaceae | NP |
| 58 | Rivina | *Rivina humtlis* | Phytolaccaceae | NP |
| 59 | Urena | *Urena lobata* | Malvaceae | NP |
| 60 | Ixora | *Ixora parviflora* | Rubiaceae | N |
| 61 | Lily | *Ltlium candidum* | Liliaceae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.6** Vegetable crops as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Brinjal | *Solanum melongena L.* | Solanaceae | P |
| 2 | Bitter gourd | *Momordica charantia L.* | Cucurbitaceae | P |
| 3 | Drumstick | *Morinja oleifera* | Moringaceae | NP |
| 4 | Ash gourd | *Benincasa hispida* | Cucurbitaceae | P |
| 5 | Snake gourd | *Trichosanthes cucurmerina* | Cucurbitaceae | P |
| 6 | Curry leaf | *Murraya koenigii* | Rutaceae | P |
| 7 | Chilly | *Capsicum annum* | Solanaceae | NP |
| 8 | Sponge gourd | *Luffa cylindrical* | Cucurbitaceae | P |
| 9 | Lady's finger | *Abelmoschus esculentus* | Malvaceae | P |
| 10 | Bottle gourd | *Lagenaria vulgaris* | Cucurbitaceae | P |
| 11 | Capsicum | *Capsicum frutescens* | Solanaceae | NP |
| 12 | Sweet gourd | *Momordica cochinchinensis* | Cucurbitaceae | P |
| 13 | Cheera | *Amaranthus sp* | Amaranthaceae | P |
| 14 | Pumpkin | *Cucurbito pepo* | Cucurbitaceae | P |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.7** Fruit crops as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Mango | *Mangifera indica L* | Caesalpiniaceae | NP |
| 2 | Papaya | *Carica papaya L.* | Caricaceae | P |
| 3 | Guava | *Psidium guajava L.* | Myrtaceae | P |
| 4 | Pomegranite | *Punica granatum L.* | Punicaceae | P |
| 5 | Banana | *Musa paradisica L* | Musaceae | P |
| 6 | Jack fruit tree | *Artocarpus integrifolius* | Moraceae | P |
| 7 | Rambutan | *Nephelium lappapeum* | Sapindaceae | N |
| 8 | Rose apple | *Euginea jambosa* | Myrtaceae | NP |
| 9 | Loovi | *Flacourtia inermis* | Flacourtiaceae | N |
| 10 | Carambola | *Averrhoa carambola* | Oxalidaceae | P |
| 11 | Jamun | *Eugenia cumini* | Myrtaceae | N |
| 12 | Passion fruit | *Passiflora edulis Sims.* | Passifloraceae | NP |
| 13 | Gooseberry | *Emblica officinalis* | Euphorbiaceae | P |
| 14 | Cherry | *Carissa carandas* | Apocynaceae | N |
| 15 | Bilimbi | *Averrhoa bilimbi* | Oxalidaceae | N |
| 16 | Litchi | *Litchi chinensis* | Sapindaceae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.8** Condiments and spices as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Tamarind | *Tamarindus indica L.* | Caesalpiniaceae | N |
| 2 | Cardamom | *Elettaria cardamom* | Zingiberaceae | NP |
| 3 | Cinnamon | *Cinnamomum zeylanicum* | Lauraceae | P |
| 4 | Mustard | *Brassica juncea* | Umbellifera | N |
| 5 | Coriander | *Coriandrum sativum L.* | Umbelliferae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.9** Field crops as a source of nectar and pollen for *Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Tapioca | *Manihot esculenta* | | NP |
| 2 | Gingelly | *Sesamum indicum L.* | Pedaliaceae | N |
| 3 | Onion | *Allium cepa* | Liliaceae | NP |
| 4 | Cotton | *Gossypium hirsutm* | Malvaceae | P |
| 5 | Jute | *Corchous olitorlus* | Tiliaceae | P |
| 6 | Pigeon pea | *Cajanus cajan* | Papilionaceae | N |
| 7 | Sunflower | *Helianthus annus L.* | Asteraceae | NP |
| 8 | Castor | *Ricinus communis L.* | Euphorbiaceae | P |
| 9 | Jetropha | *Jetropha sp.* | Euphorbiaceae | N |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.10** Trees as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Fig | *Ficus roxburghii* | Moraceae | P |
| 2 | Cannon Ball Tree | *Cauropeta guineensis* | Lecythidaceae | NP |
| 3 | Cotton tree | *Bombax malabarium* | Malvaceae | P |
| 4 | Birds cherry | *Mundingia calbura* | Verbinaceae | NP |
| 5 | Sandal | *Santalum album* | Sandalaceae | NP |
| 6 | Payyani | *Paganelia longifolia* | Bignoniaceae | P |
| 7 | Soapnut | *Sapindus emarginatus* | | NP |
| 8 | Teak | *Tectona grandis Linn.* | Verbanaceae | P |
| 9 | Coper pod tree | *Peltophorum roxburghii* | Caesalpinaceae | P |
| 10 | ‘Ettilamaram’ | *Schefflera stellata* | Araliaceae | NP |
| 11 | Bilimbi | *Averrhoa bilimbi* | Oxalidaceae | N |
| 12 | Jack tree | *Artocarpus integrifolius* | Moraceae | P |
| 13 | Oil palm | *Elacis guineensis* | Aracaceae | P |
| 14 | ‘Nagappoomaram’ | *Couropita guianensis* | Lecithidaceae | NP |
| 15 | Bombax | *Bombax malabarium* | Malvaceae | P |

***** N= nectar, P= pollen, NP= nectar and pollen

**Table.11** Shade trees as a source of nectar and pollen for*Trigona iridipennis* Smith in Kerala

| Serial number | Common name | Scientific name | Family | Source* |
|---|---|---|---|---|
| 1 | Wild Tapioca | Manihot glaziovi | Euphorbiaceae | NP |
| 2 | Glyricidia | Glyricidia maculate | papilionaceae | N |
| 3 | Birds cherry | *Mundingia calbura* | Verbinaceae | NP |
| 4 | Agave | *Agave americana* | Agavaceae | NP |
| 5 | Coper pod tree | *Peltophorum roxburghii* | Caesalpinaceae | P |
| 6 | Elengi | *Mimus elengi* | Sapotaceae | NP |

***** N= nectar, P= pollen, NP= nectar and pollen

**Fig.1** Description of the stingless bees across Bangalore a) natural habitat on mud walls; b) habitat on stone walls; f) colony showing brood and stored honey and pollen

**Fig.2** Description of the urban agriculture and urban forest across Bangalore a) and d) avenue trees in GKVK and residential area; b: community park in flats; c*) Ricinus communis* in waste lands; e) and g) balcony gardens; f) terrace garden

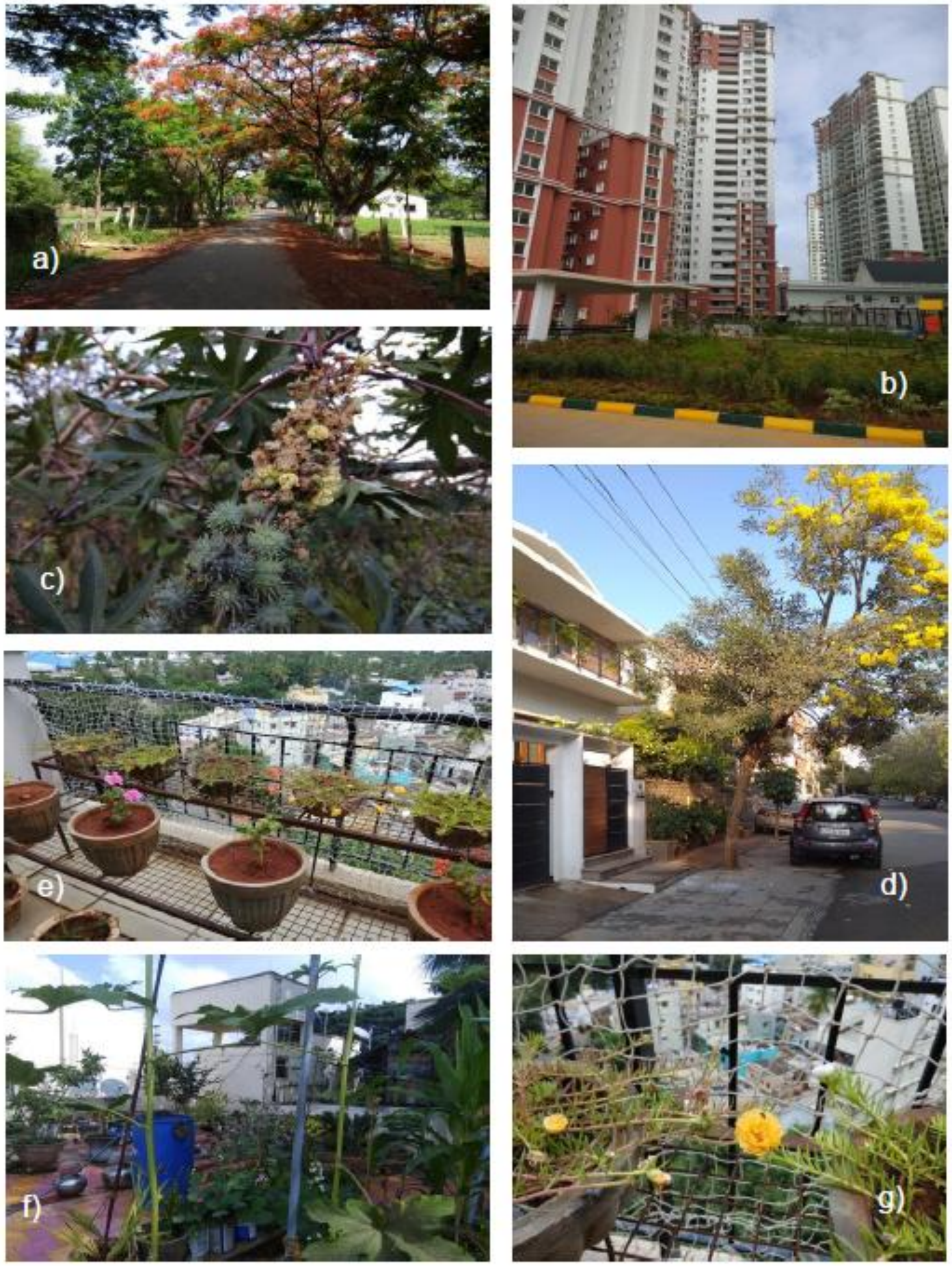

**Fig.3** Schematic representation of stingless bees in differ habitats a) bamboo pole; b) wooden box; c) inside a tree cavity

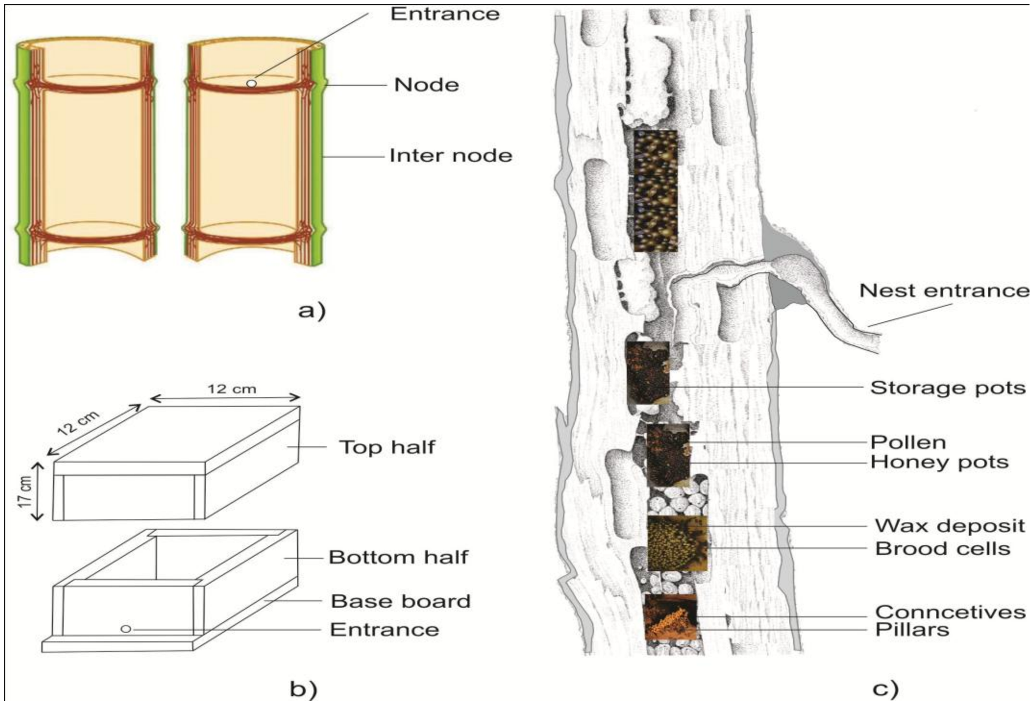


**Fig.4** Different types of bee nests a) hives placed on the stand; b) PVC pipe nest; c) earthen pot nest; d) nest in coconut shell; e) bamboo pole nest; f) earthen bowl nest exposed; g) log nest; h) nest in garden pot; i) two tier earthen bowl nest

**Fig.5** Description of a) stored honey ready to harvest; b), c) and d) stingless bee honey harvested by farmers in different types of non-standard bottles without labels


**Fig.6** Description of the different types of stingless bee honey available in the Kerala market a) pepper tulasi honey; b) and e) honey in standardized bottle with registration details; d) gooseberry

**Fig.7** Different types of standardized stingless bee honey available in Kerala market a) to f)


## Meliponiculture in Australia

The demand and interest for meliponiculture is increasing in Australia. Crop pollination services are developing, honey and cerumen are being harvested, and a stingless bee industry is being developed by the indigenous community. There is a growing interest in conserving wild stingless bee colonies. Many individual beekeepers relocate nests found in fallen trees and artificial sites. Collecting and recusing stingless bees from natural habitat is popular in Australia. Once the wild bees are captured, they are allowed to reproduce. Some of the stingless bee keepers kept stingless bee for crop pollination services and as a secondary financial activity. Many crop growers are also purchasing their own stingless bee colonies. The main species used for crop pollination are *Trigona carbonaria* and *T. hockingsi*.

Macadamia nut (*Macadamia integrifolia*), native to eastern Australia, is the most common crop pollinated with stingless bees. Stingless bees mainly collect pollen from the flowers and are efficient pollinators (Heard, 1994). Many other crops may be pollinated by stingless bees (Heard, 1999) and in Australia, successful results for lychee, melon and avocado have been reported. Wild stingless bees often provide a free pollination service (Heard and Exley, 1994). These wild bees face the problem of extinction due to land clearing and habitat destruction.

Australian stingless bees prefer to forage close to their hives, thus tend to stay within the crop area better than does Apis. Some beekeeper reports that the effective foraging range of stingless bees within a macadamia crop is 25 m. Stingless bees also cope better than Apis in crops covered by netting. However, stingless bees can be quite sensitive to pesticides, which can result in substantial bee losses. Demand for the crop pollination service with stingless bees in Australia is increasing as farmers become more aware of the importance of stingless bees and availability of the hives. Destruction of the domesticated Apis species due to small hive beetles (*Aethina tumida*) and varrora mite popularise demand for paid pollination services by stingless bees.

In addition to crops, native bushland requires pollination services. The pollinators may have been driven extinct by human induced pressures. Demand for the production and marketing of Australian stingless bees is growing. New hive designs that are suited to the extraction of honey and cerumen are being developed. In order to develop commercial markets, the price needs to increase. The main hurdles are low productivity, higher cost of production, fighting swarms and nest parasites. New hive designs that are suited to the extraction of honey and cerumen are being developed. The market price of the honey is currently about AU $50 per kg, wholesale.

The indigenous community of Aurukun in far north Queensland since 2002 to develop a stingless bee industry. Currently they have hived over 130 colonies, mostly *T. hockingsi*. Stingless bee honey, known to indigenous people as 'Sugarbag', is a major product. Cerumen is also collected for making traditional artifacts. A major potential use for the cerumen is to form the mouthpiece of the "didgeridoo", a traditional musical instrument. Until recently, cerumen was very difficult to obtain and honey bee wax was used as a substitute. However, stingless bee cerumen is the authentic and superior product.

Demand is expected to grow rapidly as awareness increases. Stingless bees are attractive subjects for public nature education. Museums, exhibitions, gardens, and schools in Australia are increasingly using social bee colonies to illustrate the beauty, complexity and fascination of nature. Topics such as sociality, parasitism andpollination can be demonstrated using these insects, which are gentle and easy to keep. Workshops on stingless bees at nature education centers are growing in popularity in Australia.

## Meliponiculture in Asia

Stingless bees far exceed honey bees in diversity and distribution. Out of more than 500 species described worldwide about 50 species occur in Asia. Southeast Asia has several honey bee species and about 45 stingless bee species. Thailand, like Viet Nam, is a very long country, extending for over 1000 km south to north. In the south, there are five Apis species and at least 30 stingless bee species, while in the north, there are four Apis and less than 10 stingless bee species. The southern Thai name formeliponines is "Oong", while in the north, they are called "Channa Long". The local people only use stingless bee honey for "medicinal purposes". Stingless bee beekeeping for pollination service is only now beginning to take root in southern Asia (in India) and in SE Asia (Malaysia and the Philippines).

In contrast to the Asian honey bee (*Apis cerana*), stingless bee colonies are typically long-lived (Roubik, 2006; Quezada-Euán, 2018) and have low absconding behavior. Some species of stingless bee continuously occupy the original nest, and the nest lives more than 20 years. These aspects of their biology make stingless bee species successful in meliponiculture in Southeast Asia, including Thailand. At least six of Thailand's native species have had nests successfully transferred into a wood box to pollinate orchard crops. Two species (*Geniotrigona thoracica* and *Tetragonula pagdeni*) have been used for honey production. Additionally, management costs have been lower than in apiculture. The meliponiculture might be useful to improve household income in the countryside of Southeast Asia, where there is a very high diversity of flora (Eltz *et al.*, 2002; Kajobe and Roubik, 2006).

There are several methods for transferring stingless bee colonies from their natural habitat to artificial hive boxes. This is one of the most important features of meliponiculture. In Southeast Asia, there are several models and sizes of commercial hive boxes available for stingless bees. However, two basic models of boxes, vertical and horizontal, are used depending on the species' arrangement of brood and food pots. For vertical boxes, the brood cluster is usually placed in the bottom section of the boxes, with honey and pollen pots built on the top of the hive. For instance, a vertical commercial hive box has successfully kept a nest of *Geniotrigona thoracica*. This type of hive box is easy to manage and harvest the honey. Horizontal boxes are the more popular for the small stingless bee species. The horizontal model is normally used for species that build the honey and pollen pots next to the brood clusters, such as *Tetragonula pagdeni* and *Tetragonula fuscobalteata.*

## Stingless bees in Indian sub-continent

The species of stingless bees are known from the Indian subcontinent: *Lepidotrigona arciferal* (Cockerell), *Lisotrigona cacciae* (Nurse), *Lisotrigona mohandasi* Jobiraj and Narendran, *Tetragonula aff. laeviceps* (Smith), *Tetragonula bengalensis* (Cameron), *Tetragonul agressitti*(Sakagami), *Tetragonula iridipennis* (Smith), *Tetragonula praeterita* (Walker), and *Tetragonula ruficornis* (Smith). Lectotypes are newly designated for *T. bengalensis* and *T. ruficornis* (Rasmuseen, 2013).

## Meliponiculture in India

India is blessed with at least three native species of honey bees namely, *Apis dorsata*, *A. florea* and *A. cerana* and one exotic species i.e. *A. mellifera*. A stingless bee, *Trigona iridipennis* (*Tetragonula sp*.) also occurs throughout India. In India only one species (*Trigona iridipennis* Smith) of stingless bee is reported. The knowledge available on the bioecology of this species is also limited.

Stingless bees are widely known in the Indian subcontinent as “dammer bees” or “dammar bees” (dammar = resin formed among dipterocarp trees). Many local names are applied with reference to the pattern of storage of pollen and honey as “Cherutheneecha” and “Arakki” in Kerala. “Tenetigalu” in Andhra Pradesh; and “Mulijenu” (Kodagu), “Mujanatejenu”, “Misrijenu”, “Nasarujenu”, “Kirujenu” in Karnataka (Nair, 2003).

## Nesting habitats of *Trigona iridipennis* in India

A diverse range of nesting habitats were chosen by *Trigonaspp*. (*Tetragonulaspp*.) corresponding to the equally varied climatic and geographic conditions prevailing in the southern regions of India. Because, nests were detected at different ecological zones involving tropical evergreen, semi evergreen, grassland, moist deciduous, dry deciduous, shrub lands, freshwater wetland, subtropical secondary scrub, grassy slopes and thorny scrub type of forest vegetation.

*T. iridipennis* is a gentle species and it can be manipulated with ease. The species found in Karnataka (Biesmeijer, 1993) Kerala (Raakhee, 2000; Devanesan *et al.*, 2017) and Tamil Nadu (Swaminathan, 2000) have been reported as *T. iridipennis*. In Kerala stingless bees are reared as backyard beekeeping practice mainly for honey production. They are kept in wooden box, mud pots, bamboo hollows or coconut shells. The stingless bees are hardy and easy to handle. The nests are constructed using wax in a mixture with resins, mud, faeces, or other materials collected by the bees. The nest has one entrance tube made of cerumen. The entrance of the nest may be a simple hole, often extended from the nest as an external tube.

## Economic potential of stingless bees

The development of traditional meliponiculture enriched with scientific knowledge provides new opportunities for people in the urban and peri-urban and rural areas, especially women and it can improve the economics of many households and provide supplementary income. The non-aggressive and gentle behaviour when compared to other defensive stinging bees (Apis varieties) of stingless bees make women and children attractive in keeping stingless bees. Stingless beekeeping provides incomes to the rural poor through honey, cerumen (mixture of wax and plant resin) and resins production. Stingless honeybees produce beeswax and this form an important honeybee product. he beeswax is used as emulsifying agent for nearly all our modern cold creams, shoe polish production, wood polish, ointment, lipstick, pomade and rouges. Other industries using beeswax include textile, ink, candle, crayon and pharmaceutical and food industries.

Despite the high market for stingless bee honey, beeswax and pollen in both local and international markets, their production and processing are not common in Karnataka and so these honeybees products are not much and readily available in the market. The stingless bees honey is sold in market places at a higher price than honey from Apis bees (Sanford, 1997). More information could therefore be made available on the production, processing and utilization of stingless honeybee honey, beeswax and pollen. Also high quality honey, beeswax and pollen could be provided for food and pharmaceutical industries and generate employment for the youths.

Another attractive feature of meliponiculture is that the meliponine bees are ‘stingless’. Unlike the situation in keeping the honeybee, beekeepers need not purchase expensive, protective clothing in order to manage and handle hives or to harvest and collect products (honey, propolis, beebread) with melipona. Thus meliponiculture can be viewed as both a compliment and advancement of the honey bee industry (Apiculture).

The antimicrobial and anticancer activity of stingless bee honeys may lead to the use of these honeys in medicinal products. Moreover in the current Covid-19 pandemic situations, the stingless bee honey may act as an immunity booster and enhance the immune system. Certainly, stingless bee honey, with its delicate taste, does fit very well in the present development of export market for speciality honey.

In addition, the role of stingless bees as providers of ecosystem services vital to the survival of several forest plants and crop species through pollination has also become a source of income generation activity. In Australia, stingless beekeepers offer stingless bee services for crop pollination, usually as their secondary financial activity (Cortopassi-Laurino *et al.,* 2006).

In conclusion *trigona iridipennis* Smith shows great diversity in plant selection for dietary as well as resin sources. The shift towards ornamental plants for foraging may be an adaptation evolved in response to human modification of the environment. The bees collect resin from a variety of sources for building nest, its maintenance and also for defence. Bee traffic is found to be related to time, season, and strength of the colony. The study also highlights the various food sources of *Trigona iridipennis* Smith in Kerala which can be further explored for flourishing meliponiculture.

The potential benefit from meliponiculture can be tapped if a concerted effort is moved toward developing a sustainable approach to beekeeping in Africa and Nigeria in particular. Several ways in which this could be accomplished is through attainment of a proper understanding of the meliponine life cycle, discovery of new ways to increase honey yield and through better bee management, including sanitary practices, the housing of colonies, multiplication and harvest procedures. In all places where meliponiculture develops, bottlenecks for their improvement include how to keep and conserve their honey, how to rear them in large quantities, how to prevent colonies from being contaminated by agricultural pesticides and maintain the bees, how to use their services and conserve their populations, and how to provide qualified information and training in all levels. A non-destructive approach in breeding, propagating and relocating of bees using pheromone technology will ensure environmental sustainability.

Stingless bees are one of the most important pollinators of native plants and economic crops in tropical and subtropical parts of the world. They not only establish large perennial colonies with complex social organization but also have a diverse nesting biology. The current status of meliponiculture in Southeast Asia is mainly focused on pollination utilization and honey and propolis production. It is concluded that small-scale beekeeping of stingless bees, which is suitable for the flowering pattern in the tropics, is one of the best potential alternative opportunities. The cost-effectiveness analysis based on production yield, investment cost, and profit-return rate should be studied in-depth. Finally, a sustainable utilization of stingless bees is considered to be an enhancer of pollination services both in an agricultural crop and natural ecosystem.

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