

**STINGLESS BEE FORAGING PATTERN IN ORNAMENTAL PLANTS**

*by*

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**(2020-11-051)**

**THESIS**

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**COLLEGE OF AGRICULTURE**

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i.

## DECLARATION

I, hereby declare that the thesis entitled “STINGLESS BEE FORAGING PATTERN IN ORNAMENTAL PLANTS” is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

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## LIST OF ABBREVIATIONS

%	Per cent
<i>et al.</i>	And others
<sup>o</sup> C	Degree Celsius
GC-HRMS	Gas-chromatograph coupled with mass spectrometer
sec	Second
min	Minute
nm	Nanometer
g	Gram
kg	Kilogram
L	Litre
mL	Millilitre
μl	Microlitre
μg	Microgram
sp. or spp.	Species (Singular and Plural)
CD	Critical difference
R	Correlation coefficient
Rpm	Rotations per minute
NS	Non-significant
<i>viz.</i> ,	Namely

# ***INTRODUCTION***

## 1. INTRODUCTION

Stingless bees frequently referred to as “dammer bees” are a group of small to medium sized bees, visiting a variety of flowering plants in tropical and subtropical regions of the world. As the name implies, these bees can’t sting as their stingers are greatly reduced, but they try to defend their colony from intruders using their mandibles (Michener, 2000). Out of more than 500 species described worldwide about 50 species occur in Asia. Among the most pervasive species of stingless bee in India is *Tetragonula iridipennis* Smith (Vijayakumar and Jayaraj 2013).

Despite the small amount of honey produced per hive, its demand is great and fetches comparatively high price in the market due to its unique flavour and medicinal value. Their abundance combined with diversity, has a vital role in pollination of crops in sustainable agriculture resulting in food safety. Stingless bee pollination is crucial for up to one-fifth of the local angiosperm flora or many tropical plant species, which are responsible for pollinating 70 to 80 per cent of blooming plants. Apart from these, they can be used very effectively in planned pollination, especially in glass house condition they can forage effectively due to their smaller foraging range than honey bees. They are harmless potential pollinators to beekeepers which visit a wide range of crops, tolerant to high temperature, active throughout the year and can be transported easily. Meliponiculture is a suitable enterprise for women as it does not involve heavy physical work and painful sting in all the homesteads of Kerala.

The existence of the colony depends on the regular and necessary activity of bee foraging. Stingless bees collect a multitude of things while foraging, such as pollen, nectar, resin, water, etc. For their metabolic processes to be maintained, bees require food that is nutritionally adequate. The bee strength, development and quantity of honey stored in a stingless bee colony are highly dependent on the collection of nectar and pollen by the worker bees which is regulated by the availability of flora in the surroundings.

Nectariferous and polleniferous plants are essential for the beekeeping business because they provide them with the majority of the necessary nutrients through floral resources, such as pollen and nectar. For the majority of bee species, nectar is their primary source of carbohydrates. Nectar has sucrose, fructose and glucose in varying proportions, essential oils, minerals and other material in traces. Pollen is the primary source of protein and essential amino acids. Bees require pollen for the development of their bodies, the generation of food

for the queen, nursing larvae into adult bees, and the overall health and hygiene of their colony. The bee pollen contains an average of 54.22 % carbohydrates, 21.30% proteins, 5.31% lipids, 8.75% fibre, 2.91% ash, 13.41 g/100 g glucose, 15.40 g/100 g fructose, 4.25 g/100 g sucrose, 4951.60 mg/kg and 30.59 mg GAE/g total phenolic content (Thakur and Nanda 2020).

Success of beekeeping depends upon many factors, among which abundant availability of bee flora within the surrounding area of an apiary is most important. Awareness on bee flora and honey flow and dearth periods of a particular region will help in the effective management of bee colonies during different periods. Information on nectariferous and polleniferous ornamental plants can help stingless beekeepers in selecting suitable sites for their apiaries as well as in enriching area with high nectar producing plants for their colonies. The extensive knowledge on duration of flowering, blooming time, type, density and quality of bee flora in a region are prerequisites for enhancing the efficiency of beekeeping industry and successful beekeeping.

Bees can utilize ornamental plant species as an important nutritional resource of food, especially when other plants are not blooming. In urban areas, they could exploit existing gardens, parks, vacant areas, etc. where ornamental flowering plants are there. Hence attractive plants with different flowering periods can be used in gardening, which favors the beautification factor and subsequently, the supply of resources remains maintained throughout the seasons.

For beekeeping as an industry, the pollen and nectar of flowers are the raw materials. Since efficient running of the industry depends on the quality, quantity and availability of raw material, the evaluation of plants for their utility to honey bees and preparation of floral calendar are essential. Hence, this study entitled “Stingless bee foraging pattern in ornamental plants” was carried out with the objective of documentation of the foraging pattern of stingless bees in nectariferous and polleniferous ornamental plants and preparation of floral calendar.

# ***REVIEW OF LITERATURE***

## 2. REVIEW OF LITERATURE

The literature pertaining to the foraging activity of stingless bee in different ornamental plants and preparation of floral calendar are reviewed under the following headings.

Stingless bees are a highly diversified and widespread species of eusocial bee that live in tropical and subtropical parts of the world. As in honey bees, their principal resources are pollen and nectar, but they also gather materials such as water, sap, wax, honeydew, excess flower nectar, resin and sap to utilize as food or nest construction materials (Roubik, 1980). Stingless bees are abundant in tropical rainforests and are pollinating many tropical plant species and potentially accounting for up to one-fifth of the local angiosperm flora (Wilms *et al.*, 1996).

### 2.1. IDENTIFICATION OF NECTARIFEROUS AND POLLENIFEROUS ORNAMENTALS

Success of beekeeping depends upon many factors, among which abundant availability of bee flora within the surrounding area of an apiary is most important (Singh, 2005). Bees require food of appropriate nutritional quality to maintain their metabolic process and majority of their nutritional needs are met by floral resources like pollen and nectar (Roubik, 2006). In establishing bee-friendly gardens, the knowledge on quantity and quality of nectar and pollen as well as the information if a floral reward is attractive to pollinators are required (Denisow *et al.*, 2014).

Stingless bees are generalist foragers of pollen and nectar (Aleixo *et al.*, 2013). Bee forage plants may be fruits, vegetables, ornamental, medicinal, forest plants and weeds (Dallo, 2013). There are three types of bee flora, plants that only supply nectar, plants that only supply pollen and plants that provide both (Bhalchandra *et al.*, 2014). Stingless bees are capable of utilizing small, medium and large tubular and non-tubular flowers for their forage. Moreover, these are efficient enough to utilize different types of flowers having different qualities and quantities of floral rewards (Vamshikrishna *et al.*, 2021).

Every species of flowers produces different concentrations of nectar as a strategy to attract different types of pollinators (Galletto *et al.*, 1998). The nectar is required by honey bees to meet their day-to-day energy requirements which serves as an important source of carbohydrates for many pollinating insects (Biesmeijer *et al.*, 1999). The concentration of

sugars in nectar varies and bees prefer a concentration of about 35 per cent (Wolff, 2006). Nectar has sucrose, fructose and glucose in varying proportions, essential oils, minerals and other material in traces (Kajobe, 2007). Climatological factors *viz*, temperature and humidity are known to influence the sugar concentration of floral nectar (Kim *et al.*, 2011). Nectar is produced in the plants in special structures called nectaries. Nectaries are found generally in or near the flowers, but they are also found in other parts of the plant like the leaves (e.g. cotton and rubber) and are called extra-floral nectaries (Faegri and Van Der Pijl 2013). Several plants do not secrete nectar, while some may produce a sweet liquid due to some injury or infection (Vaudo *et al.*, 2015).

According to Pacini (2000), pollen is considered to be an important resource as it is a main source of protein, vitamins, mineral salts, organic acids and hormones. The composition of pollen and the nutritive quality differ from one species to the other (Reyes-Carrillo *et al.*, 2007). Pollen contains proteins, carbohydrates, fats, minerals, vitamins, essential oils and colouring materials (Bhargava *et al.*, 2009). Bees need pollen for their body growth, for production of food for the queen, for nursing larvae to grow into adult bees and for general health and hygiene of their colony.

### **2.1.1. Nectar providing flowering plants**

Stingless bees collected nectar from two floras in Nagaland, *Anacardium occidentale* L and *Grevillea robusta* A (Adhikari and Ranabhat 2011). Hosamani *et al.* (2018) reported that major nectar yielding plants in Koppal district Karnataka are *Phaseolus vulgaris* L, *Cyamopsis tetragonolobus* (L), *Momordica charantia* L, *Mangifera indica* L, *Pongamia pinnata* (L), *Jasminum* sp. *Gladiolus communis* L, *Echinops echinatus* R and *Santalum album* L.

Stingless bee flora of Kerala comprises of about 137 plant species including several nectar producing plants *viz*, *Musa* sp., *Hevea brasiliensis* Mull, *Gladiolus grandiflorus* L, *Impatiens balsaminae* L, *Duranta goldiana* L, *Hamelia patens* Jacq, *Tagetes* sp., *Euphorbia hirta* L, *Canna indica* L, *Vigna radiate* (L), *Vigna sinensis* (L), *Cajanus cajan*(L), *Vinca rosea* L, *Aerva lanata* (L), *Ocimum sanctum* Linn, *Jatropha* sp., *Glyricidia maculate* Jacq, *Oxalis carniculata* L respectively (Devanesan *et al.*, 2009 and Premila *et al.*, 2007).

### 2.1.2. Pollen providing flowering plants

Suryanarayana *et al.* (1992) reported the major pollen sources for bee in Muzaffarpur, Bihar include, *Zea mays* L, *Parthenium hysterophorus* L, *Brassica* spp, *Phoenix sylvestris* L, *Borassus flabellifer* L, *Cajanus cajan* (L), *Pisum sativum* var *arvense* (L), and *Cosmos bipinnatus* Cav. Adhikari and Ranabhat (2011) found that stingless bees collected only pollen from four floras in Nagaland, ie, *Abelmoschus esculentus* (L), *Zea mays* L, *Oryza sativa* L, and *Mimosa pudica* L.

Bhargava *et al.*, (2009) reported that *Cocous nucifera* (L), as a major source of pollen and it was available throughout the year in Karnataka. Azmi *et al.* (2015) found that the most frequently collected pollen by stingless bee was from *Ixora coccinea* L (36.78%), followed by *Citrus hystrix* DC (24.27%) in Karnataka.

Stingless bee foraging for pollen in different plant species in Kerala viz, *Mangifera indica* L, *Citrus* sp., *Carica papaya* L, *Psidium guajava* L, *Benincasa hispida* (Thunb), *Cucurbita pepo* L, *Lagenaria vulgaris* Ser, *Trichosanthes cucumerina* L, *Momordica charantia* L, *Mimosa pudica* L, *Ixora* sp. and *Rosa* sp. (Devanesan *et al.*, 2009).

### 2.1.3. Both nectar and pollen providing flowering plants

Foraging for nectar and pollen is a continuous process throughout the year in tropical and subtropical areas, where bee flora is available. Honey bees and stingless bees were the most common insects visiting onion flowers for collecting pollen and nectar in Brazil (Lorenzon *et al.*, 1993). Melendez-Ramirez *et al.* (2002) recorded stingless bee were collecting nectar and pollen from pumpkin (*Cucurbita moschata* Duchesne), cucumber (*Cucumis sativus*L.), melon (*Cucumis melo* L.) and watermelon (*Citrullus lanatus* L) in Mexico.

Adhikari and Ranabhat (2011) reported 158 plant species as bee flora in Nepal. In total, 38 species were recognized as major, 35 as medium and 30 as minor sources for both nectar and pollen. The plant species provide both nectar and pollen include *Berberis* sp., *Bombax ceiba* L, *Brassica* spp, *Callistemon citrinus* C, *Citrus* spp, *Mangifera indica* L, *Rubus ellipticus* S.

Adhikari and Ranabhat (2011) reported 58 nectar and pollen sources in Nagaland and the major source of both nectar and pollen included, *Citrus* spp, *Litchi chinensis* S, *Eucalyptus* sp., *Cocos nucifera* (L), *Coffea* sp. and *Delonix regia* R. NunezOrdonez

and Pastagia (2015) reported

floral resources of stingless bee in Karnataka. They visited for nectar and pollen from flowers of Hibiscus, *Hibiscus sabdariffa* L, Hamelia *Hamelia patens* Jacq, Gardenia, *Gardenia jasminoides* Ellis, Ixora, *Ixora coccinea* L, Chrysanthemum, *Chrysanthemum indicum* L. Turnera, *Turnera subulata* Sm, Gaillardia, *Gaillardia pulchella* Foug.

Raju *et al.* (2013) found that important foraging tree sources provide both nectar and pollen for bees, trees such as *Anacardium occidentale* (L), *Mangifera indica* L, *Phoenix sylvestris* L, *Spathodea campanulata* P, *Ceiba pentandra* (L), *Caesalpinia coriaria* W, *Bauhinia purpurea* H, *Peltophorum pterocarpum* DC, *Tamarindus indica* L, respectively.

Vamshikrishna *et al.* (2021) reported 12 floral resources for nectar (40%), nine plant species for both nectar and pollen (30%), four plant species for resin (14%), two plant species for both nectar and resin (7%), one plant species for only pollen (3%), one plant species for both pollen and resin (3%) and one plant species for nectar, pollen and resin (3%) for stingless bees in Bagalkot, Karnataka, India

Stingless bee foraging for both nectar and pollen producing plants in Kerala were *Cocous nucifera* (L), *Anacardium occidentale* (L), *Theobroma cacao* L, *Coffea arabica* L, *Capsicum annum* L, *Cajanus cajan* L, *Vigna mungo* (L), *Moringa oleifera* Lam, *Lantana camera* L, *Tridax procumbens* L, *Antigonon leptopus* Hook. & Arn, *Portulaca* sp, *Caesalpinia pulcherrima* (L), *Helianthus annus* I, *Ixora* sp., *Rosa* sp., *Duranta* sp. and *Ricinus communis* L. (Devanesan *et al.*, 2009; Premila *et al.*, 2007).

## 2.2. FORAGING ACTIVITY OF *T. iridipennis*

Foraging behaviour is one of the important characteristic of any insect. Bees can also be classified as generalists or specialists depending on their foraging habits. Bees that gather nectar and pollen from a wide variety of flowers are generalists. According to Sommeijer *et al.* (1983) there are four types of foragers; pollen foragers, nectar foragers, pollen and nectar foragers and mixed foragers. Foragers are different as they come to the hive either with pollen or resin or nectar. Bees that depend on a single plant or a small number of plants for pollen and nectar are categorized as specialists (Joshi and Joshi 2010).

Ghazi *et al.* (2014) revealed that the highest outgoing foragers was observed in the morning hours. The least number of active foragers was seen in the late evening. Foraging behaviour of stingless bee was active during morning hours due to availability of pollen and

nectar or both in ample quantities and become decreased in evening hours (Bharath *et al.* 2020). Foraging activity decides the efficiency of bee survival and it directly depends on the colony population. Maintenance of colony was observed by counting the number of workers moving out and returning to the hive with pollen and nectar for a particular period (Hemalatha *et al.*, 2018).

Ghosh *et al.* (2020) indicate that the trend of active bees' foraging activity depends on the time during which foragers can obtain the highest reward from their visit to a flower.

#### **2.1.4. Foraging intensity**

The stingless bees are generalist flower visitors and their foraging range is very shorter than true honey bees (Roubik *et al.*, 1995). According to Ponnuchamy *et al.* (2014) the frequency of bee visitation was more on plants that are very nearer to the colony. Foraging intensity has been used to determine floral sources, geographical origin and genus of the plants that the bees visited.

Stingless bees may have one or two peak foraging hours, depending on species, *Tetragonula iridipennis* has two peak hours of foraging activity, which are in the morning and in the afternoon (Free 1993). The number of flowers visited per minute by any bee species depends upon a number of factors including instinctive foraging behaviour, length of proboscis and floral structure particularly the corolla depth, type and quantity of floral rewards, density of flowers of particular cultivar of the crop grown and the time of the day (Layek and Karmakar, 2018).

#### **2.1.5. Foraging rate**

Alqarni (2006) found that the foraging activity fluctuates during the day from the morning until the evening. According to Saravanan and Alagar (2007), the observation on nectar foraging activity of *T. iridipennis*, revealed that the highest activity occurred from 1100 h to 0500 h (55.69 - 69.44 foragers 10 min<sup>-1</sup>) and least foraging activity was observed from 0700 am to 0800 am (21.59 foragers 10 min<sup>-1</sup>). Foragers have the ability to remember the time of the day at which the higher food resources are available in plants (Silva *et al.*, 2013). Oliveira *et al.* (2014) also reported that the number of bees collecting resource increased until 0950 am, with a peak foraging activity between 1030-1150 am and the foraging decreased gradually.

Yucel and Duman (2005) found that bee workers visited onion flowers from 0815 h to 0400 h and the peak foraging was between 1100 to 1200 h. Pernal and Currie (2001) reported that higher foraging rate was during the afternoon period (36.02 foragers/min) than during the morning period (17.66 foragers/min) in strawberry flowers.

Panda *et al.* (1993) recorded maximum bee visitation in sunflower from 1100 h to 1200 h. Similarly, Ahmed and Rehman (2002) reported that peak activity of *A. cerana indica* on sunflower at 1100 to 1200 h and maximum number of *A. cerana* (5.66) at 1400 h on strawberry flowers.

Danareddi (2007) reported that foraging behaviour of *T. iridipennis* during different season and activity of outgoing bees was high in October and November, also pollen foraging in the month of February.

Devanesan *et al.* (2002) observed that, in Kerala peak foraging activity of *T. iridipennis* during the month of July and least foraging activity during December and January.

#### **2.1.6. Foraging speed**

Time spent per flower and number of flowers visited per minute were taken as the indicators of foraging speed (Free, 1993). The time spent by bees for foraging on the flowers depends on the availability of nectar and pollen on flowers and total length of foraging movement comprised of 10 h (Said *et al.*, 2015).

Foraging speed varies with plant and the time spent per flower was 6.92, 6.50 and 5.54 sec for Chinese cabbage, broccoli and kohlrabi respectively (Sushil *et al.*, 2013). The maximum time spent by stingless bees for collecting pollen and nectar on musk melon flower was 11.17 sec at 1500 h and 18.16 sec at 0900 h. There was no activity of stingless bees, *T. laeviceps* during 0600, 0700 and 0800 h (Gadhiya and Pastagia 2019). The length of each time for nectar collection visit by a *Scaptotrigona* sp. varied between 2.27 and 43.95 sec (Bomfim *et al.*, 2014).

#### **2.1.7. Foraging preference**

Foraging bees use visual and olfactory cues to find and select food sources and learned preferences to detect flowers (Dyer *et al.*, 2019). Choice of food sources is based on several factors, including scent marks, color and location of flowers. Azuma *et al.* (2002) reported

that flower scent and scent chemical profiles are one of the important factors for attracting pollinators.

### 2.3. RELATIONSHIP BETWEEN FORAGING RATE AND WEATHER PARAMETERS DURING PEAK FLOWERING PERIOD

According to Biesmeijer and de Vries (2001) and Abou-shaara, (2013), foraging activity will depend on in-colony factors and out-colony factors. Internal factors, such as individual memory and external factors such as environmental and colony conditions. In stingless bee colonies, food collection is influenced by both abiotic factors such as temperature (Mishra and Sharma, 1997) and rainfall and differences in floral resource availability. There is usually shortage of floral resources during summer and rainy seasons *i.e.* from June to August (Hilario *et al.*, 2001).

Stingless bees foraging behaviour could be influenced by the environment conditions which can vary depending on the time of day (Roubik *et al.*, 1995). Foraging activity of all insect visitors was affected by environmental conditions such as temperature, light intensity, wind speed and time of day and season (Kevan and Baker, 1983; Hemalatha *et al.*, 2018).

According to Corbet *et al.* (1993) the temperature is the environmental factor that mostly affects the flight activity on bees. Foraging activity is influenced passively by elevated temperature as reported by Cooper and Schaffer (1985). Little or no flight activity occurs at or below 10°C. On clear and sunny days some flight was seen at temperature of 12-15°C. Flight begins in earnest at 16°C and the number of bees taking foraging trips increases as the temperature continues to rise (Joshi and Joshi 2010).

Kaur and Sihag (1994) observed that the number of pollen foragers had a highly significant positive correlation with temperature and negative correlation with relative humidity. According to Kovac and Stabentheiner (2011), relative humidity has less effect on the flight activities of honey bees. However, combination of temperature and humidity is most important in the ripening of the anthers of the flowers and the availability of pollen to visiting insects. Therefore, low temperature and high humidity have the double effect of reducing bee activity and slow the release of pollen.

Reddy *et al.* (2015) reported that wind speeds greater than 12 kmph have a negative impact on honey bee foraging because they cannot carry loads upwind at speeds greater than

15 kmph. Bees prefer to be in their hives during rain and in periods of inclement weather but may fly between showers for short distances of up to 100 m (Aleixo *et al.*, gopinath). Hemalatha *et al.* (2018) reported that bees had not come for foraging during rainfall thus showing a strong negative correlation.

Maity *et al.* (2014) reported that honey bee abundance increased with increase in average daily maximum temperature ( $R=0.631$ ) and with increase in effective sunshine hours ( $R= 0.696$ ). But relative humidity and wind speed showed negative correlation with honey bee population ( $R= -0.736$  and  $R= -0.837$ , respectively).

#### 2.4. FLORAL CALENDAR

Pollen and nectar availability to foraging bees fluctuated with time of the year and flowering of different species of plants (Free, 1970). For efficient running of the beekeeping industry depends on the quality, quantity and availability of raw material, the evaluation of plants for their utility to honey bees and preparation of floral calendar are essential (Chaudhary, 2001). Floral calendar is one of the most useful tool in the sector of the apicultural operations which requires complete observation of the seasonal changes in the floral patterns of an area, the foraging behaviour of the bees, and the manner in which the honey bee colonies interact with their floral surroundings (Kumar *et al.*, 2015).

Waykar and Bavisker (2015) suggested that bee forage calendar for beekeeping is a period that indicates the approximate date and the duration of the blossoming period of the existing honey or pollen plants in an area. In addition to the time and duration of blossoms of honey plants, it also involves the mapping of density, distribution and honey potential of the regional bee flora.

Kumar *et al.* (2013) reported that the presence of number of diversified bee floral species in the area suitable for commercial beekeeping. In Karnataka, the peak periods of honey bee foraging activity, honey flow period were recorded during June - October of winter season and January to March of summer season and mid -April to mid- June were the critical dearth periods.

## ***MATERIALS AND METHODS***

### **3. MATERIALS AND METHODS**

Study on “Stingless bee foraging pattern in ornamental plants” was carried at Department of Entomology, College of Agriculture Vellayani, Thiruvananthapuram, Kerala. The experiment was conducted from September 2021 to August 2022. The materials and methods adopted for this study is described as follows:

#### **3.1. IDENTIFICATION OF NECTARIFEROUS AND POLLENIFEROUS ORNAMENTALS**

To identify the major flora visited by stingless bee, the flora encountered by the bees either for pollen or nectar or for both were observed regularly in and around the College and documented. Ten flowers were observed from the identified plants at full bloom stage and their flowering period and floral characteristics were recorded.

##### **3.1.1. Nectar providing flowering plants**

Plants around beehives were observed on a daily basis at hourly intervals from 0600 h to 0600 h to find out the foraging bee visit to confirm it as a nectar source. Nectar collectors were identified by observing their abdomen, it is filled with nectar or those without pollen load in their hind leg were considered as nectar foragers. Nectar concentration of flowers were measured by using hand refractometer.

##### **3.1.2. Pollen providing flowering plants**

Plants around beehives were observed on a daily basis at hourly intervals from 0600 h to 0600 h to find out the foraging bee visit to confirm it as a pollen source. Pollen collectors were identified by the pellets of pollen adhering to their hind legs.

##### **3.1.3. Both nectar and pollen providing flowering plant**

Plants around beehives were observed on a daily basis on hourly interval from 0600 h to 0600 h to to find out the foraging bee visit to confirm it as a pollen and nectar source.

##### **3.1.4. Flowering season**

For determining flowering season, identified stingless bee foraging plants were observed and flowering period was noted.

### **3.1.5. Anthesis time**

Ten randomly selected flower buds from identified plants were tagged and percentage of flowers open at hourly intervals were recorded during morning hours.

### **3.1.6. Duration of flower blooming**

Ten randomly selected flowers were tagged and observed the time of opening and closing of flower at different time period in a day.

### **3.1.7. Color of flower**

For determining flower color, ten fresh flowers were selected randomly. Flower color was identified using the color chart of Royal Horticultural Society.

### **3.1.8. Shape of flower**

For determining the shape of flower, ten flowers were selected randomly and shape of flower was identified ([www.theseedsite.co.uk](http://www.theseedsite.co.uk))

### **3.1.9. Number of flowers per plant**

In a flowering plant of the solitary type, the number of flowers per plant was counted at random. The number of flowers per inflorescence was counted for bunch-type blooming plants.

### **3.1.10. Floral temperature**

For determining flower temperature, ten fresh flowers were selected randomly. Using an infrared thermometer floral temperature was measured and their average temperature was recorded.

### **3.1.11. Other insect visitors**

Observation on other insect visitors were recorded at different time period in weekly intervals.

## 3.2. ASSESSMENT OF FORAGING ACTIVITY

Stingless bee foraging activity was studied throughout the year by placing one hive near the field with different ornamental plants during the flowering period. Observations on activity of stingless bees on plants will be recorded at weekly intervals.

### 3.2.1. Number of flowers visited per unit time

The total number of flowers visited by bees either for pollen or nectar was recorded from 6.00 AM to 6.00 PM at hourly intervals.

### 3.2.2. Number of bees visited per bloom per unit time

The total number of bees visiting in an individual flower was counted from 0600 h to 0600 h to at hourly intervals.

### 3.2.3. Time spent by bees per flower

Total time spent by bees in an individual flower was recorded.

### 3.2.4. Mode of alighting of individuals visiting bloom

Mode of alighting of bees on flowers during the peak period of bee activity was observed. Individual foragers alighting directly on top of stamen were considered as top workers while those alighting on petals as side workers.

### 3.2.5. Initiation and cessation time of foraging activity

The period of stingless bee foraging activity *i.e.* visiting the flowers for pollen and nectar was determined from the time of appearance of first forager on the flower to the time of returning by the last forager.

## 3.3. RELATIONSHIP BETWEEN FORAGING RATE AND WEATHER PARAMETERS DURING PEAK FLOWERING PERIOD

Weather parameters *viz.* temperature, relative humidity, rainfall, sunshine hours and wind velocity were collected from Department of Agricultural Meteorology, College of Agriculture, Vellayani and it was correlated with foraging activity of stingless bees. Data were correlated with the aid of GRAPES Version 1.1.0 software.

### 3.4. FLORAL CALENDAR

A complete chronological record of flowering periods of the identified bee flora was collected and floral calendar was prepared by using data of year round observation.

### 3.5. LABORATORY ANALYSIS OF POLLEN SAMPLES

#### 3.5.1. Collection and extraction of pollen samples

Pollen was collected from identified plants randomly. Composite sampling was done from different flowers of same plant. Two gram of dried pollen of each sample was taken and 15 mL of 70 per cent ethanol solution was added and then it was agitated for 30 min. After agitation, the solution was shaken for two min. Then it was centrifuged for 20 min at 3500 rpm, at 28°C. The supernatant was separated and stored at 4°C.

#### 3.5.2. Estimation of Protein

Total protein present in samples was estimated as per the procedure given by Lowry *et al.* (1951).

Preparation of Standard Bovine Serum Albumin (BSA) Solution - A stock bovine serum albumin (BSA) (SRL, Mumbai) solution was prepared by dissolving 50 mg of BSA in 50 mL of double distilled water in a volumetric flask. Working standard was prepared by pipetting out 10 mL of stock solution and making up to 50 mL with double distilled water in a volumetric flask, so that, 1 mL of the solution contained 200 µg of protein. Different aliquots of 100, 200, 300, 400, 500, 600 and 700 µl were pipetted out in to different test tubes from the working standard and made up to 1 mL with double distilled water. A test tube with double distilled water alone served as blank. The reagents used are given below. Reagent A: 2% sodium carbonate in 0.1 N sodium hydroxide. Reagent B: 0.5 % copper sulphate solution in 1% sodium potassium tartarate solution. Reagent C: Mixture of 50 ml of reagent A and 1 ml of reagent B, prepared just prior to the use. Reagent D - Folin-Ciocalteu reagent (FCR): the commercial FCR was diluted in 1:1 ratio with double distilled water before use.

Five millilitres of reagent C was added to all the test tubes including blank. The contents in the test tube were mixed well and allowed to stand for 10 min. Afterwards, reagent D (0.5 mL) was added, mixed thoroughly and incubated at room temperature in dark for 30 min.

Absorbance of the developed blue color was read at 660 nm using spectrophotometer. Standard graph was drawn by using the OD values and the corresponding concentrations of BSA.

### **3.5.3. Estimation of Lipid**

Total lipid present in samples was estimated as per the procedure given by (Evans and Needham 1987). The acetone extraction method is used for estimating pollen-coat lipids by using a rotary evaporator. 3 mL of Methanol/Chloroform was modified by adding an extra 2 mL of hexane to the lower phase, chloroform (2 mL) and hexane (4 mL) were then added to the pollen pellet for the second wash and the Methanol/water phase was washed with 1 mL of Chloroform. All Chloroform extracts were combined and the solvents removed by rotary evaporation. One g pollen was milled in a Krupps bench grinder and was extracted with a solvent. The pollen extracts were separated into neutral and polar lipid classes by the procedure of Christie (1982). The lipid sample was loaded onto 1.3 g Silica in a 10 mm diameter glass - teflon stop-cocked column, in a small volume of chloroform and eluted with 30 ml Methanol. Solvents were removed by rotary evaporation. Silica TLC was used to observe the composition and separation of the lipid classes. The mobile phase was Chloroform/Methanol/H<sub>2</sub>O (65:25:4). Phospholipids, galactolipids and carbon containing compounds were identified by zincadaze, at naphthol and iodine, respectively. The percentage composition of the lipid classes was estimated gravimetrically and corrected to dry weight.

### **3.5.4. Estimation of Phenol (Singleton and Rossi, 1965)**

A sample extract (0.1mL) was mixed with distilled water (3ml) and 0.5ml Folin Ciocalteau reagent was added. After 3 min, 2 mL of 20% sodium carbonate was added and mixed thoroughly. The tubes were incubated in a boiling water bath for 1min. It was then cooled and absorbance was measured at 650nm using spectrometer against the reagent blank. A calibration curve was constructed with different concentration of Gallic acid (0.01-0.1mM) as standard was prepared and the results were expressed as mg of Gallic acid equivalents (GAEs) per g of extract.

### **3.5.5. Estimation of total flavonoids (Ordonez *et al.*, 2006)**

A volume of 0.5mL of 2% Aluminium Chloride in ethanol solution was added to 0.5mL of sample solution. After one hour of incubation at room temperature, yellow color was developed. This was measured at 420nm with UV-Visible spectrophotometer. Flavonoids react

with aluminum chloride in ethanolic solution and formed a yellow color which was read colorimetrically at 420nm. Standard graph was prepared using the quercetin equivalent (mg/g).

### **3.5.6. Chemical composition of pollen sample**

Chemical composition of pollen samples was determined by using Gas-chromatograph coupled with mass spectrometer (GC-HRMS), model AccuTOF GCV and specification of model is electron impact EI / CI with Mass range of 10 - 2000 amu and 6000amu mass resolution. For GC, quartz capillary column of dimensions 30mm × 0.25mm × 0.25mm was used. The column temperature and flow rate were 60°C and 1.0mL/min respectively. The inlet temperature and heating rate were 250 °C and 6°C /min respectively. Pre column pressure and split ratio were 80 kpa and 40:1 respectively. The helium gas was used as carrier gas. For determining the composition of sample, the oven was set to 280°C, but the actual temperature was only 250°C.

### **3.5.7. Statistical Analysis**

Statistical analysis of the collected data was carried out using the software GRAPES Version 1.1.0 (Gopinath *et al.*, 2021)

## ***RESULTS***

## **4. RESULT**

The results of the study “Stingless bee foraging pattern in ornamental plants” conducted at Department of Entomology, College of Agriculture, Vellayani are presented in this chapter.

### **4.1. FLORAL TRAITS OF NECTARIFEROUS AND POLLENIFEROUS ORNAMENTAL PLANTS.**

Flower characteristics of nectariferous and polleniferous ornamental plants are given in Table 1 and Table 2 and stingless bee foraging on different ornamental plants are depicted in plate 1.

Table 1. Flowering season and flower characteristics of nectariferous and polleniferous ornamental plants

Common name	Scientific name	Family	N/P	Flowering season	Color of the flower	Shape of flower	Number of flowers per plant/Inflorescence	Floral temperature (°C)
Nectar providing flowering plants								
Coral vine	<i>Antigonon leptopus</i> Hook. and Arn.	Polygonaceae	N	year-round flowering	Moderate purplish pink	Kidney shaped	55/Inflorescence	35.9
Sarlet bush	<i>Hamelia patens</i> Jacq	Rubiaceae	N	year-round flowering	Vivid reddish orange	Tubular	78.33	34.6
Pollen providing flowering plants								
Moss rose/sun plant	<i>Portulaca grandiflora</i> L.	Portulacaceae	P	year-round flowering	Light yellow, Light purplish pink	Saucer	8.33	35.4
Water lilly	<i>Nymphaea</i> sp.	Nymphaeaceae	P	year-round flowering	White/Violet/Light pink	Cup like flower	3.33	35.7

Rose	<i>Rosa</i> spp.	Rosaceae	P	October -June	Greenish white	Cup like bloom	28.33	36.1
Scented Rose	<i>Rosa bourboniana</i> L.	Rosaceae	P	November - July	Light purplish pink	Cup like bloom	5.67	35.8
Ornamental palm	<i>Syagrus romanzoffiana</i> (Cham.)	Palmae	P	January – July	Yellowish white	Star shaped	78.33/rachis	36.8
Lemon vine	<i>Pereskia aculeate</i> L.	Fabaceae	P	December-March	Yellowish white	Cup like flower	62.67	36.1
Marigold	<i>Tagetes erecta</i> L.	Asteraceae	P	January - May	Strong orange	Head	8.63	35.6
Sunflower	<i>Helianthus annuus</i> l.	Asteraceae	P	January-March	Brilliant yellow	Capitulum	2.33	37.3
Both nectar and pollen providing flowering plants								
Hibiscus	<i>Malvaviscus arboreus</i> B.	Malvaceae	N+P	year-round flowering	Strong red	Tubular	55.67	36.6
Hibiscus	<i>Hibiscus rosa-sinensis</i> L.	Malvaceae	N+P	year-round flowering	Strong purplish red	Trumpet	11.67	36.3

Peacock plant	<i>Caesalpinia pulcherrima</i> L.	Fabaceae	N+P	year-round flowering	Vivid reddish orange	Butter fly shaped	38.67	35.1
Chinese powder puff	<i>Combretum constrictum</i> B.	Combretaceae	N+P	year-round flowering	Strong reddish orange	Globose	21	37.2
Chinese ixora (Red)	<i>Ixora chinensis</i> L.	Rubiaceae.	N+P	December - March	Vivid reddish orange	Tubular	92.33	36.2
Ixora(Yellow)	<i>Ixora chinensis</i> L.	Rubiaceae.	N+P	December - March	Pale yellow	Tubular	69.67	36.0
Cape honey suckle	<i>Tecoma capensis</i> L.	Begoniaceae	N+P	June to November	Strong orange	Funnel shaped	45.33	36.2
Peregrina/ Spicy Jatropha	<i>Jatropha pandurifolia</i> L.	Euphorbiaceae	N+P	year-round flowering	Strong red	Funnel shaped	50.33	35.8
Euphorbia	<i>Euphorbia mili</i> L.	Euphorbiaceae	N+P	January-July	White, Moderate red	Bowl shaped	11.33	35.9

Table 2. Flowering details of ornamental plants, foraging activity of stingless bee and other insect visitors

Ornamental plants	Anthesis time	Duration of flower blooming	Mode of alighting	Initiation and cessation time of foraging activity	Other insect visitors
<i>Antigonon leptopus</i> Hook. and Arn.	30 minutes from flower opening time	2 days	Top worker	0745-0530 h	<i>Apis dorsata</i> , <i>Apis indica</i> , <i>Anoplo lepis</i> , <i>Nomia</i> sp., <i>Camponotus compressus</i>
<i>Hamelia patens</i> Jacq.	-	3 days	Top worker	0800-0530 h	<i>Apis indica</i> , <i>Camponotus compressus</i> .
<i>Portulaca grandiflora</i> L.	0900-0930 h	1 day	Side worker	0800-0500h	<i>Apis indica</i> , <i>Apis dorsata</i> , <i>Anoplo lepis</i>
<i>Rosa</i> spp.	0800-0845 h	4-5days	Side worker	0725-0545 h	<i>Apis indica</i> , <i>Meghachilidae</i> sp.
<i>Rosa bourboniana</i> L.	0800-0845 h	4-5days	Side worker	0730-0500 h	<i>Apis indica</i> , <i>Vespula</i> sp., <i>Meghachilidae</i> sp.
<i>Nymphaea</i> sp.	0700-0900 h	4-5 days	Top worker	0700-0500 h	<i>Apis indica</i>
<i>Syagrus romanzoffiana</i> (Cham.)	-	1 day	Top worker	0800-0500 h	<i>Anoplo lepis</i> <i>Camponotus compressus</i>
<i>Tagetes erecta</i> L.	0800-0845 h	3days	Side worker	0745-0500 h	<i>Apis indica</i> , <i>Nomia</i> sp., <i>Vespula</i> sp.

<i>Helianthus annuus</i> I.	0800-0845 h	1 day	Both	0740-0515 h	<i>Apis indica</i> , <i>Nomia</i> sp.
<i>Pereskia aculeata</i> M.	-	1 day	Side worker	0800-0500 h	<i>Apis dorsata</i> , <i>Apis indica</i> , <i>Nomia</i> sp., <i>Camponotus compressus</i>
<i>Malvaviscus arboreus</i> B.	-	2-3day	Both	0715-0600 h	<i>Camponotus compressus</i> , <i>Vespula</i> sp.
<i>Caesalpinia pulcherrima</i> L.	-	2 days	Top worker	0745-0600 h	<i>Apis indica</i> , <i>Camponotus compressus</i> , <i>Solenopsis</i> sp.
<i>Combretum constrictum</i> B.	-	1-2 days	Both	0800-0545 h	<i>Apis indica</i> , <i>Anoplo lepis</i> , <i>Nomia</i> sp., <i>Camponotus compressus</i>
<i>Ixora chinensis</i> L.	-	3-4 day	Top worker	0730-0530 h	<i>Camponotus compressus</i> , <i>Apis indica</i> , <i>Nomia</i> sp.
<i>Tecoma capensis</i> L.	0845-0930 h	1 day	Top worker	0730-0515 h	<i>Apis dorsata</i> , <i>Apis indica</i> , <i>Anoplo lepis</i> <i>Camponotus compressus</i>
<i>Jatropha panduraefolia</i> L.	-	2 days	Both	0800-0500 h	<i>Camponotus compressus</i> , <i>Apis indica</i>
<i>Euphorbia mili</i> M.	-	-	Both	0800-0515 h	<i>Vespula</i> sp., <i>Nomia</i> sp.



*Antigonon leptopus* Hook. and Arn.



*Hamelia patens* Jacq.

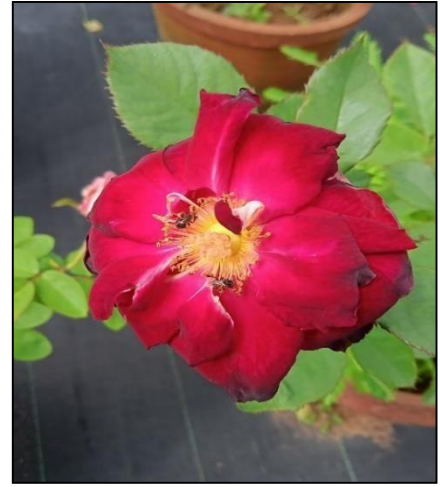


*Syagrus romanzoffiana* (Cham).



*Rosa bourboniana* L.

Plate 1: Stingless bee foraging activity in different ornamental plants



*Rosa* spp



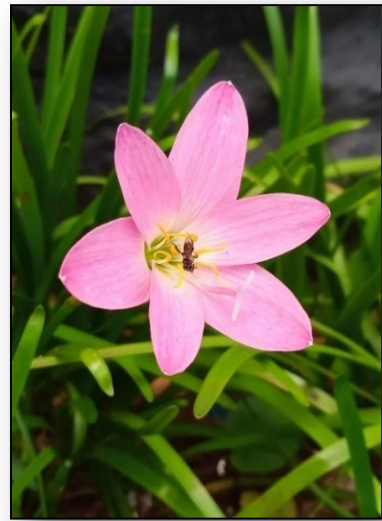
*Helianthus annuus L.*



*Tagetes erecta L.*



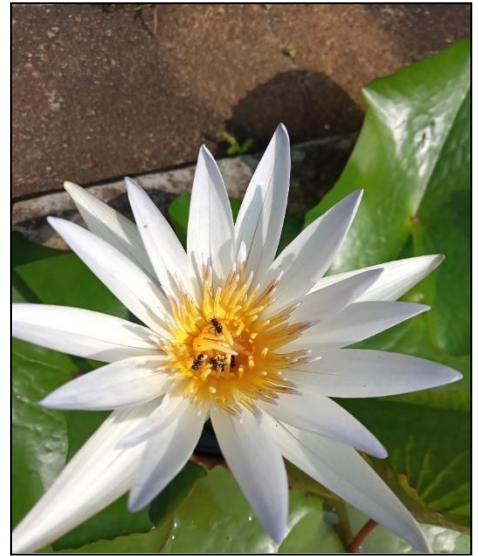
*Pereskia aculeate L.*



*Zephyranthes rosea L.*



*Portulaca grandiflora L.*



*Nymphaea sp.*



*Zinnia elegans L.*



*Gerbera jamesonii L.*



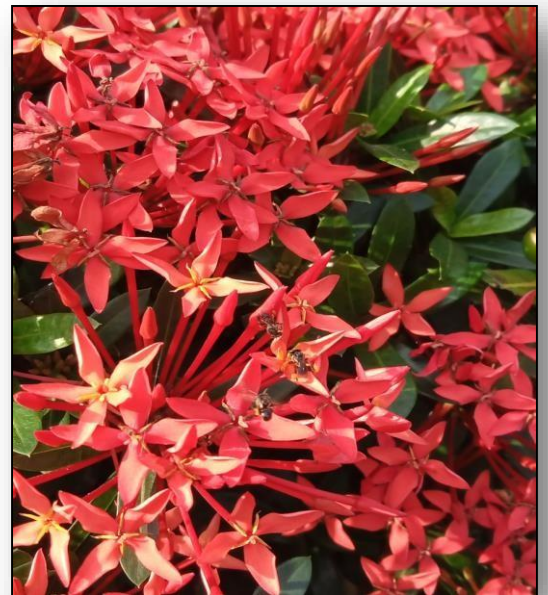
*Malvaviscus arboreus* B.



*Caesalpinia pulcherrima* L.



*Ixora chinensis* L.





*Combretum constrictum* B.



*Jatropha panduraefolia* L.



*Euphorbia mili* M.



*Dombeya* sp.



*Apis indica*



*Apis dorsata*



*Anoplo lepis*



*Camponotus compressus*



*Megachilidae* sp.



*Nomia* sp.

Plate 2: Other insect visitors

#### **4.1.1. Nectar providing flowering plants**

##### ***A. leptopus***

*A. leptopus* was a year round nectar producing flowering plant. Plant produced kidney shaped purplish pink colour flowers and duration of flower opening was 2 days. The nectar volume of the flower was very less and the concentration of nectar was 8.47%. Due to the high nectar refill ratio of the flowers, more number of bees were attracted throughout the day and frequently collected nectar from the inflorescence.

##### ***H. patens***

*H. patens* produced nectar throughout the year and their reddish orange tubular flowers were good nectar source for stingless bee. Duration of flowering was three days. Nectar volume of a single flower was 1.5 µl and the concentration of nectar was 25.45%.

#### **4.1.2. Pollen providing flowering plants**

##### ***P. grandiflora***

*P. grandiflora* was a succulent flowering plant belonging to the family Portulacaceae. Flowers come in a wide range of colors and the flowers remained open for a single day. The pollen was foraged by stingless bee throughout the year.

##### ***Nymphaea* sp.**

*Nymphaea* sp. produced fragrant flowers which borne on or above the water surface on long stalks that are attached to the underground stems. Duration of flower blooming was 4 to 5 days and the flowers were protogynous and opened in the morning. Throughout the year, flowers produced pollen and the pollen grains were larger, sticky, and spiny.

##### ***R. bourboniana***

*R. bourboniana* was one of the richest scented variety and it was highly preferred by *T.travancorica* along with having enough pollen throughout their flowering period. Flowers having light purplish pink flowers which were opened up to 4 to 5 days.

### *S. romanzoffiana*

*S. romanzoffiana* inflorescence was having more number of yellowish white colored flowers, and those flower continuously released abundant pollen during their flowering period. As a result, stingless bees visited the flowers frequently for collecting pollen.

Other pollen providing plants observed were *Rosa* spp, *P. aculeate*, *T. erecta* and *H. annuus*

#### **4.1.3. Both nectar and pollen providing flowering plants**

### *M. arboreus*

Among the Hibiscus species, *M. arboreus* produced high amount of nectar and it was considered a good source of nectar for bees. Also the flower produces adequate amount of pollen. The flowers were red tubular and the nectaries were located in the lower portion of each flower. Nectar volume of a single flower was 1.73 $\mu$ l and their concentration was 16.73%.

### *I. chinensis*

Stingless bees gather pollen and nectar from *I. chinensis*. Though there were red and yellow coloured *I. chinensis* and highest population of stingless bees were drawn to red ixora due to its increased nectar content than yellow ixora.

Other nectar and pollen producing plants were, *J. pandurifolia*, *C. pulcherrima*, *C. constrictum* and *E. mili*.

Among the observed plants, *A. leptopus*, *H. patens*, *P. grandiflora*, *Nymphaea* sp, *M. arboreus*, *C. pulcherrima*, *C. constrictum* and *J. pandurifolia* were year round flowering plants and *R. bourboniana*, *Rosa* spp, *S. romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. capensis* *I. chinensis*, *T. erecta* and *E. mili* were seasonal plants. Anthesis time of *A. leptopus*, *R. bourboniana*, *Rosa* spp, *Nymphaea* sp, *T. erecta* and *H. annuus* were found to be 0700 – 0900 h and some of the flowers viz., *H. patens*, *P. grandiflora* and *T. capensis* were having anthesis time after 0900 h. Number of flowers per plant varied from 2.33 to 149 in different ornamental plants and maximum number of flowers were observed in *A. leptopus* (55/Inflorescence) and *S. romanzoffiana* (78.33/rachis). Floral temperature of identified ornamental plants ranged from

34.6 to 37.3 and there was no significant difference among the floral temperature. Some of the other insect visitors observed were *A. dorsata*, *A. indica*, *A. lepis*, *Nomia* sp., *C. compressus*, *Meghachilidae* sp and *Vespula* sp. (Plate 2). Mode of alighting of stingless bee in different flowers was observed. Majority of the bees that were seen top workers. In some flowers, the bees were observed using both alighting modes. Stingless bee foraging activity was observed throughout the day. Majority of the stingless bee started foraging from 0700 h in the morning and continued up to 0630 h.

## 4.2. ASSESSMENT OF FORAGING ACTIVITY

Stingless bee, *T. travancorica* foraging behaviour and other insect visitors are given in Table 3 to 38. Foraging activity of stingless bee, *T. travancorica* was studied during the period September 2021 to August 2022.

### 4.2.1. Number of flowers visited by bee per unit time

Observations on number of flowers visited by stingless bee in the month of September varies from 0.83 to 9.33 (Table 3). Regarding the observation of *A. leptopus*, maximum number of flowers visited by bee was observed during 1100 to 0100 h (7.66 and 7.41) and the lowest during 0700 to 0800 h. In *H. patens*, highest number of flowers visited by bee was observed during 1100 to 0200 h (9.33, 9.25 and 9.16). The lowest number of flower visitor was observed during 0700 to 0800 h. In *C. pulcherrima* and *J. pandurifolia*, highest number of flowers were visited by bee during 1000 to 1200 h. In *Nymphaea* sp. and *P. grandiflora* there was not much significant different in number of flowers visited by bee.

Table 3. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of September 2021

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute						
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Caesalpinia pulcherrima</i>	<i>Malvaviscus arboreus</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	5.83 <sup>ab</sup>	3.06 <sup>c</sup>	1.24	0.83	3.25 <sup>bc</sup>	5.00	5.42 <sup>bc</sup>
0800 – 0900	6.16 <sup>ab</sup>	6.00 <sup>abc</sup>	1.16	2.75	4.58 <sup>ab</sup>	5.02	5.66 <sup>bc</sup>
0900 – 1000	6.83 <sup>ab</sup>	6.30 <sup>abc</sup>	1.99	5.58	5.16 <sup>ab</sup>	6.90	7.26 <sup>ab</sup>
1000 – 1100	6.80 <sup>ab</sup>	6.90 <sup>ab</sup>	2.50	5.58	6.33 <sup>a</sup>	5.33	4.58 <sup>c</sup>
1100 – 1200	7.41 <sup>a</sup>	9.33 <sup>a</sup>	2.75	5.41	3.83 <sup>abc</sup>	6.66	6.56 <sup>b</sup>
1200 – 0100	7.66 <sup>a</sup>	9.16 <sup>a</sup>	2.58	5.49	4.58 <sup>ab</sup>	6.49	8.08 <sup>a</sup>
0100 – 0200	6.41 <sup>ab</sup>	9.18 <sup>ab</sup>	2.41	4.75	6.56 <sup>a</sup>	6.25	8.00 <sup>a</sup>
0200 – 0300	6.34 <sup>ab</sup>	9.25 <sup>a</sup>	2.41	5.24	6.41 <sup>a</sup>	6.58	4.16 <sup>cd</sup>
0300 – 0400	6.50 <sup>ab</sup>	5.50 <sup>bc</sup>	1.56	5.24	3.91 <sup>abc</sup>	5.08	3.83 <sup>cd</sup>
0400 – 0500	4.90 <sup>b</sup>	4.08 <sup>bc</sup>	2.00	3.16	4.58 <sup>ab</sup>	5.25	4.82 <sup>c</sup>
0500 – 0600	1.28 <sup>c</sup>	5.25 <sup>bc</sup>	1.66	2.60	4.32 <sup>ab</sup>	5.06	4.53 <sup>c</sup>
CD (0.05)	2.107	2.341	NS	NS	1.47	NS	2.114

Number of flowers visited by stingless bee varied from 0.75 to 9.66 flowers in October (Table 4). In *A. leptopus*, *H. patens*, *Nymphaea* sp. maximum number of flowers visited by bee was observed during 1100 to 1000 h which varied between 7.16 and 9.66. In *C. pulcherrima*, *Rosa* spp. and *J. pandurifolia*, number of flowers visited by bee was not significantly different.

Stingless bees visited 0.16 to 9.94 flowers on average per day in November (Table 5). Regarding the observation of *A. leptopus*, maximum number of flowers visited by bee was observed during 1100 to 1200 h (7.25) and the lowest during 0500 to 0600 h (0.41). In *H. patens*, highest number of flowers visited by bee was observed during 0100 to 0200 h (9.91) whereas the lowest number of flower was during 0500 to 0600 h (0.40). In *J. pandurifolia*, maximum number of flowers visited by bee was observed during 1200 to 0100 h (7.11). In *Nymphaea* sp., *P. grandiflora*, *C. pulcherrima* and *R. bourboniana* the number of flowers visited by bee was not significantly different.

Regarding the observation of December number of flowers visited by stingless bee varied from 0.49 to 9.58 flowers (Table 6) During 1000-1200h, maximum numbers of flowers visited by a bee was observed in *A.leptopus* which was on par with 1100-0200 h (8.83) In *H. patens*, *Nymphaea* sp., *P. grandiflora*, *Rosa* sp and *Dombeya* sp maximum number of flowers visited by bee was observed during 1100 to 1200 h. In *P. aculeta* and *R. bouboniana* highest number of flowers visited by bee was observed during 1200 to 0100 h (6.58 and 7.91). During 0100-0200 h, maximum numbers of flowers visited by a bee was observed in *Ixora* sp and *J.*

Table 4. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of October 2021

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Caesalpinia pulcherrima</i>	<i>Malvaviscus arboreus</i>	<i>Jatropha pandurifolia</i>	<i>Rosa</i> spp.
0700 – 0800	1.83 <sup>c</sup>	6.06 <sup>bc</sup>	1.66 <sup>bc</sup>	0.83	4.00	6.00	5.58 <sup>abc</sup>	0.83
0800 – 0900	5.58 <sup>ab</sup>	6.83 <sup>bc</sup>	2.06 <sup>abc</sup>	0.41	6.16	4.02	6.66 <sup>ab</sup>	4.58
0900 – 1000	5.50 <sup>ab</sup>	6.90 <sup>bc</sup>	2.16 <sup>abc</sup>	2.49	6.91	3.90	6.26 <sup>ab</sup>	1.83
1000 – 1100	5.08 <sup>ab</sup>	8.33 <sup>ab</sup>	1.91 <sup>bc</sup>	5.49	5.41	5.33	7.42 <sup>ab</sup>	4.54
1100 – 1200	7.16 <sup>a</sup>	9.66 <sup>a</sup>	5.00 <sup>a</sup>	4.75	5.42	4.66	7.21 <sup>ab</sup>	3.64
1200 – 0100	6.99 <sup>a</sup>	9.49 <sup>a</sup>	3.61 <sup>ab</sup>	4.91	5.70	4.49	5.63 <sup>abc</sup>	5.63
0100 – 0200	6.58 <sup>a</sup>	9.25 <sup>a</sup>	2.75 <sup>abc</sup>	4.75	5.16	5.25	8.04 <sup>a</sup>	5.99
0200 – 0300	6.08 <sup>ab</sup>	9.58 <sup>a</sup>	1.75 <sup>bc</sup>	4.91	5.16	5.18	4.21 <sup>bc</sup>	4.16
0300 – 0400	5.11 <sup>abc</sup>	5.08 <sup>bc</sup>	1.66 <sup>bc</sup>	5.16	5.42	4.08	4.58 <sup>bc</sup>	4.35
0400 – 0500	5.00 <sup>b</sup>	3.25 <sup>c</sup>	0.83 <sup>c</sup>	4.41	4.49	4.25	5.32 <sup>abc</sup>	4.63
0500 – 0600	6.44 <sup>ab</sup>	3.06 <sup>c</sup>	0.75 <sup>c</sup>	1.83	4.41	4.06	3.71 <sup>c</sup>	3.58
CD (0.05)	2.011	2.851	1.089	NS	NS	NS	2.471	NS

Table 5. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of November 2021

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa bourboniana</i>	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	4.75 <sup>abc</sup>	5.16 <sup>cd</sup>	1.41	0.16	2.00	4.00	3.25	2.32 <sup>d</sup>
0800 – 0900	5.91 <sup>ab</sup>	6.08 <sup>bc</sup>	1.66	5.83	2.29	4.00	4.58	4.89
0900 – 1000	5.91 <sup>ab</sup>	7.00 <sup>abc</sup>	1.83	4.90	2.83	4.90	3.67	5.87 <sup>abc</sup>
1000 – 1100	6.66 <sup>a</sup>	7.33 <sup>abc</sup>	2.08	4.50	2.99	4.68	5.45	6.58 <sup>ab</sup>
1100 – 1200	7.25 <sup>a</sup>	8.66 <sup>ab</sup>	2.00	5.50	4.16	5.66	4.66	7.02 <sup>ab</sup>
1200 – 0100	6.58 <sup>a</sup>	8.25 <sup>abc</sup>	1.83	5.16	4.50	6.49	4.00	7.11 <sup>a</sup>
0100 – 0200	6.41 <sup>a</sup>	9.91 <sup>a</sup>	2.08	5.66	2.50	4.25	4.12	6.65 <sup>ab</sup>
0200 – 0300	6.08 <sup>ab</sup>	7.66 <sup>ab</sup>	2.00	5.16	3.99	6.58	5.68	5.16 <sup>bc</sup>
0300 – 0400	5.50	8.66 <sup>ab</sup>	1.58	4.83	4.00	5.08	3.91	4.24 <sup>bcd</sup>
0400 – 0500	2.75 <sup>bc</sup>	3.00 <sup>cd</sup>	1.25	5.83	2.83	5.25	4.58	5.23 <sup>bc</sup>
0500 – 0600	0.41 <sup>c</sup>	2.40 <sup>d</sup>	0.91	5.99	2.75	5.06	4.33	3.87 <sup>ed</sup>
CD (0.05)	3.21	3.603	NS	NS	NS	NS	NS	2.234

Table 6. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of December 2021

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute											
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malva viscosa</i> Arboreus	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>	<i>Dombeya</i> sp..
0700 – 0800	3.91 <sup>b</sup>	5.16	1.41 <sup>cd</sup>	1.66	4.00	2.52 <sup>d</sup>	3.36 <sup>bc</sup>	5.83 <sup>bc</sup>	3.88	3.65 <sup>bcd</sup>	4.32 <sup>bc</sup>	3.65 <sup>bcd</sup>
0800 – 0900	6.91 <sup>ab</sup>	8.75 <sup>ab</sup>	2.08 <sup>abcd</sup>	2.83	5.02	4.91 <sup>ab</sup>	4.00 <sup>bc</sup>	7.64 <sup>a</sup>	4.52	3.86 <sup>bc</sup>	5.32 <sup>abc</sup>	3.56 <sup>bc</sup>
0900 – 1000	7.66 <sup>ab</sup>	8.99 <sup>ab</sup>	2.00 <sup>bcd</sup>	3.16	6.90	5.41 <sup>ab</sup>	5.58 <sup>ab</sup>	5.12 <sup>bc</sup>	3.83	6.87 <sup>ab</sup>	5.36 <sup>abc</sup>	5.23 <sup>abc</sup>
1000 – 1100	8.83 <sup>a</sup>	9.01 <sup>a</sup>	2.57 <sup>ab</sup>	5.08	5.33	4.66 <sup>abc</sup>	4.99 <sup>abc</sup>	7.90 <sup>a</sup>	4.58	5.23 <sup>bc</sup>	7.02 <sup>a</sup>	3.21 <sup>c</sup>
1100 – 1200	7.25 <sup>a</sup>	9.58 <sup>a</sup>	2.83 <sup>a</sup>	5.91	6.66	5.33 <sup>abc</sup>	7.58 <sup>a</sup>	5.20 <sup>bc</sup>	3.35	6.89 <sup>ab</sup>	7.15 <sup>a</sup>	7.65 <sup>a</sup>
1200 – 0100	8.16 <sup>a</sup>	9.16 <sup>a</sup>	2.00 <sup>bcd</sup>	5.75	9.49	6.58 <sup>a</sup>	3.00 <sup>b</sup>	3.06 <sup>d</sup>	3.38	5.64 <sup>bc</sup>	7.91 <sup>a</sup>	5.68 <sup>abc</sup>
0100 – 0200	7.91 <sup>a</sup>	9.08 <sup>a</sup>	2.09 <sup>abc</sup>	4.83	9.25	4.33 <sup>abc</sup>	4.66 <sup>abc</sup>	8.16 <sup>a</sup>	5.46	8.02 <sup>a</sup>	5.47 <sup>abc</sup>	7.02 <sup>a</sup>
0200 – 0300	6.25 <sup>ab</sup>	8.66 <sup>ab</sup>	1.83 <sup>bcd</sup>	5.75	9.58	3.50 <sup>bcd</sup>	6.08 <sup>ab</sup>	7.79 <sup>a</sup>	4.52	6.25 <sup>ab</sup>	5.64 <sup>abc</sup>	6.35 <sup>ab</sup>
0300 – 0400	6.92 <sup>ab</sup>	8.12 <sup>abc</sup>	1.75 <sup>cd</sup>	4.74	5.08	3.41 <sup>cd</sup>	4.33 <sup>abc</sup>	6.81 <sup>ab</sup>	3.85	5.64 <sup>bc</sup>	5.64 <sup>abc</sup>	5.45 <sup>abc</sup>
0400 – 0500	4.58 <sup>b</sup>	6.25 <sup>cd</sup>	1.33 <sup>d</sup>	4.83	5.25	3.5 <sup>d</sup>	5.41 <sup>ab</sup>	6.50 <sup>ab</sup>	3.56	6.25 <sup>ab</sup>	6.32 <sup>ab</sup>	3.65 <sup>bc</sup>
0500 – 0600	1.58 <sup>c</sup>	0.49 <sup>de</sup>	1.00 <sup>bcd</sup>	3.58	5.06	0.83 <sup>de</sup>	3.50 <sup>bc</sup>	5.58 <sup>b</sup>	3.83	3.02 <sup>bcd</sup>	4.25 <sup>bc</sup>	3.23 <sup>c</sup>
CD (0.05)	2.246	2.07	0.756	NS	NS	1.49	2.335	2.858	NS	2.031	1.624	1.024

*pandurifolia* (8.16 and 8.02). No significant difference was observed in *M. arboreus* and *P. grandiflora*.

Observation on number of flowers visited by stingless bee in January varied from 0.91 to 9.83 flowers (Table 7). Regarding the observation of *A. leptopus*, *Nymphaea* sp., and *R. bourboniana* maximum number of flowers visited by bee was observed during 1000 to 1100 h. In *H. patens*, *M. arboreus*, *Rosa* sp, *Ixora* sp and *Dombeya* sp highest number of flowers visited by bee was observed during 1100 to 1200 h. In *C. constrictum* and *J. pandurifolia*, highest number of flowers visited by bee was observed during 0100 to 0200 h. In *S. romanzoffiana*, *P. grandiflora* and *Z. rosea* number of flowers visited by bee was not significantly different.

Stingless bees visited 0.58 to 8.97 flowers on average per visit in February and the data is included in Table 8. In case of *A. leptopus*, *Nymphaea* sp., *R. bourboniana* maximum number of flowers visited by bee was observed during 1000 to 1100 h. In *H. patens*, *M. arboreus*, *Rosa* sp, *Ixora* sp and *Dombeya* sp highest number of flowers visited by bee was observed during 1100 to 1200 h. In *C. constrictum* and *J. pandurifolia*, highest number of flowers visited by bee was observed during 0100 to 0200 h. In *S. romanzoffiana*, *P. grandiflora* and *Z. rosea* number of flowers visited by bee was no significantly different.

The number of flowers visited by stingless bees throughout the month of March ranged from 1.03 to 9.34 (Table 9). The peak flower visitation of *Nymphaea* sp. and *A. leptopus* occurred between 1100 and 1200 h. Maximum flower visits by bees were noted between 0100 and 0200 h. in *J. pandurifolia*, *M. arboreus*, and *H. patens*. The number of flowers visited by bees were not significantly different in *P. grandiflora*, *T. erecta*, *Z. rosea*, *E. mili*, and *C. pulcherrima*.

Stingless bees visited 0.75 to 9.83 flowers on average per day in April (Table 10). Regarding the observation of *A. leptopus*, maximum number of flowers visited by bee was observed during 1000 to 1100 h (9.83) and the lowest during 0500 to 0600 h (1.5). In *H. patens*, highest number of flowers visited by bee was observed during 1000 to 0200 h (9.52). The lowest number of flower visitors observed was during 0500 to 0600 h (0.40). In *J. pandurifolia*, maximum number of flowers visited by bee was observed during 1200 to 0100 h (7.11). In

Table 7. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of January 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combr etum constrictum</i>	<i>Dombeya</i> sp.	<i>Euphorbia</i> mili	<i>Zephyranthes rosea</i>
0700 -0800	6.16 <sup>bc</sup>	3.74 <sup>f</sup>	1.97 <sup>bcd</sup>	0.58	3.18 <sup>d</sup>	11.5	5.41 <sup>bc</sup>	3.00 <sup>cd</sup>	6.77 <sup>bc</sup>	4.33	4.02 <sup>bcd</sup>	5.12 <sup>abc</sup>	3.52 <sup>bcd</sup>	3.66	5.66
0800 – 0900	7.91 <sup>ab</sup>	8.75 <sup>ab</sup>	2.33 <sup>abc</sup>	5.99	7.41 <sup>a</sup>	12.16	6.83 <sup>abc</sup>	0.585 <sup>ef</sup>	7.85 <sup>ab</sup>	3.88	5.64 <sup>abc</sup>	6.87 <sup>a</sup>	5.45 <sup>bc</sup>	4.50	3.85
0900 – 1000	8.25 <sup>a</sup>	9.32 <sup>ab</sup>	2.91 <sup>a</sup>	5.75	6.75 <sup>ab</sup>	14.5	7.75 <sup>ab</sup>	4.66 <sup>abcd</sup>	7.87 <sup>ab</sup>	3.46	6.32 <sup>ab</sup>	3.24 <sup>bc</sup>	6.32 <sup>abc</sup>	5.22	4.67
1000 – 1100	8.83 <sup>a</sup>	8.83 <sup>abc</sup>	3.00 <sup>a</sup>	5.00	6.25 <sup>ab</sup>	11.5	8.16 <sup>a</sup>	5.16 <sup>abc</sup>	8.48 <sup>a</sup>	5.83	7.02 <sup>a</sup>	3.25 <sup>bc</sup>	2.57 <sup>d</sup>	3.44	5.24
1100 – 1200	7.75 <sup>ab</sup>	9.68 <sup>a</sup>	2.75 <sup>a</sup>	4.5	7.25 <sup>a</sup>	13.16	7.08 <sup>ab</sup>	6.78 <sup>a</sup>	8.95 <sup>a</sup>	4.25	7.70 <sup>a</sup>	4.02 <sup>abc</sup>	8.54 <sup>a</sup>	4.50	4.31
1200 – 0100	7.80 <sup>ab</sup>	9.33 <sup>ab</sup>	2.48 <sup>ab</sup>	5.5	4.33 <sup>d</sup>	10.85	6.83 <sup>abc</sup>	4.00	7.66 <sup>ab</sup>	4.83	6.54 <sup>ab</sup>	6.87 <sup>a</sup>	7.62 <sup>abc</sup>	3.55	5.44
0100 – 0200	7.91 <sup>ab</sup>	9.41 <sup>ab</sup>	2.66 <sup>ab</sup>	5.41	6.91 <sup>abc</sup>	10.83	4.08 <sup>bcd</sup>	6.25 <sup>ab</sup>	7.77 <sup>ab</sup>	3.84	8.03 <sup>a</sup>	6.52 <sup>a</sup>	3.35 <sup>bcd</sup>	3.74	3.03
0200 – 0300	7.85 <sup>ab</sup>	8.91 <sup>abc</sup>	1.83 <sup>bcd</sup>	5.75	4.50 <sup>cd</sup>	9.33	5.00 <sup>bc</sup>	4.33 <sup>abcd</sup>	7.43 <sup>ab</sup>	5.67	5.21 <sup>abc</sup>	4.66 <sup>abc</sup>	6.34 <sup>abc</sup>	3.83	3.83
0300 – 0400	7.33 <sup>ab</sup>	9.41 <sup>ab</sup>	2.25 <sup>abc</sup>	5.58	6.33 <sup>ab</sup>	9.66	1.75 <sup>de</sup>	5.41 <sup>abc</sup>	8.13 <sup>ab</sup>	4.80	6.23 <sup>ab</sup>	3.25 <sup>bc</sup>	4.32 <sup>bcd</sup>	3.57	3.55
0400 – 0500	4.67 <sup>cd</sup>	6.91 <sup>cd</sup>	1.41 <sup>cd</sup>	5.49	6.41 <sup>abc</sup>	10.33	4.66 <sup>bcd</sup>	3.5 <sup>cd</sup>	8.67 <sup>a</sup>	5.33	4.25 <sup>bcd</sup>	4.32 <sup>abc</sup>	3.65 <sup>bcd</sup>	4.56	4.52
0500 –0600	2.25 <sup>d</sup>	5.33 <sup>de</sup>	0.91 <sup>c</sup>	5.11	4.32 <sup>cd</sup>	9.16	4.74 <sup>bc</sup>	3.25 <sup>cd</sup>	7.33 <sup>ab</sup>	3.84	6.78 <sup>abc</sup>	1.25 <sup>d</sup>	4.25 <sup>bcd</sup>	3.44	4.50
CD (0.05)	1.759	2.387	0.861	NS	2.487	NS	2.065	2.12	1.659	NS	2.651	1.873	1.307	NS	NS

Table 8. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of February 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malva viscus arboreus</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherri ma</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Dombeya</i> sp.	<i>Euphorbia mili</i>
0700 – 0800	4.92 <sup>b</sup>	6.5 <sup>bc</sup>	1.41	1.91	5.91	4.33 <sup>bc</sup>	7.78 <sup>abc</sup>	5.33	3.58 <sup>bcd</sup>	4.53 <sup>bc</sup>	3.22	4.02 <sup>abc</sup>	2.00 <sup>cd</sup>
0800 – 0900	5.58 <sup>ab</sup>	7.24 <sup>abc</sup>	3.00	2.75	7.00	4.08 <sup>bc</sup>	7.85 <sup>abc</sup>	4.88	4.62 <sup>bc</sup>	4.84 <sup>ab</sup>	3.03	3.24 <sup>bc</sup>	3.65 <sup>bc</sup>
0900 – 1000	5.99 <sup>ab</sup>	7.08 <sup>abc</sup>	3.16	5.24	6.33	4.55 <sup>abcd</sup>	7.81 <sup>ab</sup>	4.46	5.34 <sup>abc</sup>	4.32 <sup>bc</sup>	3.45	5.32 <sup>ab</sup>	4.52 <sup>abc</sup>
1000 – 1100	7.75 <sup>a</sup>	9.74 <sup>a</sup>	3.41	5.91	7.75	5.16 <sup>abc</sup>	8.48 <sup>ab</sup>	3.38	6.02 <sup>abc</sup>	4.35 <sup>bc</sup>	4.03	2.57 <sup>bcd</sup>	3.54 <sup>bc</sup>
1100 – 1200	7.25 <sup>ab</sup>	8.9 <sup>abc</sup>	3.33	5.25	8.58	6.78 <sup>ab</sup>	8.97 <sup>a</sup>	3.25	6.53 <sup>ab</sup>	3.02 <sup>cd</sup>	4.00	5.48 <sup>ab</sup>	6.36 <sup>a</sup>
1200 – 0100	6.83 <sup>ab</sup>	7.99 <sup>abc</sup>	3.00	5.66	6.16	7.75 <sup>a</sup>	7.66 <sup>abc</sup>	4.83	5.26 <sup>abc</sup>	5.04 <sup>ab</sup>	3.21	7.02 <sup>a</sup>	2.54 <sup>bcd</sup>
0100 – 0200	6.43 <sup>ab</sup>	8.74 <sup>ab</sup>	2.58	5.16	7.33	5.66 <sup>abc</sup>	8.62 <sup>a</sup>	4.67	7.03 <sup>a</sup>	6.34 <sup>a</sup>	3.33	7.12 <sup>a</sup>	1.78 <sup>d</sup>
0200 – 0300	6.66 <sup>ab</sup>	8.91 <sup>ab</sup>	2.82	5.16	5.5	7.00 <sup>ab</sup>	7.33 <sup>abc</sup>	4.80	4.23 <sup>bc</sup>	5.32 <sup>abc</sup>	4.00	5.36 <sup>ab</sup>	5.83 <sup>ab</sup>
0300 – 0400	5.58 <sup>bc</sup>	9.00 <sup>ab</sup>	2.24	4.83	6.66	7.25 <sup>a</sup>	7.45 <sup>abc</sup>	5.34	4.32 <sup>bc</sup>	5.62 <sup>ab</sup>	3.65	4.57 <sup>abc</sup>	4.64 <sup>abc</sup>
0400 – 0500	1.83 <sup>c</sup>	5.41 <sup>cd</sup>	1.25	4.75	7.16	5.33 <sup>abc</sup>	7.77 <sup>ab</sup>	4.33	4.23 <sup>bcd</sup>	5.36 <sup>ab</sup>	4.05	5.68 <sup>ab</sup>	3.25 <sup>bc</sup>
0500 – 0600	1.00 <sup>c</sup>	2.83 <sup>d</sup>	0.58	2.00	5.91	4.08 <sup>bcd</sup>	6.62 <sup>bc</sup>	4.84	1.25 <sup>d</sup>	3.21 <sup>cd</sup>	2.25	3.34 <sup>bc</sup>	3.5 <sup>bc</sup>
CD (0.05)	2.576	2.935	NS	NS	NS	1.305	0.659	NS	2.135	1.252	NS	1.307	0.821

Table 9. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of March 2022

Time period(h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculata</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Euphorbia mili</i>	<i>Zephyranthes rosea</i>
0700 – 0800	6.41 <sup>bc</sup>	5.24 <sup>ab</sup>	1.91 <sup>ab</sup>	6.00	4.83 <sup>cd</sup>	3.25 <sup>bc</sup>	3.33 <sup>bc</sup>	6.91	3.25	4.23 <sup>abc</sup>	3.52 <sup>bcd</sup>	3.35 <sup>abc</sup>	4.02	3.31	3.86 <sup>bcd</sup>
0800 – 0900	7.00 <sup>abc</sup>	5.1 <sup>a</sup>	1.33 <sup>abc</sup>	4.75	7.64 <sup>ab</sup>	6.41 <sup>ab</sup>	4.08 <sup>abc</sup>	5.31	4.52	3.56 <sup>bc</sup>	4.32 <sup>abc</sup>	2.22 <sup>bc</sup>	3.65	3.34	3.54 <sup>bcd</sup>
0900 – 1000	6.12 <sup>ab</sup>	8.49 <sup>ab</sup>	2.41 <sup>a</sup>	4.91	8.49 <sup>a</sup>	6.75 <sup>ab</sup>	4.00 <sup>ab</sup>	6.81	3.68	3.25 <sup>bc</sup>	3.65 <sup>bcd</sup>	3.65 <sup>abc</sup>	3.45	4.65	3.34 <sup>ac</sup>
1000 – 1100	6.91 <sup>ab</sup>	8.99 <sup>a</sup>	2.33 <sup>ab</sup>	5.16	7.33 <sup>ab</sup>	7.25 <sup>a</sup>	6.34 <sup>a</sup>	5.83	4.85	3.24 <sup>bc</sup>	5.02 <sup>abc</sup>	5.62 <sup>ab</sup>	5.26	3.24	6.52 <sup>a</sup>
1100 – 1200	7.40 <sup>a</sup>	7.17 <sup>ab</sup>	2.50 <sup>a</sup>	5.58	7.33 <sup>ab</sup>	4.33 <sup>bcd</sup>	4.00 <sup>abc</sup>	7.93	3.54	5.35 <sup>ab</sup>	6.12 <sup>ab</sup>	2.05 <sup>bc</sup>	5.00	4.61	4.05 <sup>abc</sup>
1200 – 0100	6.58 <sup>abc</sup>	8.99 <sup>a</sup>	2.50 <sup>a</sup>	5.16	6.08 <sup>abc</sup>	6.85 <sup>ab</sup>	6.25 <sup>a</sup>	7.25	3.33	6.02 <sup>ab</sup>	8.95 <sup>a</sup>	6.52 <sup>a</sup>	4.36	5.32	5.34 <sup>ab</sup>
0100 – 0200	6.25 <sup>abc</sup>	9.33 <sup>a</sup>	2.41 <sup>a</sup>	5.66	8.25 <sup>a</sup>	4.41 <sup>bcd</sup>	3.85 <sup>bc</sup>	6.56	4.46	7.01 <sup>a</sup>	3.56 <sup>bcd</sup>	4.35 <sup>abc</sup>	4.21	3.41	1.34 <sup>d</sup>
0200 – 0300	7.00 <sup>abc</sup>	8.74 <sup>a</sup>	2.00 <sup>ab</sup>	5.66	6.41 <sup>abc</sup>	5.08 <sup>abcd</sup>	6.41 <sup>a</sup>	7.70	4.52	5.23 <sup>ab</sup>	4.21 <sup>abcd</sup>	6.24 <sup>a</sup>	4.00	6.54	2.83 <sup>cd</sup>
0300 – 0400	6.66 <sup>abc</sup>	8.25 <sup>ab</sup>	1.99 <sup>ab</sup>	5.99	7.66 <sup>ab</sup>	3.50 <sup>bc</sup>	5.08 <sup>ab</sup>	7.64	3.28	3.65 <sup>cd</sup>	5.62 <sup>abc</sup>	4.20 <sup>abc</sup>	5.01	3.22	5.35 <sup>ab</sup>
0400 – 0500	5.50 <sup>d</sup>	6.91 <sup>b</sup>	1.83 <sup>abc</sup>	4.05	5.33 <sup>bcd</sup>	3.33 <sup>bc</sup>	5.74 <sup>ab</sup>	6.66	3.37	3.26 <sup>d</sup>	3.25 <sup>bcd</sup>	3.02 <sup>abc</sup>	5.03	3.24	3.41 <sup>bc</sup>
0500 – 0600	3.35 <sup>e</sup>	5.16 <sup>e</sup>	1.83 <sup>abc</sup>	2.75	5.83 <sup>bcd</sup>	5.08 <sup>abcd</sup>	4.75 <sup>abc</sup>	6.58	3.67	1.03 <sup>e</sup>	2.58 <sup>cd</sup>	1.03 <sup>c</sup>	4.23	5.345	4.61 <sup>abc</sup>
CD (0.05)	1.155	1.648	0.832	NS	1.799	2.074	1.916	NS	NS	1.921	1.892	1.104	NS	NS	1.012

*Nymphaea* sp., *P. grandiflora*, *C. pulcherrima* and *R. bourboniana*, the number of flowers visited by bee was not significantly different.

Observation on number of flowers visited by stingless bee in May varied from 1.08 to 8.66 flowers (Table 11). Regarding the observation of *A. leptopus*, maximum number of flowers visited by bee was observed during 1000 to 1100 h (8.66) which was on par with 1100 – 0100 (7.83 and 7.90) and the lowest during 0500 to 0600 h (2.66). In *H patens*, highest number of flowers visited by bee was observed during 0100 to 0200 h (8.83) this was on par with 1200 – 0100 and 0200 - 0300h (7.99 and 8.33). In *M. arboreus*, highest number of flowers visited by bee was observed during 0100 to 0200 h (8.25) which was on par with 1000 – 1200 h (7.33). In *Nymphaea* sp., *P grandiflora*, *C. pulcherrima*, *J. pandurifolia* number of flowers visited by bee was not significantly different.

Stingless bees visited 2.35 to 9.16 flowers on average per day in June (Table 12). Regarding the observation of *A. leptopus*, highest number of flowers visited by bee was observed during 1100 to 1200 h (9.16) which was on par with 1000 – 1100 h (8.18) and the lowest during 0500 to 0600 h (2.91). In *H patens*, highest number of flowers visited by bee was observed during 1000 to 0300 h (8.83) which was on par with 1100 – 0100 h (7.00 and 7.91) and the lowest number of flower visitors observed during 0500 to 0600 h (3.27). In *Rosa* spp, highest number of flowers visited by bee was observed during 0100 – 0200 h (6.00) which was on par with 1000 – 1200 h (5.38 and 5.91). In *J pandurifolia*, maximum number of flowers visited by bee was observed during 1200 to 0100 h (8.63) this was on par with 1000 – 1200 h (7.02 and 7.25) and 0100 – 0200 h (7.62). In *Nymphaea* sp., *P grandiflora*, *C.pulcherrima* and *T. erecta*, the number of flowers visited by bee was not significantly different.

Regarding the observation of July foraging intensity of stingless bee varied from 0.57 to 7.93 flowers (Table 13). In *A. leptopus* highest foraging intensity was observed during 1000 – 1200 h (7.73 and 7.93) which was on par with 0100-0200 h. In, *H. patens*, maximum number of flowers visited by bee was observed during 1100 to 0100 h (6.66 and 6.91). In *R. bouboniana* highest number of flowers visited by bee was observed during 1200 to 0200 h (5.75 and 5.63). During 1100-1200 h, maximum numbers of flowers visited by a bee was observed in *J. pandurifolia* (6.02). No significant difference was observed in *M. arboreus*, *P grandiflora*. *Nymphaea* sp., *S. romanzoffiana*, *C. pulcherrima*.

Table 10. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of April 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Ixora</i> sp.	<i>Cesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constrictum</i>	<i>Euphorbia mili</i>	<i>Zephyranthes rosea</i>
0700 – 0800	5.25 <sup>c</sup>	5.58 <sup>b</sup>	1.00 <sup>bc</sup>	2.50	4.83 <sup>bcd</sup>	11.33	3.25 <sup>e</sup>	6.83 <sup>abc</sup>	4.56	3.65 <sup>cd</sup>	4.52 <sup>b</sup>	4.01	4.05
0800 – 0900	6.25 <sup>abc</sup>	7.75 <sup>a</sup>	3.08 <sup>bc</sup>	2.66	7.64 <sup>ab</sup>	11.33	6.41 <sup>cd</sup>	6.52 <sup>abc</sup>	3.52	3.86 <sup>cd</sup>	3.64 <sup>bcd</sup>	5.01	3.24
0900 – 1000	7.50 <sup>abc</sup>	8.25 <sup>ab</sup>	4.16 <sup>a</sup>	5.16	8.4 <sup>a</sup>	14.00	6.75 <sup>a</sup>	7.5 <sup>ab</sup>	3.83	6.87 <sup>b</sup>	2.31 <sup>cd</sup>	5.03	4.23
1000 – 1100	9.83 <sup>a</sup>	9.08 <sup>a</sup>	4.08 <sup>a</sup>	5.83	7.33 <sup>ab</sup>	13.00	7.25 <sup>a</sup>	7.02 <sup>ab</sup>	4.12	5.24 <sup>bcd</sup>	6.32 <sup>ab</sup>	4.23	3.52
1100 – 1200	8.33 <sup>ab</sup>	8.09 <sup>abc</sup>	3.00 <sup>ab</sup>	5.5	7.33 <sup>ab</sup>	11.67	4.33 <sup>d</sup>	8.06 <sup>a</sup>	5.35	6.80 <sup>b</sup>	5.67 <sup>abc</sup>	5.00	3.01
1200 – 0100	6.58 <sup>abc</sup>	8.91 <sup>ab</sup>	3.17 <sup>ab</sup>	4.66	6.08 <sup>abc</sup>	15.16	6.83 <sup>a</sup>	7.42 <sup>ab</sup>	3.35	5.65 <sup>bcd</sup>	3.54 <sup>bcd</sup>	4.36	4.23
0100 – 0200	6.25 <sup>abc</sup>	8.66 <sup>ab</sup>	2.91 <sup>ab</sup>	5.58	8.25 <sup>a</sup>	13.00	4.41 <sup>ab</sup>	6.77 <sup>abc</sup>	5.43	8.02 <sup>a</sup>	4.04 <sup>bc</sup>	4.21	2.35
0200 – 0300	7.00 <sup>abc</sup>	9.52 <sup>a</sup>	2.66 <sup>ab</sup>	5.16	6.41 <sup>abc</sup>	14.65	5.08 <sup>cd</sup>	6.73 <sup>abc</sup>	5.42	6.25 <sup>b</sup>	5.32 <sup>abc</sup>	5.23	6.54
0300 – 0400	6.66 <sup>abc</sup>	8.21 <sup>ab</sup>	2.41 <sup>ab</sup>	4.72	7.66 <sup>ab</sup>	13.85	3.50 <sup>de</sup>	7.33 <sup>ab</sup>	4.25	5.64 <sup>bcd</sup>	7.32 <sup>a</sup>	3.65	3.21
0400 – 0500	5.50 <sup>bc</sup>	8.16	1.33 <sup>cd</sup>	3.16	5.33 <sup>bc</sup>	12.83	3.33 <sup>e</sup>	6.82 <sup>abc</sup>	4.32	6.25 <sup>bc</sup>	6.23 <sup>ab</sup>	4.02	5.64
0500 – 0600	1.50 <sup>d</sup>	2.41 <sup>d</sup>	0.75 <sup>d</sup>	2.66	4.83 <sup>bcd</sup>	12.33	5.08 <sup>de</sup>	4.83 <sup>c</sup>	3.356	3.02 <sup>d</sup>	3.65 <sup>bc</sup>	3.62	3.02
CD (0.05)	2.238	1.985	0.799	NS	4.83	NS	2.074	1.251	NS	2.031	1.034	NS	NS

Table 11. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of May 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Rosa bourboniana</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	4.58 <sup>c</sup>	6.16 <sup>bc</sup>	1.49	4.50	4.83 <sup>bcd</sup>	3.25	4.21	5.64
0800 – 0900	5.08 <sup>bc</sup>	4.62 <sup>cd</sup>	2.25	4.83	7.64 <sup>ab</sup>	6.41	3.52	6.02
0900 – 1000	5.50 <sup>bc</sup>	5.83 <sup>cd</sup>	2.33	5.75	8.46 <sup>a</sup>	6.75	4.02	3.25
1000 – 1100	8.66 <sup>a</sup>	8.49 <sup>ab</sup>	2.16	4.82	7.33 <sup>ab</sup>	7.25	3.65	5.64
1100 – 1200	7.83 <sup>ab</sup>	7.25 <sup>abc</sup>	2.50	4.66	7.33 <sup>ab</sup>	4.33	4.03	5.25
1200 – 0100	7.90 <sup>ab</sup>	7.99 <sup>ab</sup>	2.41	5.66	6.08 <sup>abc</sup>	6.83	4.33	3.02
0100 – 0200	6.25 <sup>abc</sup>	8.83 <sup>a</sup>	2.25	5.49	8.25 <sup>a</sup>	4.41	13.3	5.03
0200 – 0300	6.00 <sup>abc</sup>	8.33 <sup>ab</sup>	2.33	5.58	6.41 <sup>abc</sup>	5.08	3.64	3.54
0300 – 0400	6.66 <sup>abc</sup>	7.75 <sup>abc</sup>	2.00	4.83	7.66 <sup>a</sup>	3.5	3.52	2.65
0400 – 0500	5.50 <sup>bc</sup>	5.58 <sup>c</sup>	0.75	2.91	5.33 <sup>bc</sup>	3.33	4.03	2.45
0500 – 0600	2.66 <sup>d</sup>	1.08 <sup>d</sup>	1.66	3.92	5.83 <sup>bc</sup>	5.08	3.83	3.68
CD (0.05)	2.078	2.861	NS	NS	1.799	NS	NS	NS

Table 12. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of June 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute								
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Tagetes erecta</i>	<i>Euphorbia mili</i>
0700 – 0800	3.62 <sup>cd</sup>	5.32 <sup>bc</sup>	1.24	5.00	4.00 <sup>abc</sup>	3.92	3.02 <sup>de</sup>	4.00	3.67 <sup>bc</sup>
0800 – 0900	5.5 <sup>bc</sup>	6.66 <sup>abc</sup>	2.24	5.75	3.91 <sup>bc</sup>	3.65	5.24 <sup>bc</sup>	3.24	2.36 <sup>de</sup>
0900 – 1000	7.33 <sup>abc</sup>	6.75 <sup>abc</sup>	2.83	5.83	3.83 <sup>abc</sup>	3.65	6.32 <sup>bc</sup>	3.64	6.54 <sup>a</sup>
1000 – 1100	8.18 <sup>ab</sup>	6.16 <sup>abc</sup>	2.75	5.99	5.91 <sup>ab</sup>	3.14	7.02 <sup>ab</sup>	5.31	5.32 <sup>ab</sup>
1100 – 1200	9.16 <sup>a</sup>	7.91 <sup>ab</sup>	3.08	5.25	5.38 <sup>ab</sup>	3.65	7.25 <sup>ab</sup>	4.02	2.45 <sup>de</sup>
1200 – 0100	5.50 <sup>bc</sup>	7.00 <sup>ab</sup>	2.33	5.5	3.65 <sup>abc</sup>	4.02	8.63 <sup>a</sup>	4.32	3.02 <sup>bc</sup>
0100 – 0200	4.16 <sup>bc</sup>	8.83 <sup>a</sup>	2.41	4.91	6.00 <sup>a</sup>	3.65	7.62 <sup>ab</sup>	5.02	6.54 <sup>a</sup>
0200 – 0300	5.00 <sup>bc</sup>	8.83 <sup>a</sup>	1.83	5.49	3.74 <sup>abc</sup>	3.54	5.32 <sup>bc</sup>	3.91	5.32 <sup>ab</sup>
0300 – 0400	4.41 <sup>bc</sup>	6.66 <sup>abc</sup>	1.91	5.00	3.41 <sup>abc</sup>	4.02	5.02 <sup>bc</sup>	4.23	6.53 <sup>a</sup>
0400 – 0500	4.66 <sup>bc</sup>	6.25 <sup>abc</sup>	1.50	2.16	3.25 <sup>bc</sup>	3.94	7.25 <sup>ab</sup>	5.03	3.45 <sup>bc</sup>
0500 – 0600	2.91 <sup>d</sup>	3.27 <sup>d</sup>	0.50	1.55	3.75 <sup>abc</sup>	3.054	4.66 <sup>abc</sup>	3.95	2.35 <sup>de</sup>
CD (0.05)	1.891	3.431	NS	NS	1.091	NS	2.103	NS	1.024

Table 13. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of July 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute								
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	3.66 <sup>bc</sup>	1.16 <sup>de</sup>	0.54	5.33	8.66	1.83 <sup>d</sup>	6.53	4.02	2.06 <sup>cde</sup>
0800 – 0900	6.58 <sup>ab</sup>	3.58 <sup>abc</sup>	1.24	5.15	12.66	5.75 <sup>ab</sup>	6.64	3.52	2.35 <sup>cd</sup>
0900 – 1000	6.74 <sup>ab</sup>	4.58 <sup>abc</sup>	1.83	5.16	13.83	4.83 <sup>abc</sup>	4.35	4.28	5.52 <sup>ab</sup>
1000 – 1100	7.73 <sup>a</sup>	5.74 <sup>ab</sup>	2.76	5.00	11.83	4.24 <sup>abc</sup>	5.33	4.58	6.02 <sup>a</sup>
1100 – 1200	7.93 <sup>a</sup>	6.66 <sup>a</sup>	3.25	5.66	10.33	5.08 <sup>ab</sup>	4.66	3.64	4.33 <sup>abc</sup>
1200 – 0100	6.16 <sup>abc</sup>	6.91 <sup>a</sup>	2.33	5.08	10.33	5.75 <sup>a</sup>	6.08	3.82	3.21 <sup>bc</sup>
0100 – 0200	6.91 <sup>ab</sup>	5.41 <sup>ab</sup>	2.42	5.16	13.66	5.63 <sup>a</sup>	6.33	4.68	4.24 <sup>abc</sup>
0200 – 0300	6.01 <sup>abc</sup>	4.82 <sup>abc</sup>	1.24	5.58	12.33	4.41 <sup>ab</sup>	6.41	3.64	4.64 <sup>abc</sup>
0300 – 0400	6.83 <sup>abc</sup>	3.24 <sup>abc</sup>	1.86	4.5	13.66	4.83 <sup>ab</sup>	5.66	2.84	4.03 <sup>abc</sup>
0400 – 0500	5.49 <sup>bc</sup>	1.90 <sup>cd</sup>	1.25	3.00	12.66	3.83 <sup>abc</sup>	3.66	5.26	2.64 <sup>cd</sup>
0500 – 0600	2.33 <sup>c</sup>	0.57 <sup>e</sup>	0.583	3.5	11.16	2.25 <sup>bc</sup>	4.83	4.83	3.25 <sup>bc</sup>
CD (0.05)	2.699	2.631	NS	NS	NS	1.708	NS	NS	2.031

Table 14. Foraging intensity of *Tetragonula travancorica* in different ornamental plants at different hours of the day during the month of August 2022

Time period (h)	*Number of flowers visited by <i>Tetragonula travancorica</i> per 10 minute						
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Caesalpinia pulcherrima</i>	<i>Malvaviscus arboreus</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	4.00 <sup>bc</sup>	1.02 <sup>de</sup>	1.5	6.02	3.86	5.66	4.62 <sup>bc</sup>
0800 – 0900	5.1 <sup>abc</sup>	6.66 <sup>ab</sup>	2.03	4.25	4.25	4.32	4.23 <sup>bc</sup>
0900 – 1000	5.4 <sup>abc</sup>	5.9 <sup>bcd</sup>	2.41	5.55	5.64	4.66	4.05 <sup>bc</sup>
1000 – 1100	7.66 <sup>a</sup>	5.33 <sup>ab</sup>	2.58	3.02	6.32	4.60	5.65 <sup>ab</sup>
1100 – 1200	6.58 <sup>ab</sup>	6.66 <sup>a</sup>	2.66	4.65	5.42	5.23	5.36 <sup>ab</sup>
1200 – 0100	6.08 <sup>ab</sup>	6.49 <sup>a</sup>	2.49	6.32	3.65	6.61	3.24 <sup>bc</sup>
0100 – 0200	7.16 <sup>a</sup>	5.25 <sup>ab</sup>	2.50	5.66	5.62	6.35	6.35 <sup>a</sup>
0200 – 0300	5.66 <sup>ab</sup>	5.58 <sup>ab</sup>	2.24	4.16	4.68	5.36	4.56 <sup>abc</sup>
0300 – 0400	3.91 <sup>bc</sup>	5.08 <sup>bc</sup>	2.33	5.83	6.35	3.65	4.32 <sup>abc</sup>
0400 – 0500	3.25 <sup>b</sup>	5.25 <sup>bc</sup>	1.99	4.67	6.31	4.32	4.35 <sup>abc</sup>
0500 – 0600	3.58 <sup>b</sup>	3.06 <sup>cd</sup>	1.08	6.33	4.25	3.98	4.02 <sup>abc</sup>
CD (0.05)	2.037	4.227	NS	NS	NS	NS	1.821

The number of flowers visited by stingless bees throughout the month of August varied from 1.02 to 7.66 (Table 14). The maximum number of flowers visited by bees was between 1000-0200 h while the lowest number was between 0300 and 0600 h. The peak flower visitation of *A. leptopus* occurred between 1000 – 1100 h (7.66) and 0100 - 0200 h (7.16) which was on par with 1100 – 0100 h (6.08 and 6.58). Maximum flower visited by bees were noted between 1100 and 1200 h in *J. pandurifolia* (6.66 and 6.49) which was on par with 1000-1200 (5.65 and 5.36). Foraging intensity by stingless bee was not significantly different in *M. arboreus*, *Nymphaea* sp, *P grandiflora*, *C. pulcherrima*.

#### **4.2.2. Number of bees visited per bloom per unit time**

Observation on foraging rate of stingless bee in September varies from 0.33 to 10.91 (Table 15). In the case of *A leptopus*, *Nymphaea* sp., *P grandiflora*, *M. arboreus*, *J. pandurifolia* maximum foraging rate of stingless bee was observed during 1100 to 0100 h (7.41 and 7.66, 3.25 and 3.33, 4.08 and 4.30, 9.84 and 10.91, 3.31 and 3.44) which was on par with 0800 – 1100 h and 0100 – 0400 h and the lowest during 0500 - 0600 h. In *H. patens* and *C. pulcherrima* highest number of bee visited by a flower was observed during 1200 - 0200 h (4.00 and 3.30, 3.25 and 3.01) and was on par with 1000 – 1200 and 1100 – 1200 h. The lowest foraging rate was observed during 0700 – 0800 and 0500 to 0600 h.

Stingless bee foraging rate varied from 0.12 to 8.91 in the month of October (Table 16). Maximum foraging rate was observed in *A leptopus*, *P. grandiflora*, *J. pandurifolia* during 1200 – 0200 (6.88 and 6.90, 2.78 and 2.80, 2.84 and 2.9) and this was on par with 1000 – 1200 h and 0200- 0300 h. In *H patens* and *Nymphaea* sp., highest number of bee visited by flower was observed during 0100 to 0200 h (3.00 and 4.66) which was on par with 1100 – 0100 h. In *Rosa* spp, *M. arboreus* and *C.pulcherrima* highest foraging rate was observed during 1200 – 0100 h (2.62, 8.91, and 4.25).

Regarding the observation of November foraging rate of stingless bee varied from 0.34 to 7.66 and the data is included in Table 17. During 1100-1200 h, the maximum foraging rate was observed in case of *A. leptopus* and *P. grandiflora* (7.66 and 4.88) and it was on par with 1200 – 0200 h (6.25 and 6.83, 3.58 and 3.83) and minimum number of bee visited by a flower was observed in 0500 – 0600 h (1.08 and 0.83). In *H. patens*, maximum number of bee visited by a flower was observed during 1200 to 0100 h (5.50) which was on par with 0900 – 1200 h and 0100 – 0200 h (4.58, 4.75, and 4.08). Peak foraging rate was observed during 1100-0200h

Table 15. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of September 2021

Time period(h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute						
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea sp.</i>	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	5.83 <sup>abc</sup>	0.53 <sup>e</sup>	1.58 <sup>bcd</sup>	0.99 <sup>e</sup>	3.41 <sup>de</sup>	1.46 <sup>bc</sup>	0.65 <sup>e</sup>
0800 – 0900	6.16 <sup>ab</sup>	2.41 <sup>abcd</sup>	1.99 <sup>abc</sup>	2.90 <sup>cd</sup>	4.75 <sup>cde</sup>	1.98 <sup>bc</sup>	1.82 <sup>cd</sup>
0900 – 1000	6.83 <sup>ab</sup>	2.90 <sup>abcd</sup>	2.24 <sup>ab</sup>	3.00 <sup>abcd</sup>	5.74 <sup>cd</sup>	2.80 <sup>ab</sup>	2.46 <sup>bcd</sup>
1000 – 1100	6.83 <sup>ab</sup>	2.40 <sup>ab</sup>	2.58 <sup>ab</sup>	3.70 <sup>abc</sup>	7.83 <sup>ab</sup>	2.45 <sup>abc</sup>	2.69 <sup>abc</sup>
1100 – 1200	7.41 <sup>a</sup>	2.91 <sup>ab</sup>	3.25 <sup>a</sup>	4.08 <sup>a</sup>	9.84 <sup>a</sup>	2.96 <sup>ab</sup>	3.31 <sup>a</sup>
1200 – 0100	7.66 <sup>a</sup>	3.30 <sup>a</sup>	3.33 <sup>a</sup>	4.30 <sup>a</sup>	10.91 <sup>a</sup>	3.25 <sup>a</sup>	3.44 <sup>a</sup>
0100 – 0200	6.49 <sup>ab</sup>	4.00 <sup>a</sup>	2.50 <sup>ab</sup>	3.90 <sup>ab</sup>	9.01 <sup>ab</sup>	3.01 <sup>a</sup>	3.03 <sup>ab</sup>
0200 – 0300	6.34 <sup>ab</sup>	2.66 <sup>abc</sup>	2.08 <sup>ab</sup>	3.31 <sup>abc</sup>	6.08 <sup>b</sup>	2.36 <sup>ab</sup>	2.67 <sup>abc</sup>
0300 – 0400	6.49 <sup>ab</sup>	1.66 <sup>bcde</sup>	1.90 <sup>abc</sup>	2.33 <sup>cd</sup>	5.90 <sup>cd</sup>	2.13 <sup>abc</sup>	2.35 <sup>bcd</sup>
0400 – 0500	4.99 <sup>b</sup>	0.99 <sup>cde</sup>	0.58 <sup>cd</sup>	1.16 <sup>de</sup>	3.64 <sup>de</sup>	1.15 <sup>bcd</sup>	1.24 <sup>cd</sup>
0500 – 0600	1.99 <sup>c</sup>	0.58 <sup>e</sup>	0.33 <sup>d</sup>	0.97 <sup>e</sup>	1.04 <sup>ef</sup>	0.36 <sup>d</sup>	0.33 <sup>ef</sup>
CD (0.05)	2.107	1.713	1.462	0.813	2.632	1.83	1.54

Table 16. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of October 2021

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	0.91 <sup>b</sup>	1.66 <sup>bcd</sup>	1.58 <sup>bcd</sup>	0.41 <sup>c</sup>	0.42 <sup>e</sup>	3.65 <sup>ef</sup>	1.23 <sup>de</sup>	0.32 <sup>cd</sup>
0800 – 0900	1.91 <sup>bc</sup>	2.16 <sup>abcd</sup>	2.33 <sup>abcd</sup>	1.31 <sup>bc</sup>	0.32 <sup>de</sup>	3.15 <sup>cde</sup>	1.69 <sup>de</sup>	0.82 <sup>bcd</sup>
0900 – 1000	2.75 <sup>abc</sup>	1.91 <sup>bc</sup>	2.16 <sup>abcd</sup>	1.66 <sup>ab</sup>	0.67 <sup>cd</sup>	5.54 <sup>cd</sup>	2.56 <sup>abcd</sup>	1.01 <sup>abc</sup>
1000 – 1100	5.74 <sup>ab</sup>	2.41 <sup>abcd</sup>	1.75 <sup>bc</sup>	1.75 <sup>ab</sup>	1.23 <sup>abc</sup>	5.13 <sup>ab</sup>	3.45 <sup>ab</sup>	1.96 <sup>ab</sup>
1100 – 1200	5.91 <sup>ab</sup>	2.91 <sup>ab</sup>	3.41 <sup>ab</sup>	1.83 <sup>ab</sup>	1.31 <sup>abc</sup>	6.4 <sup>bc</sup>	3.92 <sup>ab</sup>	1.73 <sup>ab</sup>
1200 – 0100	6.88 <sup>a</sup>	3.33 <sup>ab</sup>	3.33 <sup>ab</sup>	2.78 <sup>a</sup>	2.62 <sup>a</sup>	8.91 <sup>a</sup>	4.25 <sup>a</sup>	2.84 <sup>a</sup>
0100 – 0200	6.90 <sup>a</sup>	3.00 <sup>a</sup>	4.66 <sup>a</sup>	2.80 <sup>a</sup>	1.00 <sup>cd</sup>	7.90 <sup>ab</sup>	3.36 <sup>ab</sup>	2.96 <sup>a</sup>
0200 – 0300	5.50 <sup>ab</sup>	2.66 <sup>abc</sup>	2.16 <sup>abcd</sup>	2.00 <sup>ab</sup>	2.33 <sup>ab</sup>	7.28 <sup>b</sup>	2.65 <sup>abcd</sup>	1.73 <sup>ab</sup>
0300 – 0400	4.83 <sup>b</sup>	1.66 <sup>bcd</sup>	1.33 <sup>bcd</sup>	0.80 <sup>bc</sup>	1.22 <sup>abc</sup>	5.32 <sup>cd</sup>	2.45 <sup>abcd</sup>	1.53 <sup>abc</sup>
0400 – 0500	3.75 <sup>b</sup>	0.99 <sup>cd</sup>	1.16 <sup>bcd</sup>	0.50 <sup>bc</sup>	0.14 <sup>de</sup>	2.36 <sup>de</sup>	2.33 <sup>abcd</sup>	1.42 <sup>abc</sup>
0500 – 0600	0.49 <sup>b</sup>	0.58 <sup>d</sup>	0.50 <sup>cd</sup>	0.91 <sup>c</sup>	0.19 <sup>de</sup>	0.26 <sup>ef</sup>	0.44 <sup>e</sup>	0.65 <sup>cd</sup>
CD (0.05)	1.426	1.327	1.021	1.440	1.215	2.531	1.260	1.035

Table 17. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of November 2021

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute									
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Malvaviscus arboreus</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	2.00 <sup>de</sup>	1.50 <sup>cd</sup>	1.25 <sup>bc</sup>	0.81 <sup>de</sup>	0.58 <sup>cd</sup>	0.34 <sup>d</sup>	1.41 <sup>cd</sup>	1.42 <sup>cd</sup>	1.58 <sup>ef</sup>	0.94 <sup>cd</sup>
0800 – 0900	3.08 <sup>bcd</sup>	3.99 <sup>b</sup>	2.06 <sup>abc</sup>	1.58 <sup>cd</sup>	0.92 <sup>cd</sup>	0.65 <sup>cd</sup>	2.67 <sup>abc</sup>	3.77 <sup>bcd</sup>	3.58 <sup>cde</sup>	1.68 <sup>bcd</sup>
0900 – 1000	4.50 <sup>bc</sup>	4.58 <sup>ab</sup>	2.83 <sup>ab</sup>	2.75 <sup>abc</sup>	1.67 <sup>abc</sup>	0.97 <sup>cd</sup>	3.92 <sup>ab</sup>	4.45 <sup>abc</sup>	4.01 <sup>cd</sup>	2.86 <sup>bc</sup>
1000 – 1100	4.90 <sup>b</sup>	4.75 <sup>ab</sup>	2.91 <sup>ab</sup>	2.90 <sup>abc</sup>	1.83 <sup>abc</sup>	1.56 <sup>bc</sup>	4.56 <sup>abc</sup>	5.57 <sup>ab</sup>	4.21 <sup>ab</sup>	3.91 <sup>ab</sup>
1100 – 1200	7.66 <sup>a</sup>	4.08 <sup>ab</sup>	3.25 <sup>a</sup>	4.88 <sup>a</sup>	2.91 <sup>ab</sup>	2.64 <sup>abc</sup>	5.00 <sup>ab</sup>	6.01 <sup>a</sup>	5.47 <sup>abc</sup>	4.98 <sup>a</sup>
1200 – 0100	6.25 <sup>ab</sup>	5.50 <sup>a</sup>	3.00 <sup>a</sup>	3.58 <sup>ab</sup>	3.67 <sup>a</sup>	3.91 <sup>a</sup>	5.67 <sup>a</sup>	6.25 <sup>a</sup>	6.95 <sup>a</sup>	4.01 <sup>a</sup>
0100 – 0200	6.83 <sup>ab</sup>	5.30 <sup>ab</sup>	3.00 <sup>a</sup>	3.83 <sup>ab</sup>	3.33 <sup>a</sup>	3.45 <sup>a</sup>	5.32 <sup>a</sup>	6.03 <sup>a</sup>	6.23 <sup>a</sup>	3.93 <sup>ab</sup>
0200 – 0300	5.50 <sup>bcd</sup>	4.00 <sup>b</sup>	2.11 <sup>abc</sup>	2.24 <sup>abc</sup>	2.00 <sup>abc</sup>	2.14 <sup>bc</sup>	4.12 <sup>ab</sup>	4.00 <sup>abc</sup>	4.12 <sup>b</sup>	2.21 <sup>bc</sup>
0300 – 0400	5.49 <sup>bcd</sup>	3.75 <sup>bc</sup>	2.05 <sup>abc</sup>	1.24 <sup>cd</sup>	1.42 <sup>abc</sup>	2.65 <sup>abc</sup>	4.36 <sup>ab</sup>	3.57 <sup>bcd</sup>	4.27 <sup>cd</sup>	2.24 <sup>bc</sup>
0400 – 0500	3.08 <sup>cde</sup>	1.08 <sup>d</sup>	1.08 <sup>bcd</sup>	0.75 <sup>de</sup>	0.41 <sup>cd</sup>	1.35 <sup>c</sup>	2.02 <sup>abc</sup>	1.21 <sup>cd</sup>	3.21 <sup>de</sup>	1.07 <sup>bcd</sup>
0500 – 0600	1.08 <sup>e</sup>	0.49 <sup>d</sup>	0.66 <sup>d</sup>	0.83 <sup>ade</sup>	0.91 <sup>cd</sup>	0.64 <sup>d</sup>	2.36 <sup>cd</sup>	0.56 <sup>d</sup>	0.56 <sup>ef</sup>	0.92 <sup>cd</sup>
CD (0.05)	2.037	2.474	1.125	1.625	1.34	1.13	1.77	2.37	1.084	1.76

in *Nymphaea* sp. and *C. pulcherrima* (3.25, 3.00 and 6.01, 6.25, 5.03), this was on par with 0900 – 1100 h and 1000 – 1100 h (2.83, 2.91 and 5.57). In *R. bourboniana*, *Rosa* spp, *Ixora* sp. and *M. arboreus* maximum foraging rate was observed during 1200 – 0200 h (3.67, 3.33 and 3.91, 3.45 and 5.67, 5.32 and 6.95, 6.23) which was on par with 1000 -1200 h

Number of bee visited by a flower throughout the month of December ranged from 0.5 to 9.41 (Table 18). Regarding the observation of *A. leptopus* high foraging rate was during 1100 – 0100h (8.45 and 9.41). In *H patens*, *P. grandiflora*, *Rosa bourboniana*, *M. arboreus*, *Rosa* spp, *Ixora* sp. *C.pulcherrima* and *J pandurifolia* the maximum foraging rate was during 1200 – 0100 h (9.08, 6.06, 5.66, 9.21, 4.92, 5.87, 6.54 and 5.64) and this was on par with 1000 – 1100 h and 0100 – 0200 h. Maximum foraging rate was observed during 1200 – 0200 h in case of *P. aculeate* and *Dombeya* sp (4.65, 4.56 and 4.35, 3.98).

Observation on foraging rate of stingless bee in January varies from 0.33 to 64.53 (Table 19). In the case of *A. leptopus*, *H. patens*, *P. grandiflora*, *C. pulcherrima* and *Z. rosea* maximum foraging rate of stingless bee was observed during 1100 to 1200 h (8.81, 6.9, 4.29, 8.65 and 6.64) which was on par with 1000 – 1100 and 1200 – 0100 h. In *Nymphaea* sp. highest number of bee visited by a flower was observed during 1000 to 1200 h (3.41 and 3.33) this was on par with 1200 – 0200h (2.99 and 2.58). Peak foraging rate was observed during 1100 – 0100 in *M. arboreus*, *S. romanzoffiana* and *C. constrictum* and *Dombeya* sp. (7.9, 7.33 and 64.53, 64.5 and 5.97, 6.32 and 4.33, 4.56). In *R. bourboniana*, *Rosa* spp, *Ixora* sp., *J. pandurifolia* and *E. mili* maximum foraging rate was observed during 1100 - 0200 h (5.99, 6.1, 5.75 and 5.36, 5.67, 5.32 and 6.35, 6.97, 6.21 and 6.01, 6.35, 6.00 and 4.56, 6.34, 6.47) which was on par with 1000 – 1100 h and 0100 – 0200 h.

Stingless bee foraging rate varied from 0.35 to 11.83 in the month of February (Table 20). Maximum foraging rate in *A. leptopus*, *H. patens*, *M. arboreus*, *Rosa* spp, *Ixora* sp., *C. constrictum* and *E. mili* was observed during 1200 – 0100 h (7.92, 7.73, 7.83, 5.12, 5.89, 5.36 and 5.78) and this was on par with 1100 – 1200 h and 0100 – 0200 h. In *Nymphaea* sp. highest number of bees visited by flower was observed during 1000 – 1100 h (4.25) and this was on par with 0900 – 1000 h and 1100 – 1200 h (3.75 and 3.9). In *P. grandiflora*, *C. pulcherrima* and *T. erecta* peak foraging rate was observed during 1100 – 1200 h (5.98, 7.45 and 2.83). In *J. pandurifolia* and *Dombeya* sp., highest foraging rate was during 0100 – 0200 h (6.21 and 4.65)

Table 18. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of December 2021

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute											
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa bourboniana</i>	<i>Malvaviscus arboreus</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>	<i>Dombeya</i> sp.
0700 – 0800	3.21 <sup>f</sup>	2.16 <sup>e</sup>	1.41 <sup>bc</sup>	0.90 <sup>d</sup>	0.915 <sup>d</sup>	2.41 <sup>def</sup>	0.48 <sup>cd</sup>	1.58 <sup>ef</sup>	1.56 <sup>de</sup>	0.67 <sup>cd</sup>	0.54 <sup>cd</sup>	0.45 <sup>de</sup>
0800 – 0900	4.08 <sup>d</sup>	4.99 <sup>d</sup>	2.66 <sup>abc</sup>	2.4 <sup>bcd</sup>	3.05 <sup>abc</sup>	4.75 <sup>cde</sup>	0.89 <sup>cd</sup>	4.32 <sup>bc</sup>	3.78 <sup>bcd</sup>	1.95 <sup>bcd</sup>	1.32 <sup>bc</sup>	0.98 <sup>cd</sup>
0900 – 1000	4 <sup>bcd</sup>	5.5 <sup>d</sup>	3.08 <sup>ab</sup>	3.25 <sup>bc</sup>	3.66 <sup>abc</sup>	6.74 <sup>cd</sup>	1.02 <sup>bc</sup>	4.65 <sup>bc</sup>	4.56 <sup>abc</sup>	2.83 <sup>bc</sup>	1.56 <sup>bc</sup>	1.12 <sup>cd</sup>
1000 – 1100	4.91 <sup>ab</sup>	5.9 <sup>a</sup>	3.24 <sup>a</sup>	4.5 <sup>abc</sup>	4.41 <sup>ab</sup>	7.83 <sup>ab</sup>	1.98 <sup>bc</sup>	5.01 <sup>ab</sup>	4.68 <sup>abc</sup>	4.36 <sup>abc</sup>	1.42 <sup>bc</sup>	1.35 <sup>bc</sup>
1100 – 1200	8.45 <sup>a</sup>	7.16 <sup>cd</sup>	3.18 <sup>a</sup>	5.33 <sup>ab</sup>	5.16 <sup>ab</sup>	7.4 <sup>ab</sup>	3.88 <sup>ab</sup>	5.23 <sup>ab</sup>	5.98 <sup>ab</sup>	5.12 <sup>ab</sup>	2.95 <sup>bc</sup>	1.46 <sup>bc</sup>
1200 – 0100	9.41 <sup>a</sup>	9.08 <sup>a</sup>	3.58 <sup>a</sup>	6.06 <sup>a</sup>	5.66 <sup>a</sup>	9.21 <sup>a</sup>	4.92 <sup>a</sup>	5.87 <sup>a</sup>	6.54 <sup>a</sup>	5.64 <sup>a</sup>	4.65 <sup>a</sup>	4.35 <sup>a</sup>
0100 – 0200	5.74 <sup>abc</sup>	8.24 <sup>ab</sup>	3.08 <sup>a</sup>	3.83 <sup>abc</sup>	4.33 <sup>ab</sup>	7.02 <sup>ab</sup>	3.57 <sup>ab</sup>	5.42 <sup>ab</sup>	6.05 <sup>ab</sup>	5.93 <sup>a</sup>	4.56 <sup>a</sup>	3.98 <sup>a</sup>
0200 – 0300	3.58 <sup>cde</sup>	7.49 <sup>b</sup>	3.00 <sup>ab</sup>	3.91 <sup>abc</sup>	2.41 <sup>bcd</sup>	6.08 <sup>ab</sup>	2.56 <sup>ab</sup>	5.23 <sup>ab</sup>	4.35 <sup>abc</sup>	4.23 <sup>abc</sup>	3.21 <sup>ab</sup>	2.56 <sup>ab</sup>
0300 – 0400	4.5 <sup>e</sup>	4.99 <sup>d</sup>	2.25 <sup>abc</sup>	1.02 <sup>cd</sup>	1.49 <sup>cd</sup>	4.90 <sup>cd</sup>	1.89 <sup>abc</sup>	4.56 <sup>bc</sup>	4.37 <sup>abc</sup>	3.24 <sup>abcd</sup>	3.65 <sup>ab</sup>	2.54 <sup>ab</sup>
0400 – 0500	3.83 <sup>f</sup>	2.89 <sup>e</sup>	1.08 <sup>bc</sup>	1.16 <sup>cd</sup>	1.08 <sup>cd</sup>	3.64 <sup>de</sup>	1.07 <sup>bc</sup>	4.12 <sup>bc</sup>	2.89 <sup>cd</sup>	1.66 <sup>bc</sup>	2.41 <sup>abc</sup>	1.34 <sup>bc</sup>
0500 – 0600	3.08 <sup>f</sup>	0.66 <sup>f</sup>	0.50 <sup>cd</sup>	0.89 <sup>d</sup>	1.75 <sup>cd</sup>	1.04 <sup>ef</sup>	1.03 <sup>bc</sup>	2.24 <sup>de</sup>	1.24 <sup>de</sup>	1.02 <sup>bcd</sup>	0.98 <sup>cd</sup>	0.54 <sup>cd</sup>
CD (0.05)	2.314	1.645	1.064	0.966	1.133	2.6	1.05	1.23	1.98	1.12	1.06	0.87

Table 19. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of January 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constriatum</i>	<i>Dombeya</i> sp.	<i>Euphorbia milii</i>	<i>Zephyranthes rosea</i>
0700 – 0800	2.38 <sup>ef</sup>	2.66 <sup>e</sup>	1.41 <sup>bc</sup>	1.16 <sup>bcd</sup>	1.08 <sup>ef</sup>	5.33 <sup>f</sup>	1.75 <sup>bc</sup>	0.89 <sup>c</sup>	1.97 <sup>cd</sup>	2.87 <sup>de</sup>	1.23 <sup>d</sup>	1.12 <sup>cd</sup>	1.23 <sup>de</sup>	2.53 <sup>de</sup>	1.00 <sup>cd</sup>
0800 – 0900	2.66 <sup>cd</sup>	2.99 <sup>cd</sup>	2.00 <sup>abc</sup>	1.16 <sup>bc</sup>	2.9 <sup>ef</sup>	34.16 <sup>de</sup>	3.78 <sup>abcd</sup>	1.12 <sup>bc</sup>	2.45 <sup>bcd</sup>	5.32 <sup>cd</sup>	2.34 <sup>cd</sup>	2.56 <sup>bcd</sup>	1.57 <sup>cde</sup>	4.56 <sup>bc</sup>	2.45 <sup>bcd</sup>
0900 – 1000	5.23 <sup>cd</sup>	4.24 <sup>cd</sup>	3.16 <sup>abc</sup>	2.16 <sup>abc</sup>	3.58 <sup>de</sup>	57.16 <sup>de</sup>	4.00 <sup>abc</sup>	2.5 <sup>abc</sup>	4.92 <sup>abc</sup>	5.68 <sup>bcd</sup>	3.65 <sup>bcd</sup>	3.67 <sup>bc</sup>	2.45 <sup>cd</sup>	5.37 <sup>abc</sup>	3.87 <sup>bcd</sup>
1000 – 1100	7.00 <sup>abc</sup>	6.74 <sup>cd</sup>	3.41 <sup>a</sup>	3.25 <sup>ab</sup>	6.83 <sup>bc</sup>	38.83 <sup>cde</sup>	4.91 <sup>abc</sup>	4.58 <sup>ab</sup>	5.67 <sup>ab</sup>	6.56 <sup>bc</sup>	5.26 <sup>ab</sup>	5.62 <sup>ab</sup>	3.56 <sup>abcd</sup>	6.00 <sup>ab</sup>	5.00 <sup>ab</sup>
1100 – 1200	8.81 <sup>a</sup>	6.9 <sup>a</sup>	3.33 <sup>a</sup>	4.29 <sup>a</sup>	7.9 <sup>a</sup>	64.53 <sup>a</sup>	5.99 <sup>a</sup>	5.36 <sup>a</sup>	6.35 <sup>a</sup>	8.65 <sup>a</sup>	6.01 <sup>a</sup>	5.97 <sup>ab</sup>	4.33 <sup>ab</sup>	4.56 <sup>ab</sup>	6.64 <sup>a</sup>
1200 – 0100	8.16 <sup>ab</sup>	6.16 <sup>ab</sup>	2.99 <sup>ab</sup>	4.11 <sup>ab</sup>	7.33 <sup>a</sup>	64.5 <sup>a</sup>	6.1 <sup>a</sup>	5.67 <sup>a</sup>	6.97 <sup>a</sup>	7.32 <sup>ab</sup>	6.35 <sup>a</sup>	6.32 <sup>a</sup>	4.56 <sup>a</sup>	6.34 <sup>a</sup>	5.34 <sup>ab</sup>
0100 – 0200	6.83 <sup>bc</sup>	6.66 <sup>ab</sup>	2.58 <sup>ab</sup>	3.16 <sup>ab</sup>	5.33 <sup>abc</sup>	31.5 <sup>de</sup>	5.75 <sup>a</sup>	5.32 <sup>a</sup>	6.21 <sup>a</sup>	6.35 <sup>bc</sup>	6.00 <sup>a</sup>	5.00 <sup>ab</sup>	4.32 <sup>ab</sup>	6.47 <sup>a</sup>	5.02 <sup>ab</sup>
0200 – 0300	6.16 <sup>bc</sup>	6.99 <sup>a</sup>	2.23 <sup>abc</sup>	1.98 <sup>bc</sup>	6.32 <sup>ab</sup>	7.33 <sup>abc</sup>	3.19 <sup>bcd</sup>	4.86 <sup>ab</sup>	5.02 <sup>ab</sup>	6.00 <sup>bc</sup>	3.57 <sup>bcd</sup>	4.68 <sup>abc</sup>	3.65 <sup>abcd</sup>	5.26 <sup>abc</sup>	3.65 <sup>bcd</sup>
0300 – 0400	2.49 <sup>bce</sup>	5.32 <sup>de</sup>	2.24 <sup>abc</sup>	1.56 <sup>bcd</sup>	6.25 <sup>abc</sup>	41.17 <sup>cd</sup>	0.5 <sup>cd</sup>	3.47 <sup>ab</sup>	5.00 <sup>ab</sup>	5.64 <sup>bcd</sup>	3.12 <sup>bcd</sup>	4.00 <sup>abc</sup>	3.27 <sup>abcd</sup>	5 <sup>abc</sup>	3.05 <sup>bcd</sup>
0400 – 0500	1.33 <sup>ef</sup>	2.24 <sup>e</sup>	1.25 <sup>bc</sup>	1.65 <sup>bc</sup>	2.41 <sup>ef</sup>	49.16 <sup>bc</sup>	1.91 <sup>bc</sup>	2.31 <sup>abc</sup>	4.35 <sup>abc</sup>	4.23 <sup>cd</sup>	2.66 <sup>cd</sup>	3.52 <sup>bc</sup>	2.00 <sup>cde</sup>	4.02 <sup>bc</sup>	3.22 <sup>bcd</sup>
0500 – 0600	0.35 <sup>ef</sup>	0.83 <sup>f</sup>	0.5 <sup>bcd</sup>	0.18 <sup>cd</sup>	0.665 <sup>f</sup>	19.00 <sup>f</sup>	1.66 <sup>bc</sup>	1.58 <sup>abc</sup>	3.64 <sup>bc</sup>	2.34 <sup>de</sup>	1.24 <sup>d</sup>	1.37 <sup>cd</sup>	0.67 <sup>e</sup>	2.34 <sup>de</sup>	0.53 <sup>d</sup>
CD (0.05)	2.31	2.339	1.103	1.79	1.913	17.463	1.4	1.37	2.05	1.73	1.42	1.64	0.62	1.23 <sup>e</sup>	1.02

Table 20. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of February 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Dombeya</i> sp.	<i>Euphorbia mili</i>
0700-0800	2.02 <sup>b</sup>	3.66 <sup>de</sup>	1.58 <sup>bcd</sup>	0.74 <sup>cde</sup>	2.33 <sup>de</sup>	0.45 <sup>d</sup>	1.58 <sup>cd</sup>	1.85 <sup>c</sup>	0.83 <sup>d</sup>	1.02 <sup>cd</sup>	0.41 <sup>d</sup>	0.65 <sup>d</sup>	1.35 <sup>d</sup>
0800 – 0900	3.91 <sup>ab</sup>	5.49 <sup>cde</sup>	3.02 <sup>abc</sup>	3 <sup>bcde</sup>	4.9 <sup>cd</sup>	1.02 <sup>cd</sup>	2.34 <sup>cd</sup>	4.65 <sup>bc</sup>	1.34 <sup>cd</sup>	1.56 <sup>cd</sup>	1.31 <sup>bcd</sup>	1.82 <sup>abcd</sup>	3.42 <sup>bc</sup>
0900 – 1000	4.16 <sup>ab</sup>	5.58 <sup>bcd</sup>	3.75 <sup>ab</sup>	3.5 <sup>abcd</sup>	6.01 <sup>bcd</sup>	2.35 <sup>bcd</sup>	3.65 <sup>bc</sup>	5.46 <sup>abc</sup>	2.65 <sup>bcd</sup>	2.67 <sup>bcd</sup>	1.66 <sup>bc</sup>	2.46 <sup>abc</sup>	4.21 <sup>abc</sup>
1000 – 1100	4.91 <sup>ab</sup>	6.66 <sup>bc</sup>	4.25 <sup>a</sup>	3.64 <sup>abcd</sup>	6.33 <sup>abc</sup>	4.02 <sup>ab</sup>	4.23 <sup>abc</sup>	5.55 <sup>abc</sup>	4.32 <sup>abc</sup>	4.86 <sup>ab</sup>	1.75 <sup>bc</sup>	2.69 <sup>abc</sup>	5.03 <sup>ab</sup>
1100 – 1200	5.83 <sup>ab</sup>	7.08 <sup>ab</sup>	3.9 <sup>ab</sup>	5.98 <sup>a</sup>	6.08 <sup>abc</sup>	5.00 <sup>a</sup>	5.16 <sup>ab</sup>	7.45 <sup>a</sup>	5.02 <sup>ab</sup>	4.96 <sup>ab</sup>	2.83 <sup>a</sup>	3.31 <sup>ab</sup>	5.06 <sup>ab</sup>
1200 – 0100	7.92 <sup>a</sup>	7.73 <sup>a</sup>	3.9 <sup>ab</sup>	5.16 <sup>ab</sup>	7.83 <sup>a</sup>	5.12 <sup>a</sup>	5.89 <sup>a</sup>	6.35 <sup>ab</sup>	5.32 <sup>ab</sup>	5.36 <sup>a</sup>	2.08 <sup>ab</sup>	3.44 <sup>ab</sup>	5.78 <sup>a</sup>
0100 – 0200	6.3 <sup>ab</sup>	6.99 <sup>bc</sup>	3.00 <sup>abc</sup>	4.08 <sup>abc</sup>	7.06 <sup>ab</sup>	5.03 <sup>a</sup>	5.00 <sup>ab</sup>	6.00 <sup>ab</sup>	6.21 <sup>a</sup>	4.78 <sup>ab</sup>	1.01 <sup>bcd</sup>	4.65 <sup>a</sup>	5.05 <sup>ab</sup>
0200 – 0300	3.83 <sup>abc</sup>	6.99 <sup>bc</sup>	3.00 <sup>abc</sup>	2.41 <sup>cd</sup>	6.32 <sup>abc</sup>	4.56 <sup>ab</sup>	4.32 <sup>abc</sup>	5.32 <sup>abc</sup>	3.20 <sup>bc</sup>	4.00 <sup>abc</sup>	1.36 <sup>bc</sup>	3.24 <sup>ab</sup>	4.32 <sup>ab</sup>
0300 – 0400	2.74 <sup>bc</sup>	4.99 <sup>bcd</sup>	2.6 <sup>bcd</sup>	0.97 <sup>de</sup>	7.14 <sup>bcd</sup>	2.36 <sup>bc</sup>	4.00 <sup>abc</sup>	5.14 <sup>abc</sup>	3.01 <sup>bc</sup>	4.32 <sup>ab</sup>	1.19 <sup>bcd</sup>	3.27 <sup>ab</sup>	4.00 <sup>abc</sup>
0400 – 0500	1.5 <sup>c</sup>	3.66 <sup>de</sup>	1.81 <sup>bcd</sup>	1.08 <sup>cde</sup>	5.14 <sup>cd</sup>	2.01 <sup>bc</sup>	3.21 <sup>bc</sup>	4.05 <sup>bc</sup>	2.54 <sup>bcd</sup>	2.36 <sup>bcd</sup>	1.21 <sup>cd</sup>	2.03 <sup>abc</sup>	3.65 <sup>bc</sup>
0500 – 0600	0.75 <sup>cd</sup>	1.74 <sup>e</sup>	1.25 <sup>bcd</sup>	0.66 <sup>e</sup>	1.7 <sup>def</sup>	0.5 <sup>d</sup>	2.15 <sup>bc</sup>	3.11	0.36 <sup>d</sup>	1.02 <sup>cd</sup>	0.35 <sup>d</sup>	0.67 <sup>d</sup>	1.32 <sup>d</sup>
CD (0.05)	1.03	1.629	1.011	1.062	1.441	1.13	1.24	1.35	1.14	1.56	0.65	0.35	1.04

Observation on foraging rate of stingless bee in March varied from 0.20 to 9.50 (Table 21). In the case of *A. leptopus*, *H patens*, *Rosa* spp, *C. pulcherrima* and *P. aculeata* maximum foraging rate was during 1200 – 0100 h (9.5, 9.24, 6.32, 7.02 and 6.22) which was on par with 1100 – 1200 and 0100 – 0200 h. In *Nymphaea* sp, maximum foraging rate of stingless bee was observed during 1000 to 0100 h (4.00, 3.66, and 3.75) which was on par with 0800 – 1000 and 0100 – 0300 h. Peak foraging rate was observed during 1100 – 0100 h in *P grandiflora*, *R. bourboniana*, *Ixora* sp, *C. constrictum* and *T. erecta* (5.5, 5.25 and 5.58, 5.16 and 6.78, 6.52 and 6.35, 6.11 and 6.47, 6.33) this was on par with 0900 – 1100 h. During 1200 – 0200 h, maximum number of bees visited by a flower in *M. arboreus*, *J pandurifolia* and *E. mili* (8.5, 8.66 and 6.47, 6.32 and 6.22, 5.87) this was on par with 1000 – 1200 h and 0200 – 0300 h.

Observation on foraging rate of stingless bee in April, varied from 0.21 to 49 (Table 22). Regarding the observation of *A. leptopus*, *P.grandiflora*, *S. romanzoffiana*, *R. bourboniana*, *Ixora* sp, *C. pulcherrima*, *E. mili* and *Z. rosea* maximum number of flowers visited by bee was observed during 1200 to 0100 h and were 8.5, 5.16, 5.16, 49.8, 5.18, 6.56, 5.66, 5.36, 5.98 respectively and this was on par with 0900 – 1100 h and lowest during 0700 – 0800 h and 0500 to 0600 h. In *H patens* and *Nymphaea* sp, highest number of flowers visited by bee was observed during 1100 – 0100 h (7.00, 7.24 and 3.8, 3.83). In *J. pandurifolia* and *C. constrictum* maximum number of bee were observed during 0100 to 0200 h (5.26 and 4.12).

Number of bee visited by a flower throughout the month of May ranged from 0.12 to 8.25 (Table 23). Regarding the observation of *A. leptopus* and *M. arboreus* high foraging rate was during 0100 – 0200 h (8.25 and 4.30). In *H. patens*, *Nymphaea* sp, *P. grandiflora*, *C. pulcherrima* and *J. pandurifolia* the maximum foraging rate was during 1200 – 0100 h (8.15, 7.25, 2.58, 5.12 and 6.32) and this was on par with 1000-1100 h and 0100 – 0200 h. Maximum foraging rate was observed during 1000 – 1200 h in case of *R. bourboniana* (5.75 and 5.00) which was on par with 1200 – 0100 h (4.65).

According to observations, 0.23 to 5.25 stingless bees visited a flower during the month of June (Table 24). In *A leptopus*, *Nymphaea* sp and *E. mili*, highest foraging rate was during 1100 – 0100 h (5.25, 5.08 and 3.41, 3.00 and 5.22, 5.48) this was on par with 100 – 1100 h and 0100 – 0300 h. Regarding the observation of *H patens*, *P. grandiflora* and *T. erecta* was observed during 1200 – 0100 (4.86, 3.91 and 4.25) this was on par with 1100 – 1200 h and 0200- 0300 h. In *Rosa* spp, *C. pulcherrima* and *J. pandurifolia* highest number of bee visited

Table 21. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of March 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malva discolor boreus</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Euphorbia mili</i>	<i>Zephyranthes rosea</i>
0700 – 0800	1.33 <sup>bcd</sup>	2.24 <sup>ef</sup>	1.25 <sup>bc</sup>	0.89 <sup>d</sup>	1.16 <sup>de a</sup>	1.66 <sup>cd</sup>	0.85 <sup>d</sup>	1.85 <sup>d</sup>	2.03 <sup>cd</sup>	0.56 <sup>cd</sup>	1.03 <sup>d</sup>	1.03 <sup>cd</sup>	0.55 <sup>d</sup>	1.25 <sup>cd</sup>	0.55 <sup>de</sup>
0800 – 0900	2.49 <sup>bc</sup>	3.66 <sup>def</sup>	2.08 <sup>ab</sup>	3.25 <sup>bc</sup>	2.22 <sup>de</sup>	3.33 <sup>abc</sup>	1.03 <sup>cd</sup>	2.35 <sup>cd</sup>	3.65 <sup>bcd</sup>	1.58 <sup>bc</sup>	2.64 <sup>cd</sup>	1.56 <sup>cd</sup>	2.35 <sup>cd</sup>	3.56 <sup>bc</sup>	1.89 <sup>bcd</sup>
0900 – 1000	4.08 <sup>abc</sup>	4.8 <sup>ef</sup>	3.33 <sup>ab</sup>	4.24 <sup>ab</sup>	3.91 <sup>cde</sup>	4.91 <sup>ab</sup>	3.65 <sup>abcd</sup>	4.56 <sup>abc</sup>	4.25 <sup>bcd a</sup>	2.78 <sup>bc</sup>	2.67 <sup>cd</sup>	2.67 <sup>bvd</sup>	3.45 <sup>bcd</sup>	4.32 <sup>abc</sup>	3.65 <sup>abc</sup>
1000 – 1100	5.67 <sup>ab</sup>	6.83 <sup>cd</sup>	4.00 <sup>a</sup>	4.00 <sup>abc</sup>	6.16 <sup>bcd</sup>	4.75 <sup>ab</sup>	4.53 <sup>abc</sup>	5.23 <sup>ab</sup>	5.38 <sup>abc</sup>	4.89 <sup>ac</sup>	3.52 <sup>bcd</sup>	4.25 <sup>abcd</sup>	5.62 <sup>ab</sup>	5.03 <sup>ab</sup>	4.22 <sup>ab</sup>
1100 – 1200	6.41 <sup>ab</sup>	8.66 <sup>ab</sup>	3.66 <sup>a</sup>	5.5 <sup>a</sup>	8.24 <sup>ab</sup>	5.58 <sup>a</sup>	5.64 <sup>ab</sup>	6.78 <sup>a</sup>	6.95 <sup>ab</sup>	5.66 <sup>ab</sup>	5.97 <sup>ab</sup>	6.35 <sup>a</sup>	6.47 <sup>a</sup>	5.68 <sup>ab</sup>	5.36 <sup>a</sup>
1200 – 0100	9.5 <sup>a</sup>	9.24 <sup>a</sup>	3.75 <sup>a</sup>	5.25 <sup>a</sup>	8.5 <sup>a</sup>	5.16 <sup>a</sup>	6.32 <sup>a</sup>	6.52 <sup>a</sup>	7.02 <sup>a</sup>	6.47 <sup>a</sup>	6.22 <sup>a</sup>	6.11 <sup>a</sup>	6.33 <sup>a</sup>	6.22 <sup>a</sup>	4.78 <sup>ab</sup>
0100 – 0200	6.25 <sup>ab</sup>	8.24 <sup>bc</sup>	3.14 <sup>ab</sup>	4.41 <sup>ab</sup>	8.66 <sup>a</sup>	4.66 <sup>ab</sup>	5.21 <sup>ab</sup>	5.33 <sup>ab</sup>	6.37 <sup>ab</sup>	6.32 <sup>a</sup>	5.00 <sup>ab</sup>	4.44 <sup>abcd</sup>	5.23 <sup>ab</sup>	5.87 <sup>a</sup>	4.02 <sup>ab</sup>
0200 – 0300	5.66 <sup>abc</sup>	6.41 <sup>de</sup>	3.08 <sup>ab</sup>	1.9 <sup>cd</sup>	6.98 <sup>bcd</sup>	2.5 <sup>bcd</sup>	5.02 <sup>ab</sup>	5.12 <sup>ab</sup>	5.28 <sup>abc</sup>	5.64 <sup>ab</sup>	4.12 <sup>abc</sup>	3.98 <sup>bcd</sup>	4.11 <sup>abc</sup>	5.02 <sup>ab</sup>	2.12 <sup>bc</sup>
0300 – 0400	3.91 <sup>abc</sup>	4.16 <sup>ef</sup>	3.24 <sup>ab</sup>	2.5 <sup>bcd</sup>	3.88 <sup>cde</sup>	1.67 <sup>cd</sup>	4.32 <sup>abc</sup>	4.23 <sup>ab</sup>	3.87 <sup>bc</sup>	2.54 <sup>bc</sup>	4.00 <sup>abcd</sup>	3.24 <sup>bcd</sup>	1.32 <sup>cd</sup>	4.12 <sup>abc</sup>	1.35 <sup>cde</sup>
0400 – 0500	2.16 <sup>bc</sup>	3.08 <sup>def</sup>	1.75 <sup>bc</sup>	1.3 <sup>cd</sup>	3.16 <sup>cd</sup>	1.33 <sup>cd</sup>	3.22 <sup>bcd</sup>	4.02 <sup>ab</sup>	3.44 <sup>bc</sup>	1.22 <sup>cd</sup>	3.52 <sup>bcd</sup>	2.88 <sup>cd</sup>	1.02 <sup>cd</sup>	3.65 <sup>bc</sup>	1.89 <sup>cde</sup>
0500 – 0600	0.58 <sup>e</sup>	1.4 <sup>f</sup>	0.58 <sup>bcd</sup>	0.9 <sup>d</sup>	0.20 <sup>e</sup>	1.00 <sup>cd</sup>	2.10 <sup>cd</sup>	2.11 <sup>cd</sup>	1.65 <sup>d</sup>	0.23 <sup>d</sup>	1.66 <sup>d</sup>	0.45 <sup>d</sup>	0.33 <sup>d</sup>	1.3 <sup>cd</sup>	0.23 <sup>de</sup>
CD (0.05)	1.638	1.689	0.823	1.384	1.13	1.634	1.04	1.65	1.83	1.02	1.32	1.33	0.98	1.06	0.95

Table 22. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of April 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum mconstrictum</i>	<i>Euphorbia mili</i>	<i>Zephyranthes rosea</i>
0700 – 0800	1.25 <sup>c</sup>	1.58 <sup>e</sup>	1.16 <sup>cd</sup>	0.665 <sup>de</sup>	1.08 <sup>cd</sup>	11.67 <sup>c</sup>	1.00 <sup>cd</sup>	0.23 <sup>cd</sup>	0.89 <sup>d</sup>	0.45 <sup>d</sup>	0.76 <sup>cd</sup>	0.53 <sup>d</sup>	0.23 <sup>cd</sup>
0800 – 0900	3.16 <sup>bc</sup>	3.75 <sup>de</sup>	2.6 <sup>abcd</sup>	2.81 <sup>cd</sup>	2.16 <sup>bcd</sup>	26.5 <sup>bc</sup>	2.66 <sup>bcd</sup>	1.25 <sup>cd</sup>	1.56 <sup>bc</sup>	1.25 <sup>bcd</sup>	1.20 <sup>bc</sup>	2.56 <sup>cd</sup>	1.45 <sup>bcd</sup>
0900 – 1000	3.00 <sup>b</sup>	4.83 <sup>cd</sup>	3.16 <sup>ab</sup>	3.50 <sup>bc</sup>	3.33 <sup>abc</sup>	44.6 <sup>ab</sup>	4.16 <sup>ab</sup>	2.23 <sup>bcd</sup>	3.26 <sup>abc</sup>	2.58 <sup>bc</sup>	1.42 <sup>bc</sup>	3.37 <sup>bcd</sup>	2.78 <sup>bc</sup>
1000 – 1100	4.91 <sup>b</sup>	6.9 <sup>abc</sup>	3.17 <sup>ab</sup>	4.08 <sup>abc</sup>	5.41 <sup>a</sup>	26.16 <sup>bc</sup>	3.91 <sup>abc</sup>	3.56 <sup>bc</sup>	3.58 <sup>abc</sup>	3.36 <sup>abc</sup>	2.35 <sup>abc</sup>	5.32 <sup>a</sup>	3.00 <sup>abc</sup>
1100 – 1200	5.75 <sup>b</sup>	7.00 <sup>a</sup>	3.8 <sup>a</sup>	5.00 <sup>ab</sup>	5.50 <sup>a</sup>	36.5 <sup>abc</sup>	3.33 <sup>bc</sup>	0.64 <sup>cd</sup>	4.03 <sup>abc</sup>	4.12 <sup>ab</sup>	3.87 <sup>a</sup>	3.45 <sup>abc</sup>	3.64 <sup>abc</sup>
1200 – 0100	8.5 <sup>a</sup>	7.24 <sup>a</sup>	3.83 <sup>a</sup>	5.16 <sup>a</sup>	5.16 <sup>a</sup>	49.8 <sup>a</sup>	5.18 <sup>a</sup>	6.56 <sup>a</sup>	5.66 <sup>a</sup>	4.68 <sup>ab</sup>	3.31 <sup>a</sup>	5.36 <sup>a</sup>	5.98 <sup>a</sup>
0100 – 0200	6.25 <sup>b</sup>	6.9 <sup>abc</sup>	3.41 <sup>ab</sup>	5.44 <sup>a</sup>	3.50	39.33 <sup>abc</sup>	3.08 <sup>abc</sup>	5.87 <sup>ab</sup>	4.56 <sup>ab</sup>	5.26 <sup>a</sup>	4.12 <sup>a</sup>	4.32 <sup>ab</sup>	4.65 <sup>ab</sup>
0200 – 0300	5.66 <sup>b</sup>	4.58 <sup>cd</sup>	2.58 <sup>abcd</sup>	1.58 <sup>cde</sup>	4.08 <sup>ab</sup>	39 <sup>abc</sup>	2.5 <sup>bcd</sup>	5.21 <sup>ab</sup>	3.68 <sup>abc</sup>	4.36 <sup>ab</sup>	2.45 <sup>abc</sup>	3.2 <sup>abc</sup>	4.36 <sup>ab</sup>
0300 – 0400	3.91 <sup>bc</sup>	3.66 <sup>de</sup>	2.67 <sup>abcd</sup>	1.25 <sup>cde</sup>	2.78 <sup>abcd</sup>	38.33 <sup>abc</sup>	1.58 <sup>cd</sup>	4.23 <sup>abc</sup>	3.22 <sup>abc</sup>	3.34 <sup>abc</sup>	2.01 <sup>ac</sup>	1.25 <sup>bcd</sup>	3.23 <sup>abc</sup>
0400 – 0500	2.16 <sup>bcd</sup>	2.16 <sup>de</sup>	1.5 <sup>cd</sup>	0.66 <sup>de</sup>	1.33 <sup>cd</sup>	33.83 <sup>abc</sup>	1.25 <sup>cd</sup>	3.35 <sup>bcd</sup>	1.56 <sup>bcd</sup>	1.23 <sup>bcd</sup>	1.56 <sup>bc</sup>	1.12 <sup>cd</sup>	2.11 <sup>bcd</sup>
0500 – 0600	0.41 <sup>cd</sup>	0.91 <sup>e</sup>	0.49 <sup>d</sup>	0.66 <sup>de</sup>	0.58 <sup>d</sup>	28.83 <sup>bc</sup>	1.58 <sup>cd</sup>	1.02 <sup>cd</sup>	1.24 <sup>cd</sup>	0.65 <sup>d</sup>	0.56 <sup>d</sup>	0.32 <sup>d</sup>	0.21 <sup>cd</sup>
CD (0.05)	1.474	1.807	0.513	1.029	1.567	11.916	1.24	1.135	1.35	0.37	1.25	0.65	0.25

Table 23. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of May 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Rosa bourboniana</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	1.16 <sup>de</sup>	2.03 <sup>bcd</sup>	1.75 <sup>cd</sup>	1.41 <sup>bc</sup>	0.71 <sup>cd</sup>	2.66 <sup>abcd</sup>	0.52 <sup>cd</sup>	1.23 <sup>cd</sup>
0800 – 0900	2.74 <sup>cd</sup>	3.65 <sup>bc</sup>	4.16 <sup>bc</sup>	2.08 <sup>abc</sup>	1.90 <sup>bc</sup>	3.50 <sup>abc</sup>	1.24 <sup>bcd</sup>	2.74 <sup>bcd</sup>
0900 – 1000	3.01 <sup>cd</sup>	5.57 <sup>abc</sup>	5.00 <sup>abc</sup>	2.51 <sup>ab</sup>	3.16 <sup>abc</sup>	3.90 <sup>abc</sup>	1.36 <sup>bcd</sup>	3.45 <sup>abcd</sup>
1000 – 1100	3.99 <sup>bc</sup>	6.69 <sup>ab</sup>	4.90 <sup>bc</sup>	2.58 <sup>ab</sup>	3.25 <sup>ab</sup>	5.75 <sup>a</sup>	4.23 <sup>bcd</sup>	4.25 <sup>abc</sup>
1100 – 1200	5.28 <sup>ab</sup>	7.00 <sup>ab</sup>	6.25 <sup>abc</sup>	2.59 <sup>a</sup>	4.08 <sup>a</sup>	5.00 <sup>a</sup>	4.56 <sup>ab</sup>	5.01 <sup>ab</sup>
1200 – 0100	5.33 <sup>ab</sup>	8.15 <sup>a</sup>	7.25 <sup>a</sup>	2.58 <sup>a</sup>	3.66 <sup>ab</sup>	4.65 <sup>ab</sup>	5.12 <sup>a</sup>	6.32 <sup>a</sup>
0100 – 0200	8.25 <sup>a</sup>	5.92 <sup>abc</sup>	6.58 <sup>ab</sup>	3.08 <sup>a</sup>	4.30 <sup>a</sup>	3.50 <sup>abc</sup>	4.20 <sup>ab</sup>	4.23 <sup>abc</sup>
0200 – 0300	5.66 <sup>ab</sup>	7.23 <sup>ab</sup>	4.08 <sup>bcd</sup>	2.33 <sup>abc</sup>	1.40 <sup>bcd</sup>	3.16 <sup>ab</sup>	3.23 <sup>abcd</sup>	3.65 <sup>abcd</sup>
0300 – 0400	3.91 <sup>bc</sup>	3.67 <sup>bc</sup>	2.90 <sup>bcd</sup>	1.75 <sup>bcd</sup>	1.41 <sup>bcd</sup>	2.00 <sup>abcd</sup>	2.33 <sup>bcd</sup>	2.64 <sup>bcd</sup>
0400 – 0500	2.16 <sup>cde</sup>	2.66 <sup>bcd</sup>	1.90 <sup>cd</sup>	1.16 <sup>bcd</sup>	0.60 <sup>d</sup>	0.99 <sup>bcd</sup>	0.86 <sup>cd</sup>	1.56 <sup>cd</sup>
0500 – 0600	0.25 <sup>e</sup>	1.03 <sup>cd</sup>	0.58 <sup>d</sup>	0.50 <sup>dd</sup>	0.66 <sup>d</sup>	0.16 <sup>bcd</sup>	0.12 <sup>d</sup>	0.33 <sup>cd</sup>
CD (0.05)	2.16	1.807	2.988	0.615	1.527	1.023	0.891	1.87

Table 24. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of June 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute								
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Tagetes erecta</i>	<i>Euphorbia mili</i>
0700 – 0800	1.25 <sup>bc</sup>	0.75 <sup>ef</sup>	1.25 <sup>bc</sup>	0.58 <sup>d</sup>	0.23 <sup>cd</sup>	0.98 <sup>cd</sup>	0.23 <sup>d</sup>	1.23 <sup>cd</sup>	0.33 <sup>d</sup>
0800 – 0900	2.58 <sup>abc</sup>	1.66 <sup>cde</sup>	2.41 <sup>abc</sup>	1.5 <sup>cd</sup>	0.45 <sup>cd</sup>	1.54 <sup>bcd</sup>	0.65 <sup>cd</sup>	1.69 <sup>cd</sup>	1.59 <sup>cd</sup>
0900 – 1000	2.74 <sup>abc</sup>	2.30 <sup>bcd</sup>	2.83 <sup>abc</sup>	2.33 <sup>bcd</sup>	1.25 <sup>bc</sup>	1.89 <sup>abcd</sup>	1.89 <sup>bcd</sup>	2.56 <sup>abcd</sup>	2.58 <sup>bcd</sup>
1000 – 1100	3.66 <sup>ab</sup>	2.75 <sup>bcd</sup>	2.33 <sup>ab</sup>	2.5 <sup>bcd</sup>	2.56 <sup>abc</sup>	2.98 <sup>ab</sup>	1.78 <sup>bcd</sup>	3.45 <sup>abc</sup>	4.35 <sup>ab</sup>
1100 – 1200	5.25 <sup>a</sup>	3.97 <sup>ab</sup>	3.41 <sup>a</sup>	3.01 <sup>ab</sup>	2.88 <sup>ab</sup>	3.98 <sup>ab</sup>	3.45 <sup>abc</sup>	3.92 <sup>ab</sup>	5.22 <sup>a</sup>
1200 – 0100	5.08 <sup>a</sup>	4.86 <sup>a</sup>	3.00 <sup>a</sup>	3.91 <sup>a</sup>	3.56 <sup>a</sup>	4.03 <sup>a</sup>	5.68 <sup>a</sup>	4.25 <sup>a</sup>	5.48 <sup>a</sup>
0100 – 0200	3.61 <sup>ab</sup>	2.99 <sup>bcd</sup>	2.9 <sup>ab</sup>	2.5 <sup>bcd</sup>	3.96 <sup>a</sup>	3.98 <sup>a</sup>	5.23 <sup>a</sup>	3.36 <sup>ab</sup>	4.56 <sup>ab</sup>
0200 – 0300	3.91 <sup>ab</sup>	2.99 <sup>bcd</sup>	2.5 <sup>abc</sup>	1.66 <sup>cd</sup>	2.51 <sup>ab</sup>	2.98 <sup>ab</sup>	4.21 <sup>ab</sup>	3.89 <sup>ab</sup>	4.02 <sup>ab</sup>
0300 – 0400	2.33 <sup>abc</sup>	2.66 <sup>def</sup>	2.33 <sup>abc</sup>	0.97 <sup>cd</sup>	2.34 <sup>ab</sup>	2.54 <sup>ab</sup>	3.65 <sup>abc</sup>	2.45 <sup>abcd</sup>	3.98 <sup>cd</sup>
0400 – 0500	1.53 <sup>bc</sup>	0.66 <sup>ef</sup>	1.17 <sup>bc</sup>	0.58 <sup>d</sup>	1.65 <sup>bcd</sup>	2.33 <sup>ab</sup>	2.41 <sup>abcd</sup>	2.33 <sup>abcd</sup>	3.21 <sup>cd</sup>
0500 – 0600	1.03 <sup>c</sup>	0.41 <sup>f</sup>	0.5 <sup>c</sup>	0.75 <sup>d</sup>	1.22 <sup>bcd</sup>	0.44 <sup>d</sup>	1.56 <sup>bcd</sup>	1.23 <sup>cd</sup>	0.62 <sup>d</sup>
CD (0.05)	2.446	3.532	0.613	1.828	0.965	1.161	1.07	1.337	1.015

by flower was observed during 1200 to 0200 h which was on par with 1100 – 1200 h and 0200 – 0400 h.

Observation on foraging rate of stingless bee in July varies from 0.41 to 41.86 (Table 25). In case of *A. leptopus*, *H patens* and *Nymphaea* sp maximum foraging rate of stingless bee was observed during 1100 - 0100 h (7.74, 7.32 and 6.5, 6.9 and 3.66, 3.58) which was on par with 1000 – 1100 and 0100 – 0200 h and the lowest during 0500 to 0600 h. In *P. grandiflora*, *R. bourboniana* and *C. pulcherrima* highest number of bee visited by a flower was observed during 1100 - 1200 h (4.39 and 4.01 and 5.21) this was on par with 1000 – 1100 and 1200 – 0200 h. During 0900 – 1100 h *S. romanzoffiana* was having peak foraging rate (41.16 and 41.86). In *Rosa* spp, *J. pandurifolia* and *T. erecta* maximum foraging rate was observed during 1200 – 0100 h (5.12, 5.98 and 6.87) and the lowest foraging rate was observed during 0500 – 0600 h.

During August foraging rate of stingless bee varies between 0.17 to 6.75 in a flower (Table 26). Maximum foraging rate was observed at 1100 – 1200 h in *A. leptopus*, *M. arboreus* and *J. pandurifolia* (6.75, 5.22 and 5.06) this was on par with 1000 – 1100 h and 1200 – 0100 h. In *H. patens*, *Nymphaea* sp, *P. grandiflora*, *Rosa* spp, *C. pulcherrima* and *J. pandurifolia* peak foraging activity was observed during 1200 – 0100 h (6.24, 4.66, 6.33, 5.63, 4.12 and 5.66) this was on par with 1000 – 1200 h and 0100 - 0300 h.

#### **4.2.3. Time spent by bees per flower**

According to observation, time spent by stingless bee in a flower varied from 6.64 - 28.65 second in the month of September (Table 27). In *A. leptopus* 1000 – 0200 h was recorded as maximum time spent by bee (20.06, 19.72 and 19.46) this was on par with 0900 – 1000 h and 0100 – 0200 h. In *H. patens*, *M. arboreus* and *C. pulcherrima* longest time spent by stingless bee was observed between 1200 – 0100 h (12.9, 27.32 and 20.36) which was on par with 1100 – 1200 h and 0100 – 0200 h. In *Nymphaea* sp, *P. grandiflora* and *J. pandurifolia* time spent by bee was not significantly different.

Foraging speed of stingless bee in the month of October varies from 5.36 to 30.5 second. (Table 28). Regarding the observation of *A. leptopus* and *Nymphaea* sp. maximum foraging speed was recorded as 0100 – 0200 h (18.61, 18.05 and 30.5, 30.44) this was on par with 1100 – 0100h and 0200 – 0300 h. Regarding the observation of *P. grandiflora* and *C. pulcherrima* longest time spent by bee was during 0900 – 1000 h (23.2 and 20.95) which was

Table 25. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of July 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute									
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Tagetes erecta</i>
0700 – 0800	0.91 <sup>ef</sup>	1.16 <sup>e</sup>	0.91 <sup>d</sup>	0.75 <sup>d</sup>	15.66 <sup>de</sup>	0.50 <sup>d</sup>	0.45 <sup>bcd</sup>	1.22 <sup>cd</sup>	1.25 <sup>cd</sup>	1.58 <sup>c</sup>
0800 – 0900	2.74 <sup>cde</sup>	3.58 <sup>bcd</sup>	2.4 <sup>cd</sup>	2.16 <sup>bcd</sup>	22.16 <sup>bcde</sup>	1.5 <sup>cd</sup>	1.02 <sup>bc</sup>	1.34 <sup>bcd</sup>	2.36 <sup>bcd</sup>	2.85 <sup>abc</sup>
0900 – 1000	3.66 <sup>abc</sup>	4.58 <sup>abcd</sup>	3.33 <sup>bcd</sup>	2.82 <sup>bcd</sup>	41.16 <sup>a</sup>	2.16 <sup>abc</sup>	2.35 <sup>bc</sup>	2.65 <sup>abcd</sup>	2.98 <sup>bcd</sup>	3.65 <sup>abc</sup>
1000 – 1100	4.08 <sup>abc</sup>	5.74 <sup>ab</sup>	3.36 <sup>bcd</sup>	3.58 <sup>ab</sup>	41.86 <sup>a</sup>	2.91 <sup>ab</sup>	4.02 <sup>abc</sup>	3.23 <sup>abc</sup>	3.56 <sup>ab</sup>	4.25 <sup>ab</sup>
1100 – 1200	7.74 <sup>a</sup>	6.5 <sup>a</sup>	3.66 <sup>a</sup>	4.39 <sup>a</sup>	32.5 <sup>bc</sup>	4.01 <sup>a</sup>	5.00 <sup>ab</sup>	5.21 <sup>a</sup>	3.33 <sup>abc</sup>	4.89 <sup>ab</sup>
1200 – 0100	7.32 <sup>a</sup>	6.9 <sup>a</sup>	3.58 <sup>a</sup>	3.31 <sup>ab</sup>	16.33 <sup>de</sup>	2.5 <sup>ab</sup>	5.12 <sup>a</sup>	4.98 <sup>ab</sup>	5.98 <sup>a</sup>	6.87 <sup>a</sup>
0100 – 0200	6.16 <sup>ab</sup>	5.4 <sup>ab</sup>	2.49 <sup>bcd</sup>	3.72 <sup>ab</sup>	14 <sup>de</sup>	2.58 <sup>abc</sup>	5.03 <sup>ab</sup>	4.16 <sup>ab</sup>	3.64 <sup>bc</sup>	5.68 <sup>ab</sup>
0200 – 0300	2.91 <sup>bcd</sup>	4.82 <sup>abcd</sup>	2.2 <sup>bcd</sup>	1.4 <sup>cd</sup>	21.6 <sup>bc</sup>	1.41 <sup>cd</sup>	4.56 <sup>abc</sup>	4.44 <sup>ab</sup>	4.02 <sup>abc</sup>	4.44 <sup>ab</sup>
0300 – 0400	2.16 <sup>cdef</sup>	3.24 <sup>bcd</sup>	2.08 <sup>cd</sup>	2.08 <sup>bcd</sup>	15.16 <sup>de</sup>	0.83 <sup>cd</sup>	2.36 <sup>bc</sup>	4.00 <sup>ab</sup>	3.15 <sup>bc</sup>	3.25 <sup>bc</sup>
0400 – 0500	1.5 <sup>def</sup>	1.9 <sup>e</sup>	1.78 <sup>cd</sup>	1.58 <sup>cd</sup>	31.16 <sup>bcd</sup>	0.66 <sup>cd</sup>	2.01 <sup>bcd</sup>	3.21 <sup>bcd</sup>	2.02 <sup>bc</sup>	2.48 <sup>bc</sup>
0500 – 0600	0.41 <sup>f</sup>	0.57 <sup>ef</sup>	0.58 <sup>d</sup>	1.11 <sup>cd</sup>	16.6 <sup>de</sup>	0.41 <sup>cd</sup>	0.56 <sup>bcd</sup>	2.15 <sup>bcd</sup>	1.65 <sup>cd</sup>	1.22 <sup>c</sup>
CD (0.05)	1.956	2.631	1.214	1.719	16.793	0.995	1.13	1.24	1.35	1.32

Table 26. Foraging rate of *Tetragonula travancorica* at different hours of the day during the month of August 2022

Time period (h)	*Number of <i>Tetragonula travancorica</i> visited per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	0.83 <sup>d</sup>	1.49 <sup>cde</sup>	1.33 <sup>cd</sup>	1.22 <sup>bcd</sup>	0.65 <sup>d</sup>	0.22 <sup>d</sup>	0.48 <sup>d</sup>	0.26 <sup>d</sup>
0800 – 0900	3.33 <sup>bc</sup>	3.41 <sup>cd</sup>	2.5 <sup>bc</sup>	2.54 <sup>abcd</sup>	2.33 <sup>bcd</sup>	1.20 <sup>bc</sup>	0.89 <sup>cd</sup>	3.26 <sup>abc</sup>
0900 – 1000	3.16 <sup>c</sup>	4.11 <sup>bc</sup>	2.58 <sup>bc</sup>	3.25 <sup>abc</sup>	3.45 <sup>abc</sup>	2.46 <sup>bc</sup>	1.02 <sup>cd</sup>	3.54 <sup>abc</sup>
1000 – 1100	3.49 <sup>c</sup>	4.99 <sup>b</sup>	3.5 <sup>abc</sup>	4.23 <sup>ab</sup>	4.56 <sup>abc</sup>	3.21 <sup>ab</sup>	1.98 <sup>bcd</sup>	4.98 <sup>ab</sup>
1100 – 1200	6.75 <sup>a</sup>	6.08 <sup>ab</sup>	3.08 <sup>ab</sup>	5.06 <sup>ab</sup>	4.23 <sup>abc</sup>	5.22 <sup>a</sup>	2.88 <sup>bcd</sup>	4.46 <sup>ab</sup>
1200 – 0100	4.83 <sup>ab</sup>	6.24 <sup>a</sup>	4.66 <sup>a</sup>	6.33 <sup>a</sup>	5.63 <sup>a</sup>	4.02 <sup>ab</sup>	4.12 <sup>a</sup>	5.66 <sup>a</sup>
0100 – 0200	3.66 <sup>bc</sup>	5.00 <sup>b</sup>	3.56 <sup>ab</sup>	4.83 <sup>ab</sup>	4.21 <sup>abc</sup>	3.40 <sup>abc</sup>	3.87 <sup>abc</sup>	5.23 <sup>ab</sup>
0200 – 0300	3.58 <sup>bc</sup>	4.66 <sup>bc</sup>	3.31 <sup>vbc</sup>	3.92 <sup>abc</sup>	3.33 <sup>bcd</sup>	0.23 <sup>bcd</sup>	2.56 <sup>bcd</sup>	4.21 <sup>ab</sup>
0300 – 0400	2.91 <sup>c</sup>	2.33	2.67 <sup>bc</sup>	1.33 <sup>abc</sup>	2.35 <sup>bcd</sup>	1.23 <sup>bcd</sup>	2.89 <sup>bcd</sup>	3.67 <sup>abc</sup>
0400 – 0500	1.25 <sup>d</sup>	1.24 <sup>cde</sup>	1.25 <sup>cd</sup>	0.89 <sup>cd</sup>	2.03 <sup>bcd</sup>	0.82 <sup>d</sup>	1.67 <sup>cd</sup>	3.68 <sup>abc</sup>
0500 – 0600	1.08 <sup>d</sup>	0.54 <sup>e</sup>	0.49 <sup>d</sup>	0.23 <sup>cd</sup>	0.75 <sup>d</sup>	0.17 <sup>d</sup>	1.43 <sup>cd</sup>	1.12 <sup>cd</sup>
CD (0.05)	1.549	1.32	0.779	0.353	0.657	1.527	1.05	1.36

Table 27: Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of September 2021

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute						
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	11.63 <sup>bc</sup>	7.36 <sup>bcd</sup>	28.61	15.07	10.47 <sup>de</sup>	10.23	14.59
0800 – 0900	13.67 <sup>abc</sup>	9.36 <sup>bcd</sup>	33.63	19.85	16.33 <sup>cd</sup>	15.67 <sup>abcd</sup>	15.36
0900 – 1000	19.32 <sup>ab</sup>	11.3 <sup>abc</sup>	33.26	17.25	15.24	9.65 <sup>cde</sup>	18.55
1000 – 1100	20.06 <sup>a</sup>	9.49 <sup>abcd</sup>	31.34	17.13	25.97 <sup>ab</sup>	18.36 <sup>ac</sup>	14.26
1100 – 1200	19.72 <sup>a</sup>	11.4 <sup>ab</sup>	33.16	17.33	25.65 <sup>ab</sup>	12.54 <sup>abcd</sup>	14.89
1200 – 0100	18.12 <sup>ab</sup>	12.9 <sup>a</sup>	30.44	16.67	27.32 <sup>a</sup>	20.36 <sup>a</sup>	15.63
0100 – 0200	19.46 <sup>a</sup>	10.9 <sup>ab</sup>	31.81	14.56	18.36	18.96 <sup>ab</sup>	16.98
0200 – 0300	10.34 <sup>bc</sup>	11.61 <sup>ab</sup>	28.09	16.49	14.23 <sup>d</sup>	10.65 <sup>cd</sup>	12.56
0300 – 0400	18.57 <sup>ab</sup>	9.63 <sup>abcd</sup>	29.83	16.52	20.64 <sup>bcd</sup>	8.65 <sup>cde</sup>	15.65
0400 – 0500	17.65 <sup>ab</sup>	6.64 <sup>cd</sup>	25.4	17.25	15.64 <sup>d</sup>	17.36 <sup>abc</sup>	14.23
0500 – 0600	11.97 <sup>bc</sup>	10.06 <sup>bcd</sup>	25.8	22.5	16.34 <sup>cd</sup>	16.03 <sup>acd</sup>	15.23
CD (0.05)	5.346	1.054	NS	NS	3.512	5.218	NS

Table 28. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of October 2021

Time period(h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	7.71 <sup>d</sup>	8.95	26.98 <sup>ab</sup>	11.45 <sup>cd</sup>	15.36 <sup>cd</sup>	8.05 <sup>e</sup>	11.56 <sup>bcd</sup>	15.23 <sup>bcd</sup>
0800 – 0900	10.04 <sup>bcd</sup>	10.59	27.7 <sup>ab</sup>	19.23 <sup>bc</sup>	18.96 <sup>bcd</sup>	14.35 <sup>cd</sup>	16.65 <sup>abc</sup>	14.98 <sup>bcd</sup>
0900 – 1000	16.19 <sup>ab</sup>	11.3	26.32 <sup>abc</sup>	23.2 <sup>a</sup>	24.53 <sup>a</sup>	10.35	20.95 <sup>a</sup>	15.02 <sup>bcd</sup>
1000 – 1100	14.64 <sup>abc</sup>	9.49	26.4 <sup>bc</sup>	19.5 <sup>bc</sup>	22.68 <sup>ab</sup>	24.25 <sup>ab</sup>	12.34 <sup>bcd</sup>	13.66 <sup>bcd</sup>
1100 – 1200	16.71 <sup>ab</sup>	11.42	26.9 <sup>ab</sup>	21.7 <sup>ab</sup>	26.35 <sup>a</sup>	26.35 <sup>a</sup>	18.6 <sup>ab</sup>	18.96 <sup>a</sup>
1200 – 0100	16.85 <sup>ab</sup>	12.97	28.69 <sup>ab</sup>	18.97 <sup>bcd</sup>	15.63 <sup>cd</sup>	18.52 <sup>bcd</sup>	16.36 <sup>abc</sup>	16.23 <sup>abc</sup>
0100 – 0200	18.61 <sup>a</sup>	10.9	30.5 <sup>a</sup>	14.32 <sup>cd</sup>	18.38 <sup>gcd</sup>	20.14 <sup>bc</sup>	11.36 <sup>bcd</sup>	17.36 <sup>ab</sup>
0200 – 0300	18.05 <sup>a</sup>	11.6	30.44 <sup>a</sup>	14.44 <sup>cd</sup>	24.68 <sup>ab</sup>	15.36 <sup>cd</sup>	10.65 <sup>bcd</sup>	12.36 <sup>bcd</sup>
0300 – 0400	16.1 <sup>ab</sup>	9.63	28.22 <sup>abc</sup>	14.92 <sup>cd</sup>	22.36 <sup>bc</sup>	16.23 <sup>bcd</sup>	9.36 <sup>cd</sup>	15.44 <sup>bcd</sup>
0400 – 0500	9.05 <sup>bc</sup>	6.64	29.87 <sup>ab</sup>	20.8 <sup>ab</sup>	20.68 <sup>abc</sup>	16.64 <sup>cd</sup>	7.21 <sup>abc</sup>	17.36 <sup>abcd</sup>
0500 – 0600	6.62 <sup>de</sup>	8.06	13.25 <sup>abc</sup>	15.38 <sup>cd</sup>	18.98 <sup>bcd</sup>	10.23 <sup>cde</sup>	5.36 <sup>bcd</sup>	10.3 <sup>cd</sup>
CD (0.05)	5.642	NS	8.016	4.381	4.368	3.235	6.354	2.687

on par with 1100 – 1200 h. In *Rosa* spp, *M. arboreus* and *J. pandurifolia* maximum time spent was observed during 1100 – 1200 h (26.35, 26.35 and 18.96). In *H. patens*, foraging speed by bee was not significantly different.

During November, time spent by stingless bee varied between 5.31 to 28.26 seconds in a flower (Table 29). Maximum foraging speed was observed at 1000 – 1100 h in *A. leptopus* (22.2) and *R. bourboniana* it was 1200 – 0100 h (28.56). In *J. pandurifolia* and *P. aculeata* the maximum time spent by bee was observed between 1200 – 0100 h (25.13 and 20.50). In *H. patens*, *Nymphaea* sp, *P. grandiflora*, *Rosa* spp and *Ixora* sp foraging speed by bee was not significantly different.

Regarding the observation of December, time spent by stingless bee in a flower varied between 1.58 – 28.56 second (Table 30). In *A. leptopus*, *H. patens* and *Nymphaea* sp, maximum time spent was observed between 1000 – 1100 h (8.83, 13.44 and 28.14) this was on par with 0900 – 1000 h and 1100 – 1200 h. In *P. grandiflora*, *R. bourboniana* and *M. arboreus* longest time spent by stingless bee was between 1100 – 1200 h (21.24, 25.69 and 28.56) which was on par with 1000 – 1100 h and 1200 – 0100 h. There was no significant difference in time spent by bee on *Rosa* spp, *Ixora* sp, *C. pulcherrima*, *P. aculeate*, *J. pandurifolia* and *Dombeya* sp.

Foraging speed of stingless bee in the month of January varied between 3.98 to 32.35 second (Table 31). Regarding the observation of *A. leptopus*, *H. patens*, *M. arboreus*, *S. romanzoffiana*, *E. mili* and *Z. rosea* longest time spent was recorded during 1200 – 0100 h (20.15, 13.78, 25.68, 18.56, 22.11 and 20.33), this was on par with 1000 – 1100 h, 1100 – 1200 h and 0100 – 0200 h. In *Nymphaea* sp peak foraging speed was during 1000 – 1100 h (32.35) which was on par with 0900 – 1000 h. There was no significant difference in the foraging speed of *P. grandiflora*, *R. bourboniana*, *Rosa* spp, *Ixora* sp, *C. pulcherrima*, *J. pandurifolia*, *C. constrictum* and *Dombeya* sp.

According to observation in February, time spent by stingless bee in a flower varied from 1.58 to 23.72 second (Table 32). In *A. leptopus*, *C. pulcherrima* and *T. erecta* highest foraging speed was during 1100 – 1200 h (18.92, 23.72 and 20.78) this was on par with 1200 – 0100 h. Regarding the observation of *H. patens*, *Nymphaea* sp, *M. arboreus* and *Dombeya* sp maximum foraging speed was observed during 0100 – 0200 (10.73, 26.33, 17.53 and 18.65)

Table 29. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of November 2021

Time period	*Time spent by <i>Tetragonula travancorica</i> per unit time									
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaeae</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> sp.	<i>Ixora</i> sp.	<i>Cesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>
0700 – 0800	15.49 <sup>abc</sup>	6.96	23.42	12.03	16.93 <sup>cd</sup>	15.36	15.96	12.77 <sup>cd</sup>	18.83 <sup>abcd</sup>	13.15 <sup>cd</sup>
0800 – 0900	15.44 <sup>abc</sup>	12.15	25.84	14.77	17.56 <sup>bcd</sup>	17.23	10.28	19.64 <sup>a</sup>	15.30	15.40 <sup>bcd</sup>
0900 – 1000	18.39 <sup>ab</sup>	12.14	27.84	20.02	15.68 <sup>cd</sup>	20.36	12.91	8.92 <sup>d</sup>	21.52 <sup>abc</sup>	13.73 <sup>cd</sup>
1000 – 1100	22.2 <sup>a</sup>	9.16	27.05	16.98	25.68 <sup>ab</sup>	21.36	15.34	17.72 <sup>abc</sup>	21.26 <sup>abc</sup>	14.23 <sup>bc</sup>
1100 – 1200	19.33 <sup>ab</sup>	10.6	27.79	17.12	13.68 <sup>cd</sup>	14.53	10.85	18.52 <sup>ab</sup>	20.65 <sup>abcd</sup>	17.33 <sup>ab</sup>
1200 – 0100	17.03 <sup>ab</sup>	10.64	26.87	18.33	28.56 <sup>a</sup>	18.36	10.79	8.91 <sup>d</sup>	25.13 <sup>a</sup>	20.50 <sup>a</sup>
0100 – 0200	16.85 <sup>abc</sup>	10.05	30.59	20.13	12.68 <sup>cde</sup>	15.23	12.50	19.87 <sup>a</sup>	12.35 <sup>cd</sup>	11.57 <sup>cd</sup>
0200 – 0300	18.05 <sup>ab</sup>	9.47	30.32	13.6	10.36 <sup>de</sup>	10.89	12.36	15.68 <sup>bc</sup>	15.68 <sup>bcd</sup>	14.00 <sup>bc</sup>
0300 – 0400	19.87 <sup>ab</sup>	11.12	31.2	20.25	18.56 <sup>bc</sup>	16.34	10.91	10.3 <sup>cd</sup>	16.75 <sup>bcd</sup>	15.36 <sup>bc</sup>
0400 – 0500	8.72 <sup>cd</sup>	4.54	22.23	20.45	25.89 <sup>ab</sup>	13.32	10.84	14.63 <sup>bc</sup>	14.35 <sup>cd</sup>	16.35 <sup>abc</sup>
0500 – 0600	5.31 <sup>d</sup>	8.6	18.35	18.85	19.89 <sup>bcd</sup>	17.81	12.40	14.23 <sup>bc</sup>	18.36 <sup>abcd</sup>	17.48 <sup>ab</sup>
CD (0.05)	10.153	NS	NS	NS	7.895	NS	NS	5.681	6.987	4.891

Table 30. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of December 2021

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per unit time											
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea sp.</i>	<i>Portulaca grandiflora</i>	<i>Rosa bourboniana</i>	<i>Malvaviscus arboreus</i>	<i>Rosa spp.</i>	<i>Ixora sp.</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>	<i>Dombeya sp.</i>
0700 – 0800	3.91 <sup>d</sup>	6.63 <sup>d</sup>	25.36 <sup>ab</sup>	16.23 <sup>cd</sup>	15.64 <sup>bcd</sup>	16.93 <sup>cd</sup>	17.56	8.96	14.56	12.36	17.10	14.15
0800 – 0900	6.91 <sup>b</sup>	13 <sup>bcd</sup>	21.33 <sup>abc</sup>	13.05 <sup>bc</sup>	11.23 <sup>cd</sup>	17.56 <sup>bcd</sup>	21.36	10.28	13.71	14.98	17.21	13.14
0900 – 1000	7.66 <sup>ab</sup>	12.25 <sup>ab</sup>	15.66 <sup>cd</sup>	18.39 <sup>bcd</sup>	15.67 <sup>bcd</sup>	15.68 <sup>bcd</sup>	12.36	12.91	15.88	12.36	14.96	15.39
1000 – 1100	8.83 <sup>a</sup>	13.44 <sup>a</sup>	28.14 <sup>a</sup>	18.34 <sup>ab</sup>	13.25 <sup>cd</sup>	25.68 <sup>ab</sup>	10.54	15.34	15.85	18.65	13.80	13.73
1100 – 1200	7.25 <sup>ab</sup>	11.36 <sup>abc</sup>	25.36 <sup>ab</sup>	21.24 <sup>a</sup>	25.69 <sup>a</sup>	28.56 <sup>a</sup>	10.36	10.85	13.60	17.23	19.78	12.3
1200 – 0100	6.16 <sup>b</sup>	12.13 <sup>ab</sup>	18.99 <sup>bcd</sup>	15.85 <sup>cd</sup>	23.65 <sup>ab</sup>	12.68 <sup>de</sup>	17.23	10.79	12.62	14.63	15.78	17.32
0100 – 0200	7.95 <sup>ab</sup>	11.87 <sup>abc</sup>	16.33	14.9 <sup>cd</sup>	14.58 <sup>bcd</sup>	13.68 <sup>cd</sup>	11.56	10.50	10.31	15.68	14.28	14.23
0200 – 0300	8.25 <sup>a</sup>	12.01 <sup>ab</sup>	14.89 <sup>cd</sup>	19.32 <sup>bcd</sup>	10.36 <sup>cd</sup>	10.36 <sup>e</sup>	10.85	12.36	14.52	10.38	16.14	11.57
0300 – 0400	7.92 <sup>ab</sup>	11.68 <sup>ab</sup>	24.65 <sup>abc</sup>	14.49 <sup>cd</sup>	18.97 <sup>bcd</sup>	18.56 <sup>bc</sup>	19.36	10.91	14.36	14.87	15.14	14.01
0400 – 0500	4.58 <sup>cd</sup>	7.08 <sup>cd</sup>	19.12 <sup>bc</sup>	5.73 <sup>e</sup>	12.35 <sup>cd</sup>	25.89 <sup>ab</sup>	11.35	9.84	16.98	14.23	14.25	12.36
0500 – 0600	2.58 <sup>e</sup>	9.49 <sup>cd</sup>	18.36 <sup>cd</sup>	16.23 <sup>cd</sup>	13.68 <sup>cd</sup>	19.89 <sup>bc</sup>	19.36	12.40	15.81	18.36	12.8	15.75
CD (0.05)	2.246	3.288	7.865	5.387	7.521	7.895	NS	NS	NS	NS	NS	NS

Table 31. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of January 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arbor</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum rictum</i>	<i>Dombeya</i> sp.	<i>Euphorbia milii</i>	<i>Zephyranthes rosea</i>
0700 – 0800	13.29 <sup>c</sup>	11.46 <sup>abc</sup>	20.36 <sup>bcd</sup>	15.23	18.23 <sup>bcd</sup>	10.76 <sup>cd</sup>	13.96	14.14	11.36	18.96	11.15	11.33	14.15	18.70 <sup>ab</sup>	15.26 <sup>bcd</sup>
0800 – 0900	15.5 <sup>bc</sup>	12.44 <sup>ab</sup>	27.56 <sup>ab</sup>	15.23	15.68 <sup>bcd</sup>	15.27 <sup>bc</sup>	18.45	15.90	10.39	14.35	22.37	11.43	13.15	16.14 <sup>bc</sup>	10.28 <sup>cd</sup>
0900 – 1000	16.78 <sup>abc</sup>	11.6 <sup>abc</sup>	15.38 <sup>cd</sup>	14.25	11.23 <sup>cd</sup>	12.72 <sup>bcd</sup>	14.63	18.80	10.05	15.26	10.10	17.59	15.40	14.95	9.63 <sup>e</sup>
1000 – 1100	15.32 <sup>bc</sup>	12.36 <sup>ab</sup>	32.35 <sup>a</sup>	16.35	18.56 <sup>bc</sup>	14.43 <sup>ab</sup>	15.87	15.01	10.80	18.64	18.26	16.95	13.73	17.44 <sup>ab</sup>	19.35 <sup>ab</sup>
1100 – 1200	17.8 <sup>ab</sup>	12.88 <sup>ab</sup>	25.68 <sup>b</sup>	12.65	10.23 <sup>d</sup>	8.96 <sup>d</sup>	14.21	10.83	9.94	17.26	21.72	15.96	18.50	13.03 <sup>cd</sup>	17.56 <sup>ab</sup>
1200 – 0100	20.15 <sup>a</sup>	13.78 <sup>a</sup>	24.32 <sup>bc</sup>	12.88	25.68 <sup>a</sup>	18.56 <sup>a</sup>	16.98	18.17	11.77	18.96	21.87	15.10	17.33	22.11 <sup>a</sup>	20.33 <sup>a</sup>
0100 – 0200	18.7 <sup>ab</sup>	10.33 <sup>bc</sup>	24.68 <sup>bc</sup>	15.65	20.36 <sup>Ab</sup>	13.86 <sup>abc</sup>	12.57	18.89	10.58	15.23	17.26	13.76	14.23	17.13 <sup>ab</sup>	15.67 <sup>bc</sup>
0200 – 0300	18.53 <sup>ab</sup>	12.58 <sup>ab</sup>	30.25 <sup>a</sup>	13.65	19.68 <sup>abc</sup>	9.23	17.42	19.79	14.42	15.63	17.67	13.97	11.57	15.18 <sup>bc</sup>	14.28 <sup>bc</sup>
0300 – 0400	16.02 <sup>abc</sup>	12.03 <sup>ab</sup>	24.36 <sup>bc</sup>	14.52	12.34 <sup>bc</sup>	14.72 <sup>ab</sup>	21.49	19.73	10.79	14.33	14.78	15.69	14.00	14.26 <sup>bcd</sup>	10.78 <sup>cd</sup>
0400 – 0500	13.4 <sup>cd</sup>	10.2 <sup>bc</sup>	20.33 <sup>cd</sup>	14.49	10.56 <sup>cd</sup>	9.65 <sup>cd</sup>	22.13	19.18	8.04	15.36	15.36	12.56	11.25	12.33 <sup>cd</sup>	20.33 <sup>a</sup>
0500 – 0600	9.57 <sup>d</sup>	3.98 <sup>d</sup>	21.68 <sup>cd</sup>	15.68	14.78 <sup>cd</sup>	10.31 <sup>cd</sup>	11.30	14.29	14.65	14.25	18.23	15.44	10.56	11.98 <sup>d</sup>	18.99 <sup>ab</sup>
CD (0.05)	5.466	4.843	7.356	NS	4.568	3.27	NS	NS	NS	NS	NS	3.657	NS	4.023	5.69

Table 32. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of February 2022.

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea a</i> sp.	<i>Portulaca grandiflora</i>	<i>Malva viscus s arboreus</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Dombeya</i> sp.	<i>Euphorbia mili</i>
0700 – 0800	11.72 <sup>b</sup>	10.02 <sup>b</sup>	17.36 <sup>b</sup>	15.33	14.63 <sup>bc</sup>	11.97	13.25	18.96 <sup>bc</sup>	15.78	17.10	15.36 <sup>bc</sup>	12.8 <sup>cd</sup>	15.36
0800 – 0900	11.53 <sup>b</sup>	9.71 <sup>c</sup>	20.77 <sup>ab</sup>	13.50	16.33 <sup>ab</sup>	10.89	8.42	22.37 <sup>ab</sup>	14.28	17.21	15.66 <sup>bc</sup>	18.6 <sup>a</sup>	14.78
0900 – 1000	15.05 <sup>ab</sup>	11.01 <sup>ab</sup>	12.69 <sup>cd</sup>	15.36	10.25 <sup>d</sup>	14.05	13.29	10.10 <sup>de</sup>	16.14	14.96	14.53 <sup>bc</sup>	18 <sup>a</sup>	16.35
1000 – 1100	16.96 <sup>ab</sup>	13.12 <sup>a</sup>	17.85 <sup>b</sup>	19.23	12.33 <sup>cd</sup>	12.18	10.67	8.62 <sup>e</sup>	15.14	13.80	12.36 <sup>cd</sup>	18.6 <sup>a</sup>	15.44
1100 – 1200	18.92 <sup>a</sup>	10.12 <sup>b</sup>	17.85 <sup>b</sup>	16.16	17.56 <sup>a</sup>	11.14	10.82	23.72 <sup>a</sup>	14.25	19.78	20.78 <sup>a</sup>	13.5 <sup>cd</sup>	12.03
1200 – 0100	16.35 <sup>ab</sup>	11.13 <sup>ab</sup>	25.36 <sup>ab</sup>	15.31	15.36 <sup>ab</sup>	22.18	9.03	21.87 <sup>abc</sup>	12.8	15.68	15.66 <sup>bc</sup>	10.53 <sup>de</sup>	15.66
0100 – 0200	16.85 <sup>ab</sup>	10.73 <sup>a</sup>	26.33 <sup>a</sup>	12.14	17.53 <sup>a</sup>	13.57	10.25	17.26 <sup>bc</sup>	14.33	10.38	17.35 <sup>bc</sup>	18.65 <sup>a</sup>	20.33
0200 – 0300	16.16 <sup>abc</sup>	10.58 <sup>b</sup>	22.14 <sup>ab</sup>	15.63	15.36 <sup>ab</sup>	24.36	9.80	17.67 <sup>bc</sup>	10.25	19.87	15.68 <sup>bc</sup>	16.4 <sup>ab</sup>	21.33
0300 – 0400	17.04 <sup>ab</sup>	11.98 <sup>ab</sup>	26.75 <sup>a</sup>	14.23	15.33 <sup>ab</sup>	13.43	14.36	11.11 <sup>de</sup>	18.96	14.23	19.4 <sup>ab</sup>	14.4 <sup>bcd</sup>	14.23
0400 – 0500	4.56 <sup>c</sup>	5.78 <sup>d</sup>	20.36 <sup>bc</sup>	15.23	15.67 <sup>ab</sup>	23.68	15.33	14.25 <sup>cde</sup>	17.25	18.36	14.78 <sup>cd</sup>	14.35 <sup>bcd</sup>	14.23
0500 – 0600	2.51 <sup>c</sup>	1.58 <sup>de</sup>	15.69 <sup>cd</sup>	15.36	14.78 <sup>bc</sup>	14.55	10.25	15.36 <sup>cd</sup>	16.33	12.8	10.36 <sup>d</sup>	16.35 <sup>bc</sup>	18.56
CD (0.05)	6.324	3.83	6.325	NS	3.564	NS	NS	4.69	NS	NS	2.658	2.158	NS

this was on par with 1200 – 0100 h. There was no significant different in time spent of *P. grandiflora*, *Rosa* spp, *Ixora* sp, *J. pandurifolia*, *C. constrictum*, *Dombeya* sp and *E. mili*.

Time spent by stingless bee varied between 5.01 to 29.36 second in the month of March (Table 33). Maximum speed was observed during 1200 – 0200 h in *A. leptopus* and *H patens* (17.2, 17.94 and 14.9, 14.6) this was on par with 1000 – 1200 h. In *Nymphaea* sp, *M. arboreus*, *R. bourboniana*, *Ixora* sp and *C. constrictum* peak foraging speed was recorded during 1200 – 0100 h (29.36, 18.23, 18.36, 20.38 and 18.26) which was on par with 1000 – 1200 h and 0200 – 0300 h. In *P. grandiflora*, *Rosa* spp, *C. pulcherrima*, *J. pandurifolia*, *P. aculeata*, *T. erecta*, *E. mili* and *Z. rosea* time spent by bee was not significantly different.

According to observation, time spent by stingless bee in a flower varied 5.68 - 28.65 second in the month of April. (Table 34). In *A. leptopus*, *Nymphaea* sp and *C. constrictum* maximum time spent by bee was recorded as 1100 – 1200 h (18.07, 20.32 and 18.65) this was on par with 0900 – 1100 h. In *H. patens*, and *Ixora* sp longest time spent by stingless bee was observed between 1200 – 0100 h (15.14 and 18.26). In *P grandiflora*, *R. bourboniana*, *C. pulcherrima*, *E. mili*, *Z. rosea* and *J. pandurifolia* time spent by bee was not significantly different.

Foraging speed of stingless bee in the month of May varied between 2.54 to 29.35 second (Table 35). Regarding the observation of *A. leptopus* peak foraging speed was observed during 0900 – 1100 h (17.86 and 16.9) and 1200 – 0100 h (16.8) this was on par with 1100 – 1200 h and 0100 – 0300 h. In *Nymphaea* sp and *M. arboreus*, longest time spent was recorded during 1200 – 0100 h (29.35 and 19.10) this was on par with 0100 – 0200 h. There was no significant difference in foraging speed of *H patens*, *P. grandiflora*, *C. pulcherrima* and *J. pandurifolia*,

In June, foraging speed varies between 3.76 to 27.36 seconds (Table 36). Highest foraging speed by stingless bee was recorded during 1100 – 1200 h in *A. leptopus*, *H. patens* and *Nymphaea* sp this was on par with 1000 – 1100 h and 0100 – 0300 h. In *Rosa* spp, *C. pulcherrima* and *M. arboreus* maximum foraging speed was during 1000 – 1100 h (24.53, 23.31 and 27.36). Foraging speed was not significantly different among *P. grandiflora*, *J. pandurifolia*, *T. erecta* and *E. mili*.

During July, time spent by of stingless bee varied between 3.59 to 26.35 second in a flower (Table 37). Maximum foraging speed was observed at 1000 – 1100 h in *A. leptopus*

Table 33. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of March 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute														
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arborus</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Ixora</i> sp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Pereskia aculeata</i>	<i>Combretum constrictum</i>	<i>Tagetes erecta</i>	<i>Euphorbia mili</i>	<i>Zephyranthes rosea</i>
0700 –0800	11.22 <sup>b</sup>	10.77 <sup>bc</sup>	12.36 <sup>e</sup>	12.33	15.23 <sup>bc</sup>	12.35 <sup>c</sup>	11.97	7.88 <sup>d</sup>	11.10	14.23	15.23	15.63 <sup>ab</sup>	17.66	15.23	12.77
0800 -0900	16.35 <sup>ab</sup>	10.46 <sup>bc</sup>	15.86 <sup>de</sup>	10.23	14.23 <sup>cd</sup>	16.35 <sup>abc</sup>	10.89	10.88 <sup>cd</sup>	18.92	13.25	14.23	14.25 <sup>bc</sup>	15.76	14.25	19.64
0900 – 1000	13.75 <sup>ab</sup>	11.3 <sup>bc</sup>	18.65 <sup>cd</sup>	14.53	16.33 <sup>bc</sup>	15.88 <sup>bc</sup>	14.05	11.5 <sup>cd</sup>	15.29	14.35	15.03	16.56 <sup>abc</sup>	18.4	16.35	8.92
1000 – 1100	15.69 <sup>ab</sup>	12.27 <sup>abc</sup>	16.48 <sup>cd</sup>	16.33	17.22 <sup>ab</sup>	18.69 <sup>a</sup>	12.18	16.92 <sup>bc</sup>	9.04	16.38	13.80	14.3 <sup>bc</sup>	19.4	18.35	17.72
1100 – 1200	13.85 <sup>ab</sup>	10.57 <sup>bc</sup>	18.56 <sup>cd</sup>	16.12	10.25 <sup>d</sup>	18.36 <sup>a</sup>	11.14	19.45 <sup>ab</sup>	13.15	18.65	14.36	12.36 <sup>bcd</sup>	14.78	14.23	18.52
1200 – 0100	17.2 <sup>a</sup>	14.9 <sup>a</sup>	29.36 <sup>a</sup>	10.23	15.66 <sup>bc</sup>	15.36 <sup>bcd</sup>	22.18	20.38 <sup>a</sup>	13.69	15.36	15.78	18.26 <sup>a</sup>	20.36	15.23	8.91
0100 – 0200	17.94 <sup>a</sup>	14.6 <sup>a</sup>	29.35 <sup>a</sup>	11.23	18.23 <sup>a</sup>	14.25 <sup>cd</sup>	13.57	18.72 <sup>bc</sup>	9.81	15.33	15.11	14.25 <sup>bcd</sup>	15.23	14.69	13.37
0200 – 0300	15.74 <sup>ab</sup>	13.26 <sup>ab</sup>	26.35 <sup>bc</sup>	12.45	14.33 <sup>cd</sup>	15.6 <sup>bcd</sup>	24.36	12.31 <sup>cd</sup>	12.23	12.33	16.14	15.32 <sup>ab</sup>	15.36	17.35	18.53
0300 – 0400	14.4 <sup>ab</sup>	13.92 <sup>ab</sup>	27.36 <sup>bc</sup>	16.33	10.23 <sup>d</sup>	15.33 <sup>bcd</sup>	13.43	10.63 <sup>cd</sup>	9.65	15.36	15.14	14.36 <sup>bc</sup>	16.35	16.35	15.23
0400 – 0500	11.33 <sup>b</sup>	9.7 <sup>c</sup>	24.56 <sup>bcd</sup>	12.33	15.66 <sup>bc</sup>	17.56 <sup>abc</sup>	23.68	8.04 <sup>d</sup>	12.14	17.85	14.25	13.25 <sup>bc</sup>	17.85	15.36	14.25
0500 –0600	5.75 <sup>c</sup>	5.01 <sup>d</sup>	26.31 <sup>bc</sup>	10.54	14.44 <sup>cd</sup>	19.35 <sup>bc</sup>	14.55	12.09 <sup>cd</sup>	15.26	18.56	13.25	17.35 <sup>ab</sup>	14.35	18.65	15.68
CD (0.05)	4.822	2.88	7.865	NS	3.568	6.354	NS	5.65	NS	NS	NS	4.325	NS	NS	NS

Table 34. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of April 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute												
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Ixora</i> sp.	<i>Caesalpinia iapulcheria</i>	<i>Jatropha pandurifolia</i>	<i>Combretum constricatum</i>	<i>Euphorbia hili</i>	<i>Zephyranthes rosea</i>
0700 – 0800	11.72 <sup>cd</sup>	9.17 <sup>c</sup>	18.13 <sup>ab</sup>	15.07	14.23 <sup>ab</sup>	9.63 <sup>c</sup>	12.36	15.23 <sup>bc</sup>	15.02	9.63	10.36 <sup>cd</sup>	15.23	15.33
0800 – 0900	16.94 <sup>abc</sup>	12.48 <sup>bc</sup>	20.01 <sup>a</sup>	19.85	15.36 <sup>a</sup>	12.30 <sup>ab</sup>	15.36	14.23 <sup>bc</sup>	12.33	15.63	13.25 <sup>bcd</sup>	14.23	12.36
0900 – 1000	17.86 <sup>ab</sup>	15.23 <sup>a</sup>	14.65 <sup>bc</sup>	17.26	14.36 <sup>ab</sup>	12.22 <sup>ab</sup>	14.23	14.23 <sup>bc</sup>	15.32	15.36	15.56 <sup>bc</sup>	17.56	14.25
1000 – 1100	21.5 <sup>a</sup>	11.24 <sup>cd</sup>	18.32 <sup>ab</sup>	17.14	17.66 <sup>a</sup>	15.22 <sup>a</sup>	14.58	12.33 <sup>cd</sup>	9.36	14.33	15.68 <sup>bc</sup>	12.35	16.35
1100 – 1200	18.07 <sup>ab</sup>	12.44 <sup>bc</sup>	20.32 <sup>a</sup>	17.33	16.35 <sup>ab</sup>	14.63 <sup>a</sup>	16.33	18.26 <sup>a</sup>	12.36	15.33	18.65 <sup>a</sup>	14.22	12.36
1200 – 0100	15.74 <sup>bcd</sup>	15.14 <sup>a</sup>	15.32 <sup>bc</sup>	16.68	14.33	12.33 <sup>ab</sup>	17.56	15.23 <sup>bc</sup>	14.23	18.23	13.23 <sup>bcd</sup>	10.36	20.13
0100 – 0200	15.94 <sup>bcd</sup>	12.65 <sup>bc</sup>	15.33 <sup>bc</sup>	24.44	14.65	10.23 <sup>bc</sup>	15.36	16.30 <sup>bc</sup>	15.32	16.50	17.56 <sup>ab</sup>	16.35	19.37
0200 – 0300	17.2 <sup>abc</sup>	13.5 <sup>bc</sup>	18.56 <sup>ab</sup>	16.49	16.33 <sup>ab</sup>	9.23 <sup>c</sup>	16.32	15.62 <sup>bc</sup>	14.52	14.30	14.52 <sup>bc</sup>	18.36	15.00
0300 – 0400	14.4 <sup>bcd</sup>	12.92 <sup>bc</sup>	14.23 <sup>bc</sup>	16.52	15.36 <sup>ab</sup>	12.33 <sup>ab</sup>	15.23	14.23	10.26	15.63	14.36 <sup>bc</sup>	14.36	15.86
0400 – 0500	11.33 <sup>d</sup>	13.37 <sup>bc</sup>	15.68 <sup>ab</sup>	17.25	14.33 <sup>ab</sup>	11.23 <sup>bc</sup>	12.13	14.53 <sup>bcd</sup>	15.36	15.36	17.23 <sup>bcd</sup>	18.35	14.25
0500 – 0600	5.68 <sup>e</sup>	10.17 <sup>cd</sup>	14.32 <sup>bc</sup>	22.51	15.33 <sup>ab</sup>	10.31 <sup>bc</sup>	16.33	16.30 <sup>bc</sup>	14.65	10.33	9.33 <sup>d</sup>	16.35	13.26
CD (0.05)	5.51	3.535	6.325	NS	2.563	2.87	NS	3.43	NS	NS	3.232	NS	NS

Table 35. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of May 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute						
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Malvaviscus arboreus</i>	<i>Rosa bourboniana</i>	<i>Caesalpinia pulcherrima</i>
0700 – 0800	8.05 <sup>c</sup>	10.35	25.36 <sup>bc</sup>	13.78	8.15 <sup>d</sup>	15.86	12.23
0800 – 0900	13.68 <sup>ab</sup>	11.7	24.36 <sup>bcd</sup>	14.09	11.43 <sup>cd</sup>	21.33	15.67
0900 – 1000	17.86 <sup>a</sup>	11.78	24.12 <sup>bcd</sup>	14.09	17.59 <sup>bc</sup>	26.35	11.65
1000 – 1100	16.9 <sup>a</sup>	7.6	28.15 <sup>ab</sup>	15.19	16.95 <sup>bc</sup>	21.36	15.36
1100 – 1200	16.1 <sup>ab</sup>	14.3	10.53 <sup>d</sup>	14.11	15.96 <sup>bcd</sup>	26.35	15.54
1200 – 0100	16.8 <sup>a</sup>	13.44	29.35 <sup>a</sup>	15.91	19.10 <sup>a</sup>	23.56	14.36
0100 – 0200	15.9 <sup>ab</sup>	12.55	28.98 <sup>a</sup>	14.13	13.76 <sup>cd</sup>	24.55	14.96
0200 – 0300	15.2 <sup>ab</sup>	9.67	15.63 <sup>cd</sup>	14.18	13.97 <sup>cd</sup>	25.30	15.65
0300 – 0400	14.45 <sup>abc</sup>	11.52	24.35 <sup>bcd</sup>	15.18	15.69 <sup>bcd</sup>	10.01	14.65
0400 – 0500	11.33 <sup>bc</sup>	6.82	19.36 <sup>cd</sup>	15.74	15.23 <sup>bcd</sup>	11.40	13.36
0500 – 0600	2.54 <sup>d</sup>	9.92	25.3 <sup>bc</sup>	15.23	10.33 <sup>cd</sup>	8.83	15.03
CD (0.05)	4.513	NS	3.654	NS	3.25	NS	NS

Table 36. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of June 2022.

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute									
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Malvaviscus arboreus</i>	<i>Tagetes erecta</i>	<i>Euphorbi a mili</i>
0700 – 0800	15.1 <sup>abc</sup>	11.8 <sup>bc</sup>	15.13 <sup>bcd</sup>	14.20	10.58 <sup>cd</sup>	14.75 <sup>cd</sup>	14.23	9.35 <sup>cd</sup>	10.05	9.65
0800 – 0900	15.98 <sup>abc</sup>	12.08 <sup>abc</sup>	10.33 <sup>d</sup>	13.50	11.58 <sup>bcd</sup>	13.36 <sup>cd</sup>	16.33	12.56 <sup>c</sup>	11.22	10.33
0900 – 1000	14.8 <sup>bc</sup>	11.3 <sup>bc</sup>	14.65 <sup>a</sup>	14.34	12.47 <sup>bc</sup>	15.57 <sup>bcd</sup>	15.28	25.36 <sup>ab</sup>	13.57	10.32
1000 – 1100	12.6 <sup>bc</sup>	14 <sup>a</sup>	18.32 <sup>ab</sup>	17.00	24.53 <sup>a</sup>	23.31 <sup>a</sup>	14.02	27.36 <sup>ab</sup>	13.01	13.23
1100 – 1200	14.28 <sup>bc</sup>	11.06 <sup>bc</sup>	20.32 <sup>a</sup>	13.51	18.36 <sup>bc</sup>	20.13 <sup>ab</sup>	16.35	25.86 <sup>ab</sup>	10.00	13.26
1200 – 0100	20.53 <sup>a</sup>	12.2 <sup>abc</sup>	15.32 <sup>bcd</sup>	14.87	19.32 <sup>bcd</sup>	18.01 <sup>bc</sup>	14.23	29.12 <sup>a</sup>	10.49	11.23
0100 – 0200	20.24 <sup>a</sup>	10.6 <sup>bc</sup>	15.33	12.34	23.65 <sup>ab</sup>	14.80 <sup>cd</sup>	18.56	24.20 <sup>ab</sup>	11.65	13.65
0200 – 0300	18.78 <sup>ab</sup>	10.5 <sup>bc</sup>	18.56 <sup>ab</sup>	14.67	18.52 <sup>bc</sup>	17.86 <sup>bc</sup>	13.65	15.63 <sup>cd</sup>	10.55	12.23
0300 – 0400	16.88 <sup>abc</sup>	13.6 <sup>ab</sup>	14.23 <sup>bcd</sup>	16.54	11.26 <sup>cd</sup>	18.58 <sup>bc</sup>	14.23	19.36 <sup>bc</sup>	10.63	11.23
0400 – 0500	13.54 <sup>bc</sup>	9.1 <sup>cd</sup>	15.68 <sup>bcd</sup>	13.36	20.32 <sup>abc</sup>	9.59 <sup>d</sup>	15.63	18.21 <sup>bc</sup>	14.23	12.33
0500 – 0600	3.76 <sup>e</sup>	7.06 <sup>cd</sup>	14.32 <sup>bcd</sup>	15.23	10.3 <sup>cd</sup>	14.25 <sup>cd</sup>	15.23	17.42 <sup>bc</sup>	11.56	10.25
CD (0.05)	4.253	3.654	5.238	NS	3.56	5.32	NS	4.257	NS	NS

Table 37. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of July 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute									
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Syagrus romanzoffiana</i>	<i>Rosa bourboniana</i>	<i>Rosa</i> spp.	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>	<i>Tagetes erecta</i>
0700 – 0800	8.56 <sup>cd</sup>	11.77 <sup>bc</sup>	10.13 <sup>cd</sup>	11.45	15.36	10.23 <sup>d</sup>	9.94	18.89	14.35	11.15 <sup>bc</sup>
0800 – 0900	17.36 <sup>ab</sup>	10.7 <sup>bc</sup>	10.33 <sup>cd</sup>	13.56	18.96	12.37 <sup>cd</sup>	13.77	11.88	15.26	11.43 <sup>bc</sup>
0900 – 1000	20 <sup>ab</sup>	12.4 <sup>ab</sup>	14.65 <sup>bcd</sup>	12.23	24.53 <sup>abc</sup>	15.64 <sup>bc</sup>	12.40	12.96	18.64	17.59 <sup>a</sup>
1000 – 1100	22.3 <sup>a</sup>	12.7 <sup>ab</sup>	18.32 <sup>abc</sup>	15.51	22.68 <sup>bc</sup>	16.32 <sup>bc</sup>	10.65	10.34	17.26	16.95 <sup>ab</sup>
1100 – 1200	16.85 <sup>abc</sup>	13.7 <sup>a</sup>	20.32 <sup>a</sup>	12.35	26.35 <sup>a</sup>	19.33 <sup>ab</sup>	9.74	12.64	18.96	15.96 <sup>abc</sup>
1200 – 0100	18.96 <sup>ab</sup>	10.7 <sup>bc</sup>	15.32 <sup>cd</sup>	15.97	15.63	20.35 <sup>a</sup>	10.45	14.60	15.23	15.10 <sup>abc</sup>
0100 – 0200	20.33 <sup>ab</sup>	11.7 <sup>bc</sup>	15.33 <sup>a</sup>	14.32	18.38	12.34 <sup>c</sup>	9.81	14.14	15.63	13.76 <sup>bc</sup>
0200 – 0300	18.53 <sup>ab</sup>	11.92 <sup>bc</sup>	18.56 <sup>abc</sup>	15.23	25.68	13.65 <sup>bcd</sup>	8.37	13.28	14.33	13.97 <sup>bc</sup>
0300 – 0400	17.23 <sup>ab</sup>	9.8	14.23 <sup>bcd</sup>	14.92	22.36	18.36 <sup>ab</sup>	11.76	10.79	15.36	10.69 <sup>c</sup>
0400 – 0500	14.02 <sup>bc</sup>	10.16 <sup>bc</sup>	15.68 <sup>cd</sup>	16.25	20.68	18.56 <sup>bc</sup>	9.10	13.26	16.36	12.56 <sup>bc</sup>
0500 – 0600	3.59 <sup>d</sup>	9.01 <sup>c</sup>	14.32 <sup>bcd</sup>	15.38	18.98	11.30 <sup>d</sup>	9.29	14.65	14.25	10.44 <sup>c</sup>
CD (0.05)	5.766	3.564	3.214	NS	4.368	6.35	NS	NS	NS	3.542

Table 38. Foraging speed of *Tetragonula travancorica* per flower at different hours of the day during the month of August 2022

Time period (h)	*Time spent by <i>Tetragonula travancorica</i> per 10 minute							
	<i>Antigonon leptopus</i>	<i>Hamelia patens</i>	<i>Nymphaea</i> sp.	<i>Portulaca grandiflora</i>	<i>Rosa</i> spp.	<i>Malvaviscus arboreus</i>	<i>Caesalpinia pulcherrima</i>	<i>Jatropha pandurifolia</i>
0700 – 0800	7.87 <sup>d</sup>	9.53	20.13	19.62	15.23 <sup>bcd</sup>	10.91 <sup>cd</sup>	15.67 <sup>bcd</sup>	14.35
0800 – 0900	14.35 <sup>abc</sup>	12.59	20.33	17.74	10.28 <sup>cd</sup>	18.65 <sup>bc</sup>	11.65 <sup>d</sup>	15.26
0900 – 1000	15.05 <sup>a</sup>	13.18	14.65	19.83	15.66 <sup>bcd</sup>	20.34 <sup>ab</sup>	16.70 <sup>bcd</sup>	15.64
1000 – 1100	15.69 <sup>abc</sup>	9.7	18.32	16.47	14.32 <sup>cd</sup>	18.65 <sup>ab</sup>	27.67 <sup>a</sup>	17.26
1100 – 1200	16.86 <sup>ab</sup>	10.25	20.32	14.80	12.36 <sup>cd</sup>	22.36 <sup>ab</sup>	20.09 <sup>abc</sup>	18.96
1200 – 0100	15.32 <sup>abc</sup>	14.08	15.32	15.71	19.36 <sup>a</sup>	24.33 <sup>a</sup>	21.80 <sup>ab</sup>	15.64
0100 – 0200	14.51 <sup>abc</sup>	10.6	15.33	20.70	15.23 <sup>ab</sup>	18.23 <sup>ab</sup>	17.65 <sup>bc</sup>	15.63
0200 – 0300	16.16 <sup>ab</sup>	11.16	18.56	12.86	15.60 <sup>bc</sup>	14.33 <sup>bc</sup>	18.4 <sup>abc</sup>	14.33
0300 – 0400	14.39 <sup>abc</sup>	12.12	14.23	13.51	18.23 <sup>abc</sup>	19.36 <sup>ab</sup>	17.65 <sup>bc</sup>	11.23
0400 – 0500	16.01 <sup>ab</sup>	12.27	15.68	13.36	13.30 <sup>bc</sup>	15.13 <sup>bcd</sup>	19.87 <sup>abc</sup>	12.36
0500 – 0600	3.08 <sup>bc</sup>	9.09	14.32	17.81	12.36 <sup>c</sup>	15.33 <sup>bcd</sup>	14.23 <sup>cd</sup>	15.66
CD (0.05)	6.485	NS	NS	NS	3.56	3.042	5.681	NS

(22.3) and 1100 – 1200 h in *H. patens*, *Nymphaea* sp, *S. romanzoffiana*, *R. bourboniana* and *T. erecta* (13.7, 20.32, 26.35, 20.35 and 17.59). There was no significant difference in *P. grandiflora*, *Rosa* spp, *C. pulcherrima* and *J. pandurifolia*.

Foraging speed of stingless bee in the month of August varied 7.87 to 27.67 second (Table 38). Regarding the observation of *A.leptopus* and *C.pulcherrima* maximum foraging speed was recorded as 0900 – 1000 h (15.05 and 27.67) this was on par with 1000 – 1100 h. Regarding the observation of *Rosa* spp and *M. arboreus* longest time spent by bee was during 1200 – 0100 h (19.36 and 24.33) which was on par with 1100 – 1200 h. In *H patens*, *Nymphaea* sp and *P. grandiflora* time spent by bee was not significantly different.

#### **4.2.4. Foraging preference of stingless bee**

Foraging preference was studied in terms of the number of bees visited in a flower per 10 minute. Regarding the observation of foraging rate in different colored roses, maximum number of bee visit in a flower was observed in *R. bourboniana* (5.23) followed by white rose (3.85) (Fig.1).

In different types of hibiscus flower, maximum foraging rate was observed in *M. arboreus* (5.29) compared with other hibiscus flowers (Fig.2). When the different coloured ixora was observed, more number of bees were observed in red ixora (8.62) (Fig. 3).

#### **4.2.5. Chemical composition of pollen**

On analysis of pollen in flowers of *A. leptopus*, *M. arboreus*, *Rosa* spp, *R. bourboniana* and *S. romanzoffiana*, high protein and lipid content was found in *R. bourboniana* (7.613 mg/ml and 324 mg/ml) (fig 4 and 5). Protein and lipid ratio was high in *S. romanzoffiana* (fig 6). On analysis of total phenol and flavonoid content in pollen of *R. bourboniana* (0.514µl.and 0.113 µl) and *S. romanzoffiana* (0.521 µl. and 0.299 µl), phenol content was almost equal and flavonoid content was high in *S. romanzoffiana* (Fig7).

Chemical composition of important pollen providing ornamental plants were done (Table 39).The major chemical components detected from the pollen of *R. bourboniana* and *Rosa* spp are hexadecanoic acid, docosanoic acid, 1, 2,3propanetriylester. In, *S. romanzoffiana* the major pollen chemical compounds are 1,2, benzene dicarboxylic acid ,butyl2 ethylexylester

Hexadecanoic acid ethylester, trilinolein, 2-(16-acetoxy-11-hydroxy-4,8,10,14-tetramethyloxohexadeca-hydrocyclopenta(a)phenanthren-17-ylidene)-6-methylheptanoic acid, methylester.

Table 39: Chemical composition of pollen from ornamental plants

Ornamental plants	Chemical components
<i>Rosa bourboniana</i>	<ul style="list-style-type: none"> <li>• Hexadecanoic acid, ethyl ester (C<sub>18</sub>H<sub>36</sub>O<sub>2</sub>)</li> <li>• Docosanoic acid, 1,2,3-propanetriyl ester (C<sub>69</sub>H<sub>134</sub>O<sub>6</sub>)</li> </ul>
<i>Rosa</i> sp.	<ul style="list-style-type: none"> <li>• Hexadecanoic acid, ethyl ester (C<sub>18</sub>H<sub>36</sub>O<sub>2</sub>)</li> <li>• 9,12,15-Octadecatrienoic acid, 2-phenyl-1,3-dioxan-5-yl ester (C<sub>28</sub>H<sub>40</sub>O<sub>4</sub>)</li> <li>• Docosanoic acid, 1,2,3-propanetriyl ester (C<sub>69</sub>H<sub>134</sub>O<sub>6</sub>)</li> <li>• Phenol, 2-methoxy-5-(1-propenyl)-. (E) (C<sub>10</sub>H<sub>12</sub>O<sub>2</sub>-trans-m-Propenyl</li> </ul>
<i>Syagrus romanzoffiana</i>	<ul style="list-style-type: none"> <li>• 1,2-Benzenedicarboxylic acid, butyl--2-ethylhexylester</li> <li>• Hexadecanoic acid, ethyl ester (C<sub>18</sub>H<sub>36</sub>O<sub>2</sub>)</li> <li>• Trilinolein (C<sub>57</sub>H<sub>98</sub>O<sub>6</sub>)</li> <li>• 2-(16-acetoxy-11-hydroxy-4,8,10,14-tetraethyl-3-oxohexadeca-hydrocyclopenta(a)phenanthren-17-ylidene)-6-methylheptanoic acid, methylester (C<sub>32</sub>H<sub>48</sub>O<sub>6</sub>)-</li> </ul>

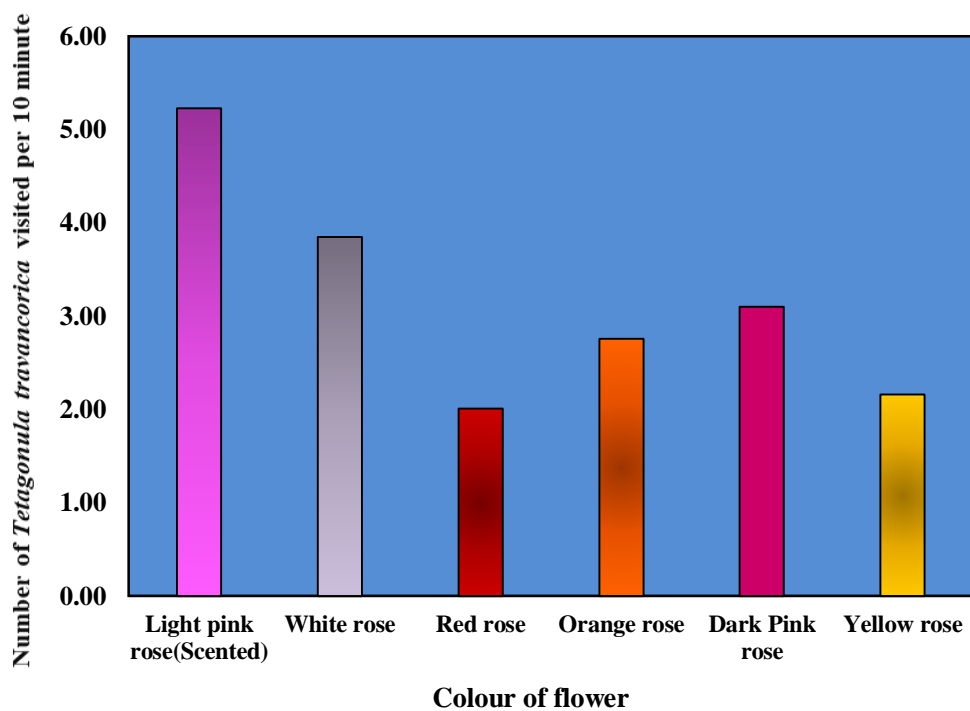


Fig 1: Foraging preference of *Tetragonula travancorica* on different colored roses

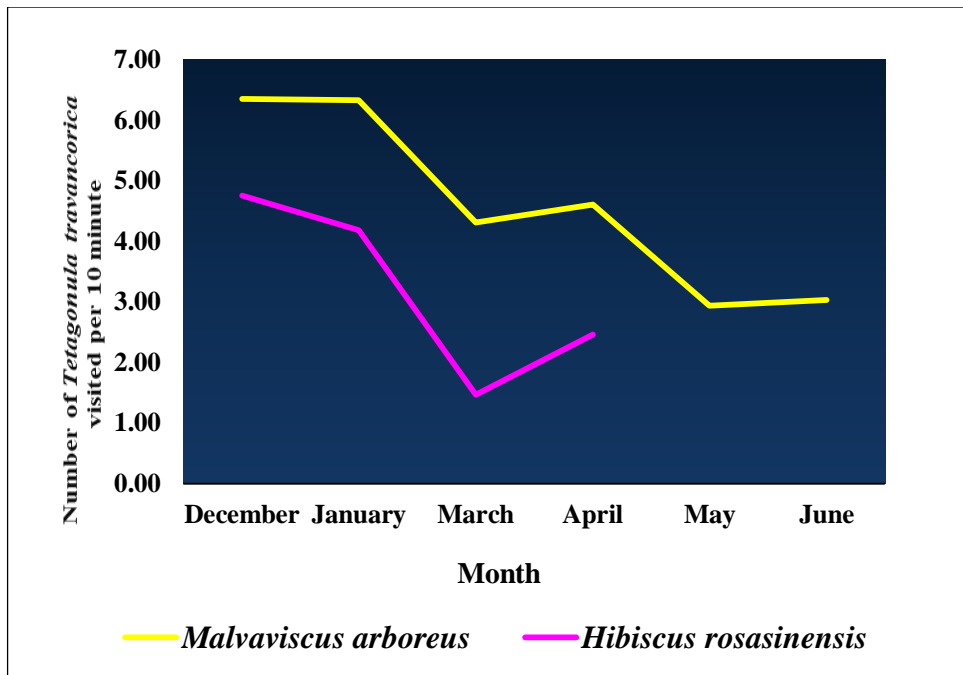


Fig 2: Foraging preference of *Tetrasonula travancorica* on different types of Hibiscus

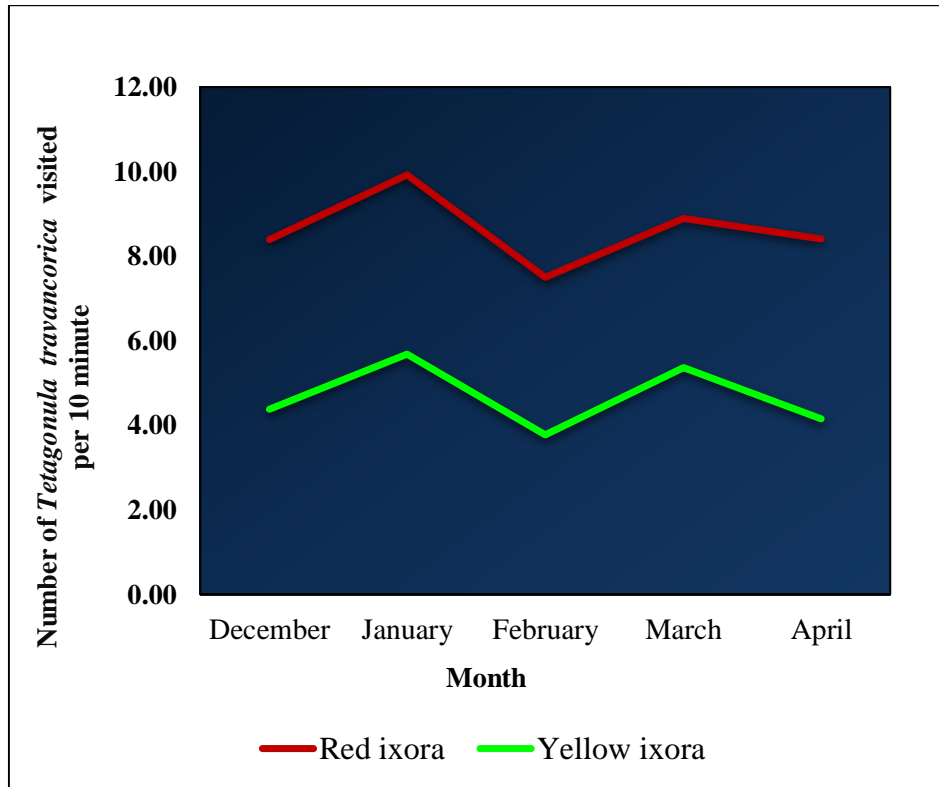


Fig 3: Foraging preference of *Tetragonula travancorica* on different types of Ixora

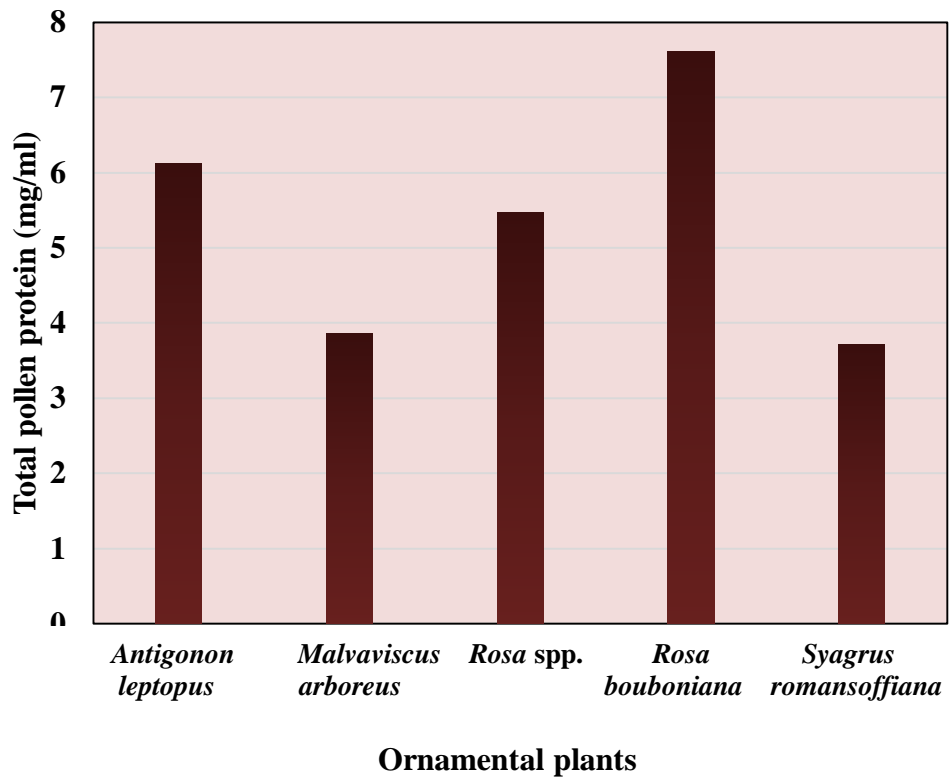


Fig 4: Total protein content of pollen in different ornamental plants

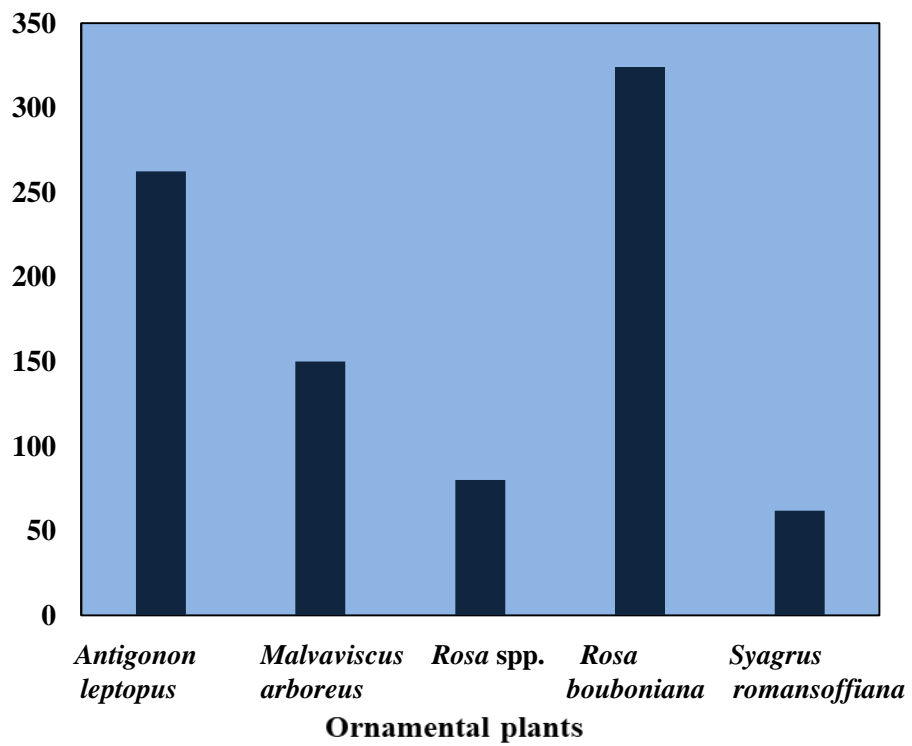


Fig 5: Total lipid content of pollen in different ornamental plants

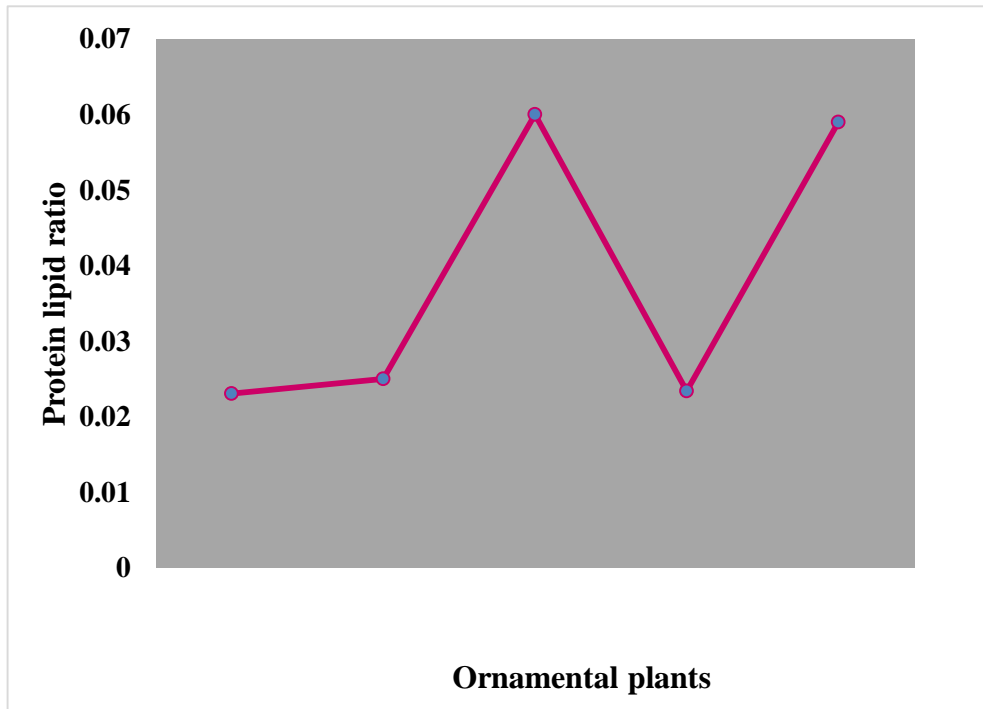


Fig 6: Protein- lipid ratio of pollen in different ornamental plants

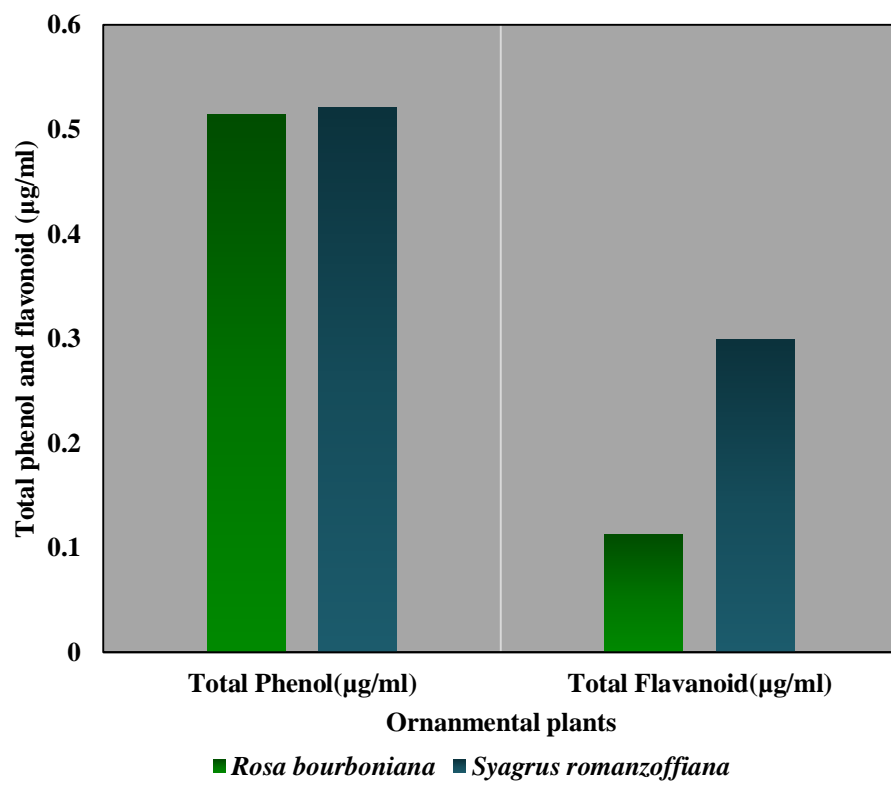


Fig 7: Total phenol and flavonoid content of pollen in different ornamental plant

#### 4.3. RELATIONSHIP BETWEEN FORAGING RATE AND WEATHER PARAMETERS DURING PEAK FLOWERING PERIOD

Relationship between foraging rate and weather parameters viz temperature, relative humidity, wind velocity, rainfall and sunshine hours were done (Table 40). Significant positive correlation was observed with temperature and number of foragers in case of *A.leptopus* (R= 0.221), *C. pulcherrima* (R= 0.271), *P. grandiflora* (R= 0.402), *J pandurifolia* (R= 0.454), *S. romansoffiana* (R= 0.213), *R bourboniana* (0.71) and *E. mili* (R= 0.57). Significant negative correlation was observed between relative humidity and number of foragers in case of *A.leptopus* (R= -0.157), *H patens* (R= -0.216), *Nymphaea* sp (R= -0.356), *C.pulcherrima* (R= -0.256), *P. grandiflora* (-0.295), *J. pandurifolia* (R= -0.311), *M. arboreus* (R= -0.142), *C. constrictum* (R= -0.293), *S. romansoffiana* (R= -0.401) and *Rosa* spp (R= -0.139). In *Z. rosea*, significant positive correlation was observed between relative humidity with foraging rate.

Significant negative correlation was found between rainfall and number of foragers in case of *A.leptopus* (R= -0.024), *H patens* (R= -0.042), *J. pandurifolia* (R= -0.052), *S. romanzoffiana* (R= -0.068), *R bourboniana* (R= -0.675) whereas significant positive correlation was observed in *Nymphaea* sp. (R= 0.407), *C. constrictum* (R= 0.463), *E. mili* (R= 0.343), *P. grandiflora* (R= 0.568), *I. chinensis* (R= 0.731), *T. erecta* (R= 0.435). Significant positive correlation was recorded with sunshine hours and foraging rate in *A.leptopus* (R= 0.302), *H. patens* (R=0.652), *C.pulcherrima* (R=0.418), *J. pandurifolia* (R=0.592), *C. constrictum* (R=0.635), *M. arboreus* (R=0.625), *Rosa* spp (R=0.625) and *R. bourboniana* (R=0.384) while significant negative correlation was found between sunshine hours and number of foragers in case of *I. chinensis* (R=-0.523).

#### 4.4. FLORAL CALENDAR

According to observation, a complete chronological record of flowering periods of the identified plant was compiled, and the data was shown in a pie chart (Fig 8). Year round availability of nectar was found in *A. leptopus* and *H. patens* as well as the year-round availability of pollen was found in *P. grandiflora* and *Nymphaea* sp. *M. arboreus*, *C .pulcherrima*, *J. pandurifolia* and *C. constrictum* produced both nectar and pollen throughout the year. Pollen from *S. romanzoffiana* and both nectar and pollen from *E. mili* was available in January and July. Pollen from *Rosa* spp. was available from October to June, while from *R.*

*bourboniana* it was during November to July. From December to March, *I. chinensis* offered both pollen and nectar. Both *T. erecta* and *H. annus* pollen was available from January to May.

Table 40: Influence of weather parameters on foraging rate of *Tetragonula travancorica*

Ornamental plants	Temperature	Relative humidity	Wind velocity	Rainfall	Sunshine hours
<i>Antigonon leptopus</i>	0.221*	-0.157*	0.235	-0.024*	0.302*
<i>Hamelia patens</i>	0.194	-0.216*	0.375	-0.042*	0.652*
<i>Nymphaea sp.</i>	-0.117	0.356	0.389	0.407*	-0.409
<i>Caesalpinia pulcherrima</i>	0.271*	-0.236*	0.564	0.023	0.418*
<i>Portulaca grandiflora</i>	0.402*	-0.295	0.55	0.482	0.499
<i>Jatropha pandurifoliae</i>	0.454*	-0.311	0.627	-0.521*	0.592*
<i>Combretum constrictum</i>	0.293*	-0.149*	0.264	0.463*	0.635*
<i>Malvaviscus arboreus</i>	0.213	-0.142*	0.272	0.285	0.625*
<i>Euphorbia mili</i>	0.112	-0.071	-0.319	0.343*	0.184

\*Correlation is significant at 0.05 level

Table 40: Influence of weather parameters on foraging rate of *Tetragonula travancorica* (Contd)

Ornamental plants	Temperature	Relative humidity	Wind velocity	Rainfall	Sunshine hours
<i>Syagrus romanzoffiana</i>	0.213*	-0.448*	-0.411	-0.068	0.243
<i>Rosa</i> sp.	0.453	-0.139*	0.165	0.872	0.625*
<i>Rosa bourboniana</i>	0.71*	0.144	0.078	-0.675*	0.384*
<i>Portulaca grandiflora</i>	-0.381	-0.206	0.234	0.568*	0.318
<i>Ixora chinensis L</i>	0.57*	-0.229	-0.447	0.731*	-0.823*
<i>Dombeya</i> sp.	0.295	-0.813	0.199	0.005	-0.499
<i>Tagetes erecta</i>	-0.148	0.212	0.513	0.435*	-0.355
<i>Zephyranthes rosea</i>	-0.47	0.323*	0.327	0.32	-0.536

\*Correlation is significant at 0.05 level

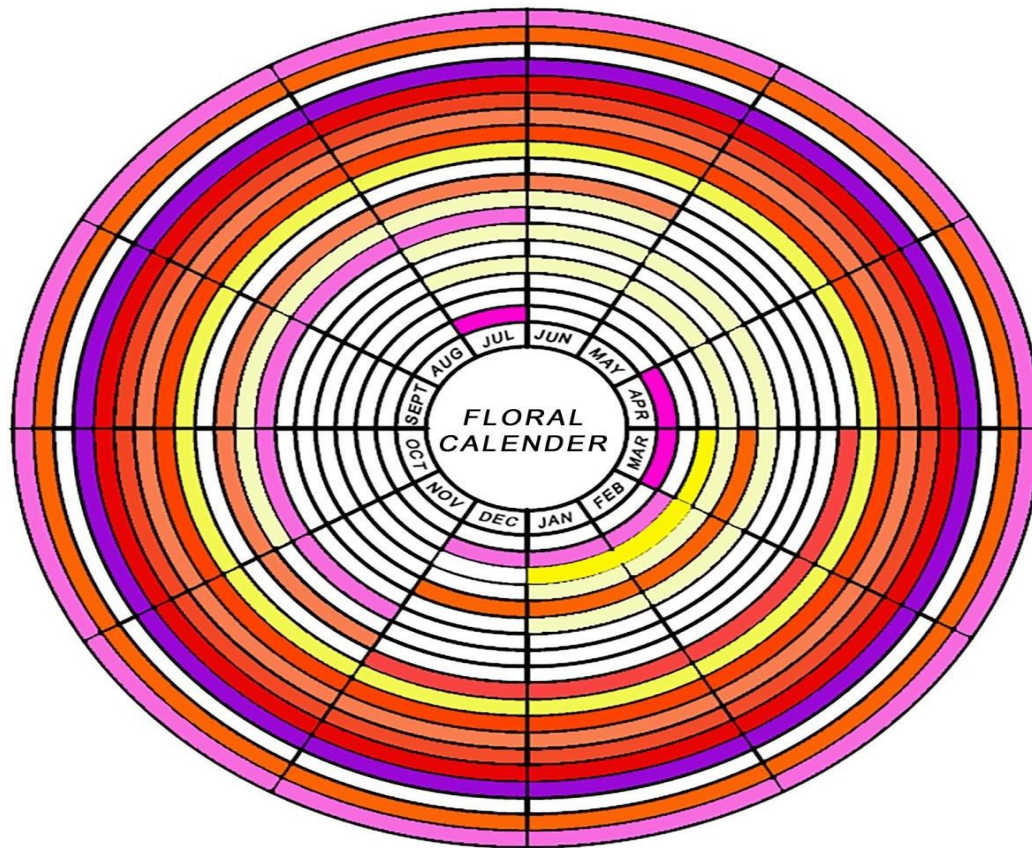


Fig 8: Floral calendar of identified bee flora

Outer round -1 – *A.leptopus*

2- *H.patens*

3- *P.grandiflora*

4- *Nymphaea* sp

5- *M.arboreus*

6 – *C.pulcherrima*

7- *J. pandurifolia*

8 - *C.constructum*

9 – *E.mili*

10- *I. chinensis*

11- *T.capensis*

12- *S. romanzoffiana*

13- *R.bourboniana*

14- *Rosa* spp

15-- *T. erecta*

16 – *P. aculeate*

17- *H.annus*

18 – *Dombeya* sp

Inner round - 19- *Z.rosea*

***DISCUSSION***

## 5. DISCUSSION

The investigations on “Stingless bee foraging pattern in ornamental plants” was carried out from September 2021 to August 2022 at Department of Agricultural Entomology, College of Agriculture Vellayani to identify the floral resources and to evaluate the foraging activity of stingless bee and preparation of floral calendar. The result obtained in this study are discussed in this chapter.

### 5.1. IDENTIFICATION OF NECTARIFEROUS AND POLLENIFEROUS ORNAMENTALS

Stingless bee, *T. travancorica*, visited a range of ornamental plants during the blooming seasons for obtaining sufficient nectar and pollen to maintain the health of honey bee colonies. This included *A. leptopus*, *H. patens*, *P. grandiflora*, *Nymphaea* sp., *M. arboreus*, *C. pulcherrima*, *C. constrictum*, *J. pandurifolia* that were year round and seasonal plants were *R. bourboniana*, *Rosa* spp, *S.romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. capensis* *I. chinensis*, *T. erecta* and *E. mili*. Roubik (1979) and Muthuraman *et al.* (2013) reported that stingless bee visited flowers of vegetable crops, fruit crops, oilseeds, pulse crops, forage crops, weed plants and ornamental plants. Bhalchandra *et al.* (2014) reported the various nectariferous and polleniferous agricultural bee flora for stingless bees in Anjaneri and Dugarwadi hills and Vijayakumar and Jeyaraaj (2016) reported the floral sources in Nellithurai village, Tamil Nadu.

Premila *et al.* (2007) reported floral resources of stingless bee in Kerala, nectar producing plants include, *Musa paradisiaca* L. *Hevea brasiliensis* W, *Vigna radiata* L *Vigna sinensis* E. *Euphorbia pulchereima* C, *Tagetes* sp., *Gladiolus grandiflorus* L Pollen providing plants include *Mangifera indica* L, *Citrus* sp., *Carica papaya* L, *Psidium guajava* L, *Benincasa hispida* C, *Cucurbita pepo*, *Lagenaria vulgaris* Ser, *Trichosanthes cucumerina* L *Momordica charantia* L, *Mimosa pudica* L, *Ixora* sp. and *Rosa* sp. Both nectar and pollen producing plants were, *Cajanus cajan* L, *Vigna mungo* L, *Moringa oleifera* L, *Cocos nucifera* (L) L, *Anacardium occidentale* L, *Theobroma cacao* L, *Coffea arabica* L, *Lantana camera* L, *Tridax procumbens* L, *Antigonon leptopus* H, *Portulaca* sp. and *Cesalpinia pulcherrima* L.

In this study, only two nectar providing plants were there, *A. leptopus* and *H. patens*. The various pollen providing plants observed were *P. grandiflora*, *Nymphaea* sp, *R. bourboniana*, *Rosa* spp, *S. romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. erecta* and *E.*

*mili*. Plants like *M. arboreus*, *C. pulcherrima*, *C. constrictum*, *J. pandurifolia*, *T. capensis* and *I. chinensis* were both nectar and pollen providing plants.

Among this, *A. leptopus* is a climber, grows vigorously and produce profuse flowering throughout the year showing high nectar refill ratio. Moreover, the bunched flowers in the plant with so many inflorescence is an additional advantage for the bees to frequently forage on these flowers for collecting nectar. Even though the flower also produces sufficient pollen, the stingless bees are mostly preferring nectar from this plant. Raju *et al.* (2001) found that *Antigonon leptopus* flowers were foraged daily by different insects which included bees, wasps, flies and butterflies.

*H. patens* was another one with round the year flowering which produces showy, conspicuous and bright flower in aggregated form and hence effective to attract bees from long distances. As it possesses several closely arranged flowers, in a single visit without spending extra energy for searching the foraging source, bees will get adequate amount of nectar from this plant. Even though it is with the long tubular corolla and hidden nectar, the short tongued bees could collect nectar due to suction by the action of capillary forces. Likewise, *C. pulcherrima* and *C. constrictum* being mass bloomers promised the visiting stingless bees with the required caloric reward by reducing the search time. Ramalho, (2004) also found that stingless bees commonly visit mass flowering plants. Similarly, Akter *et al.* (2017) found that single plants with many flowers and large clusters were generally more attractive to flower-visiting insects than those with a smaller number of flowers.

The present study found that, *S. romanzoffiana* is a medium-sized to large solitaire palm with branched inflorescence. The number of rachis in the inflorescence ranged from 45 to 50 and around 78–100 flowers were produced by each rachis. So, enormous number of flowers produced by the inflorescence contains a large amount of pollen. This greatly reduces the search time and energy expenditure for the bees and hence large number of bees visit the flowers in succession at great speed and collect adequate amount of pollen. Nunez Avellaneda and Carreno (2017) found that the most effective pollinators of *S. orinocensis* were stingless bees as they transferred in average 83% of the pollen that reached receptive inflorescences.

Among pollen providing flowering plants, *Nymphaea* sp. and *P. grandiflora*, produce pollen throughout the year. In *Nymphaea*, flowers were seen in exposed condition to the insect visitors, so bees can easily access the pollen from these flower. Though the flowers have a

stigmatic watery fluid, it is found that it possesses no sugar concentration. It is also seen that the bees drop carelessly into the stigmatic fluid and get trapped in it. Robertson (1889), also noted that flowers of *N. odorata* contained fluid in the stigmatic bowl without any taste and smell and the insects are seen accidentally drop down in this fluid. Zhang *et al.* (2021) found that the bright coloured *N. hybrid* was with aromatic odour to attract insects to pollinate which is seen secreting colourless and tasteless nectar on the stigma disc.

*P. grandiflora* is with constant pollen output throughout the year. Though plants with single and multiple petal types are there, bees prefer single whorl type as they can be easily accessed by stingless bees. The pollen from the stamens are hidden under their multiple petals in multi whorled type. Verma (1990) reported *P. grandiflora* as major pollen source in Hind-Kush Himalayan region which was commonly grown as garden flower.

In this study, majority of the plant species foraged for nectar and pollen by *T. travancorica* belonged to the family Asteraceae (21%) followed by Rubiaceae, Euphorbiaceae, Malvaceae (Fig.9). Suryanarayana *et al.* (1992) and Terrab *et al.* (2002) reported the importance of Asteraceae family as foraging source of honey bee. The inflorescence of Asteraceae family is capitulum, which appears to be a single flower is actually a cluster of much smaller flowers. The multitude of florets as a single flower and shape of the flower attracts stingless bees.

Foraging bee interactions with flowers depend on several factors. The bee utilizes a combination of tactile, olfactory and visual floral cues to choose the appropriate host plant for foraging. Here in this experiment, it was found that the majority of bee flora were of strong orange, yellowish white followed by strong red, vivid reddish orange (Fig.9) and cup-like and tubular shape (Fig.10). When the foraging rate of various coloured roses were observed, *R. bourboniana*, attracted most of the bees, even though colour is a visual factor for attracting bees, but here it was found that stingless bee may be attracted due to the fragrance of the flower.

This result is in line with the findings of Yadav and Kaushik (2012). They found that apart from floral shape and size, flowers release olfactory attractants which act as factors for attracting pollinators. Dudareva and Pichersky (2006) reported that floral scent is a complex blend of volatile compounds produced by the different floral tissues. Azuma *et al.* (2002) revealed that flower scent and scent chemical profiles are one of the important factors in attracting pollinators.

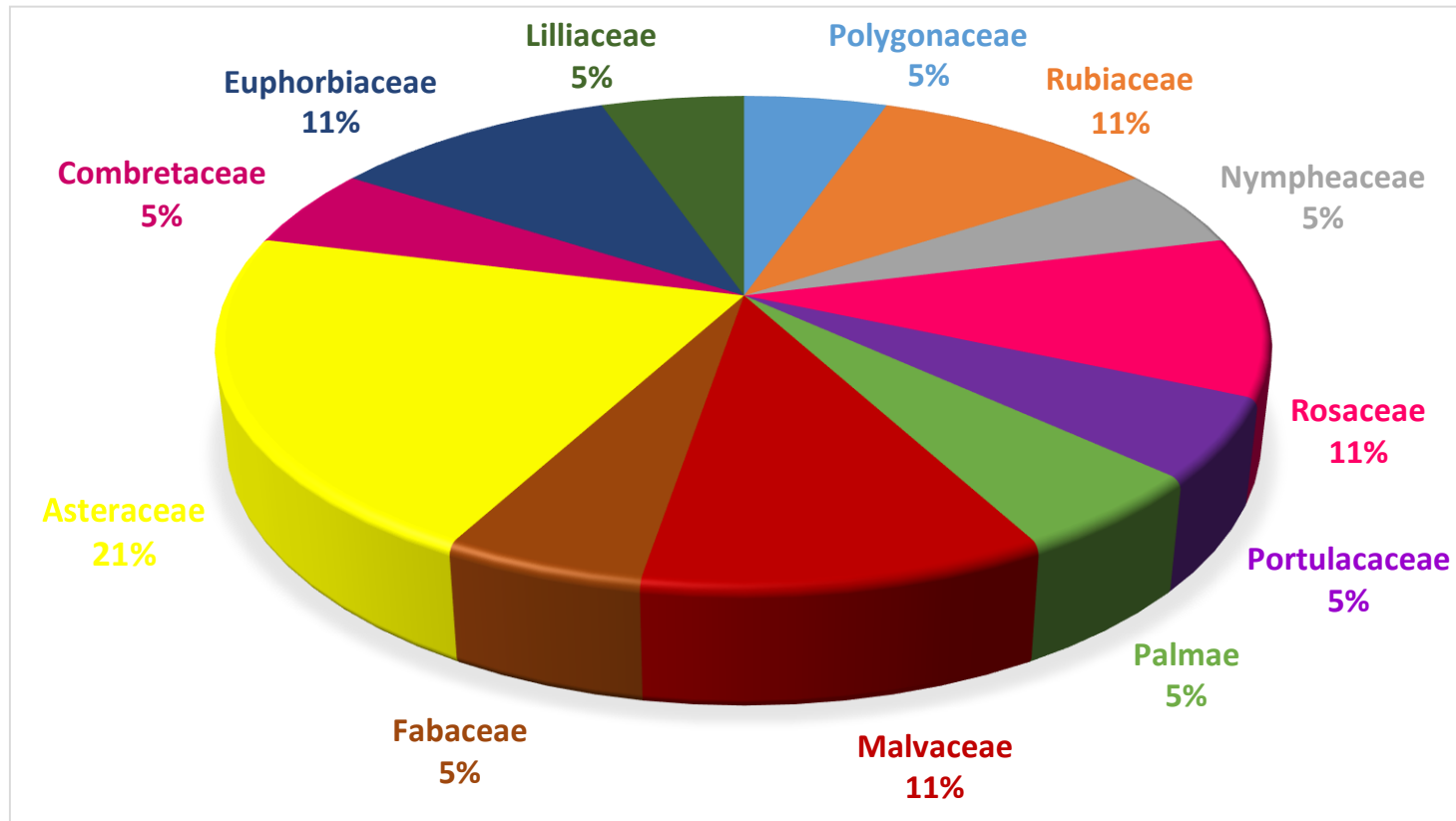


Fig 9: Percentage distribution of Stingless bee visiting different families of ornamental plants

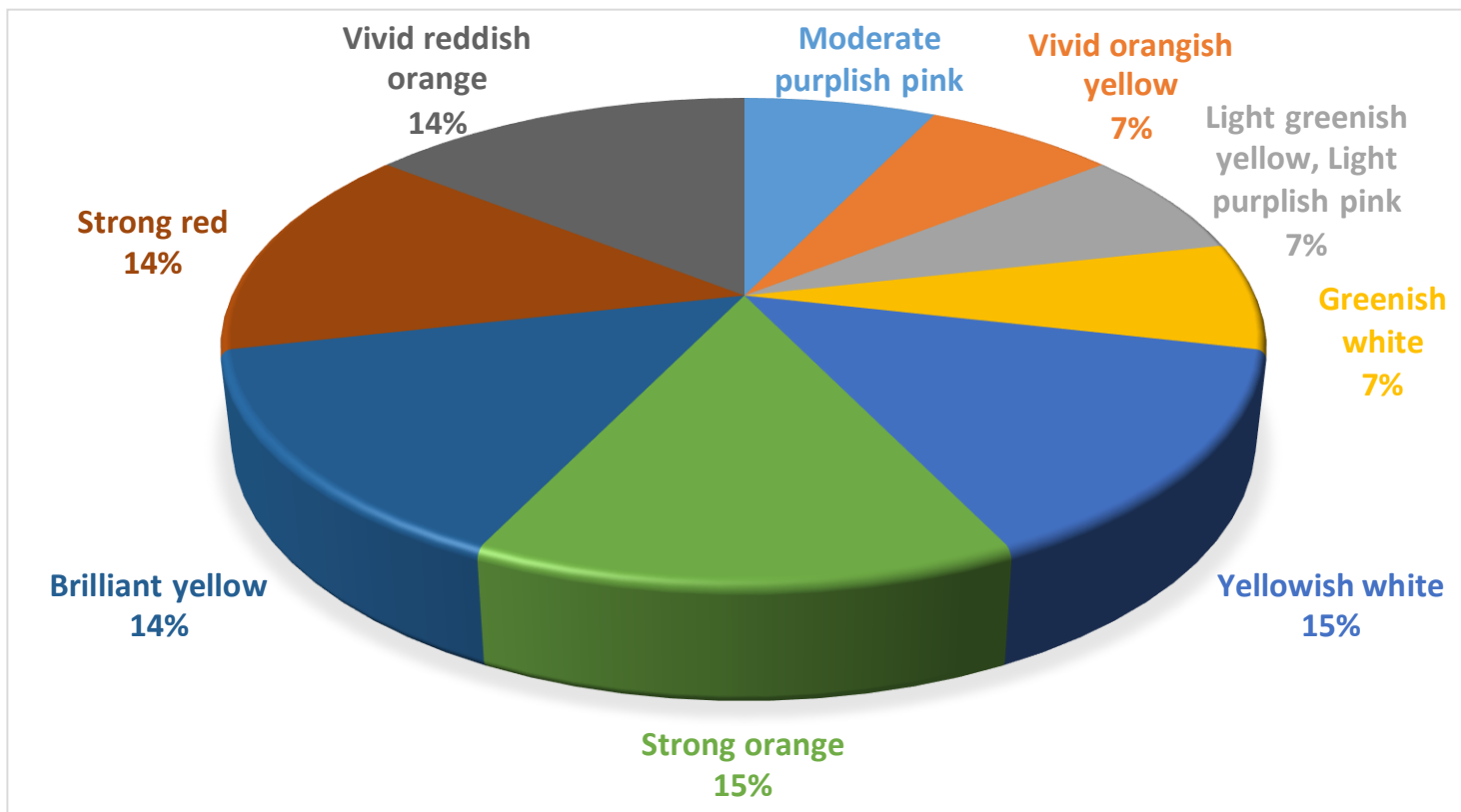


Fig 10: Percentage distribution of stingless bee visiting different coloured flowers

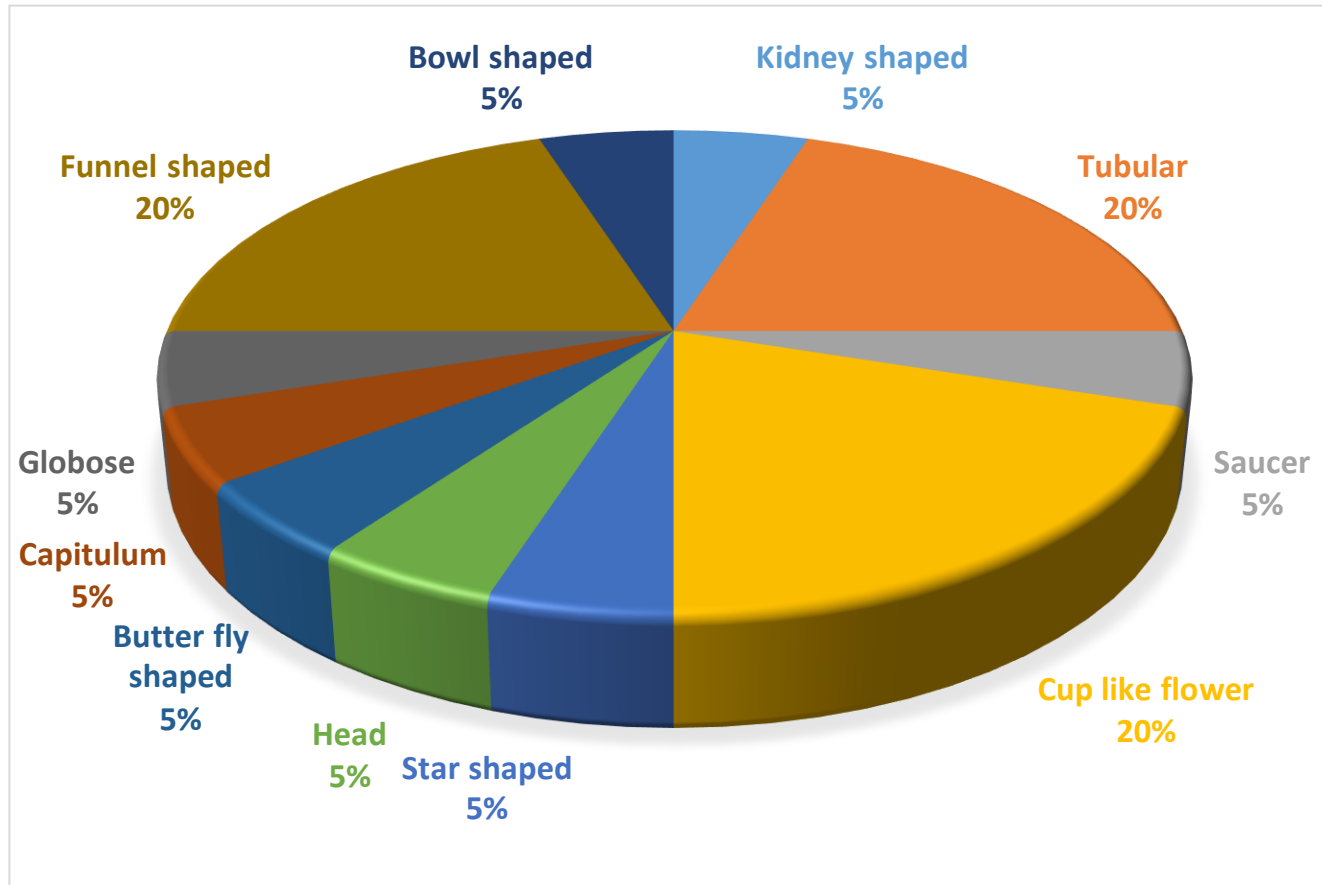


Fig 11: Percentage distribution of stingless bee visiting different shapes of ornamental flowers

It was found that, besides colour, size, shape and scent, several parameters such as nutrient quality and quantity of nectar and pollen also influences foraging. Although stingless bee generally prefer cup like flowers, but this experiment revealed that they were also attracted to tubular flowers with high nectar volume. It was found that, among different types of hibiscus species, foraging was observed in two types of hibiscus and maximum foraging rate was observed in *M. arboreus* which is a tubular hibiscus. This may be due to the high availability of the energetically rewarding nectar source compared with other hibiscus flowers owing to the high nectar volume (8.47 $\mu$ L) and sugar content (23.06%). Among different types of ixora, more number of bees were observed in both yellow and red coloured chinese ixora, and highest bee population was there in red coloured ixora. It was mainly due to the volume (1.73 $\mu$ L) and concentration (16.73%) of nectar present in the flower.

Bees obtain their protein and lipid from pollen, which is essential for larval growth and development as well as adult health and reproduction. Ghosh *et al.* (2020) found that first criteria for honey bee foraging preference of pollens would be the nutritional contents of protein. The present study also showed that, stingless bee prefers flowers having pollen with high levels of protein and lipid as well as a high protein to lipid ratio. High protein and lipid content was found in the mostly foraged plant, *R. bourboniana* (7.613 mg/mL and 324 mg/mL) and protein and lipid ratio was high in *S. romanzoffiana*, the plant which is heavily visited by pollen foraging stingless bees. Pollen protein to lipid ratios showed bee foraging preferences among pollen host-plant species, and these preferred ratios are related to the health and vitality of bee colonies (Vaudo *et al.*, 2020). These plants are having high phenol and flavonoid content compared with other pollen producing plants *ie.* *R. bourboniana* (0.514 $\mu$ L and 0.113 $\mu$ L) and *S.romanzoffiana* (0.521 $\mu$ L.and 0.299 $\mu$ L). Campos *et al.* (1997) reported that red and blue anthocyanin pigments which is a class of flavonoids acts as insect pollinator attractants. Also Liu *et al.* (2006) reported that foraging activities of a honey bee colony are regulated by quantitative changes in phenolic contents of pollen.

In this study, it is seen that the chemical composition of pollen influenced the foraging behaviour of stingless bees. The chemical composition may influence the amount of pollen collected and the probability of next visit of similar flower. The present study analysed pollen from highly foraged plants and found the presence of different chemical components possessing attractive properties. The components present in the floral pollen were,

Hexadecanoic acid ethylester, Docosanoic acid, 1,2,3 propanetriylester, 1,2, Benzene dicarboxylic acid, butyl 2 ethyl hexylester, 2(16 Acetoxy 1 hydroxy 4,8,10,14 tetramethyl 3 oxo hexadeca hydro cyclopenta(a) phenanthrene 7 ylidene) 6 methyl heptanoic acid, methyl ester. Dobson and Bergstrom, (2000) stated that the chemicals present in pollen are shown to play an important role in host plant recognition by bees.

## 5.2. FORAGING ACTIVITY OF *T. travancorica*

Stingless bee foraging activity on different ornamental plants was observed throughout the day at different hours from September 2021 to August 2022. The bees adjust their foraging activity depending upon the availability and profitability of floral rewards. Majority of the foragers started visiting the flowers from 0700 h in the morning and continued till evening 0630 h.

The bee visitation to the flowers reached a maximum during the peak period of nectar or pollen production. The observations on foraging intensity of *T. travancorica* in the identified ornamental plants revealed that it was highest (9.91 flowers 10 min<sup>-1</sup>) during 1000 – 1200 h and was least (0.15 flowers 10 min<sup>-1</sup>) during 0500 – 0600 h. The result confirms with the report of Devanesan *et al.* (2002) who recorded that foraging activity of stingless bee in different crops was maximum at 1000 h to 1200 h and a decline in the activity was observed at 1300 h and there was almost no activity at 1800 h. Painkra and Kumaranag (2019) observed that stingless bee population was maximum on sunflower during 1000 h to 1100 followed by 1200 h to 0100 h and the lowest activity was recorded in between 0800 h to 0900h. Similarly, Said *et al.* (2015) recorded maximum foraging activity of *A. cerana* in sunflower at 1100 – 1200 h with mean number of 6.00 bees, which was followed by a second peak at 0100 h of the day.

Among the year round foraging plants, *A. leptopus* (5.02) was showing the highest foraging rate followed by *M. arboreus* (4.87) (Fig 12). And it was also found that, among the different nectar and pollen providing plants, maximum foraging rate (Fig 13) was observed in *M. arboreus* (4.87) and highest nectar foragers was recorded at 1000-0100 h. The foraging activity of pollen foragers was highest in *S. romazoffiana* (51.83) and foraging rate increased at 0900 – 1000 h and reached a highest peak at 1100 – 1200 h and declined thereafter (Fig.14). This is in confirmation with the findings of Nunes- Silva *et al.* (2013) who found that the number of bees collecting pollen increased from 0900 and a peak of activity was found between 1100 h and 1200 h.

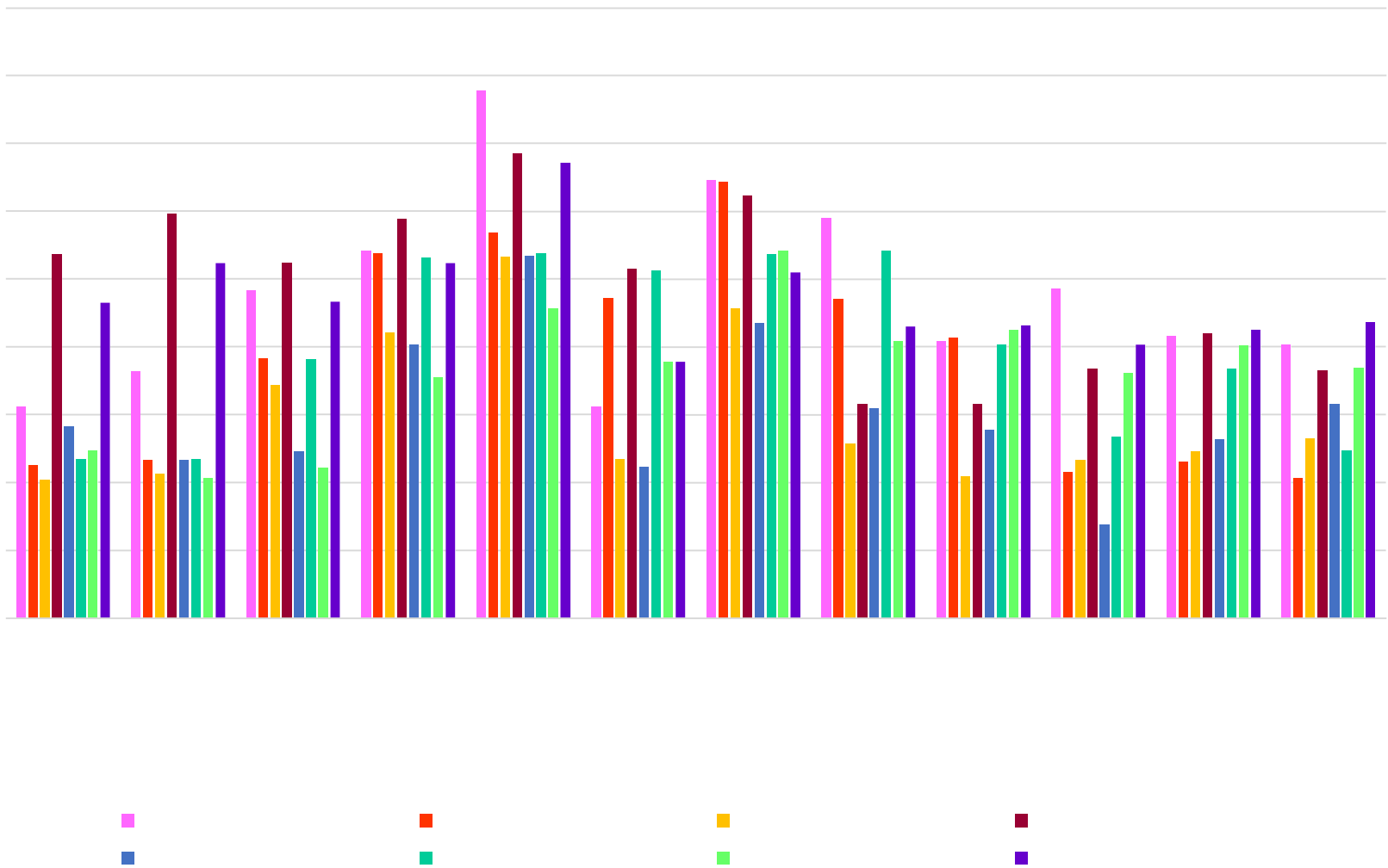


Fig 12: Foraging rate of *Tetragonula travancorica* in year round foraging plants

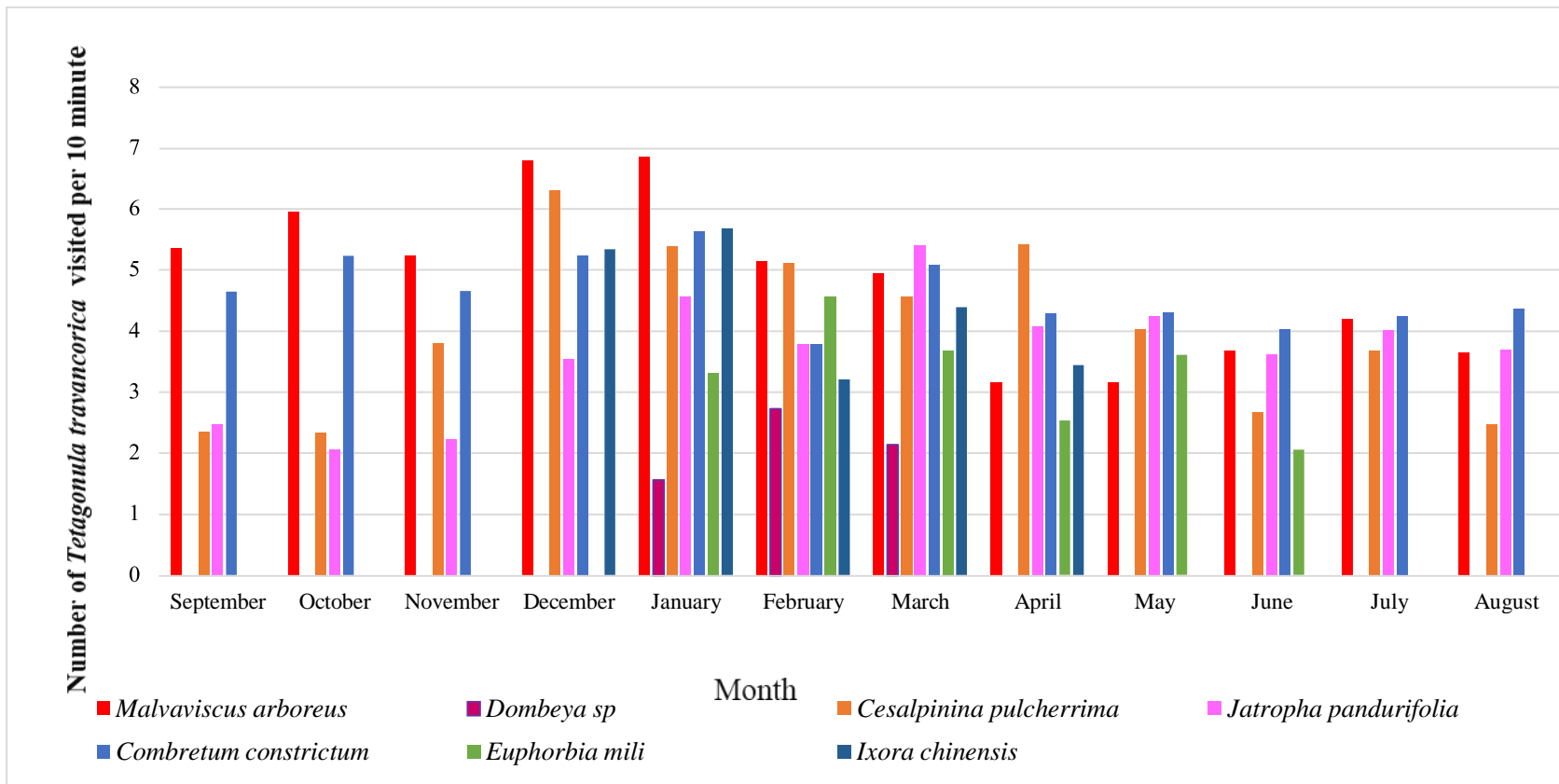


Fig 13: Foraging rate of *Tetragonula travancorica* in nectar and pollen providing flowering plants

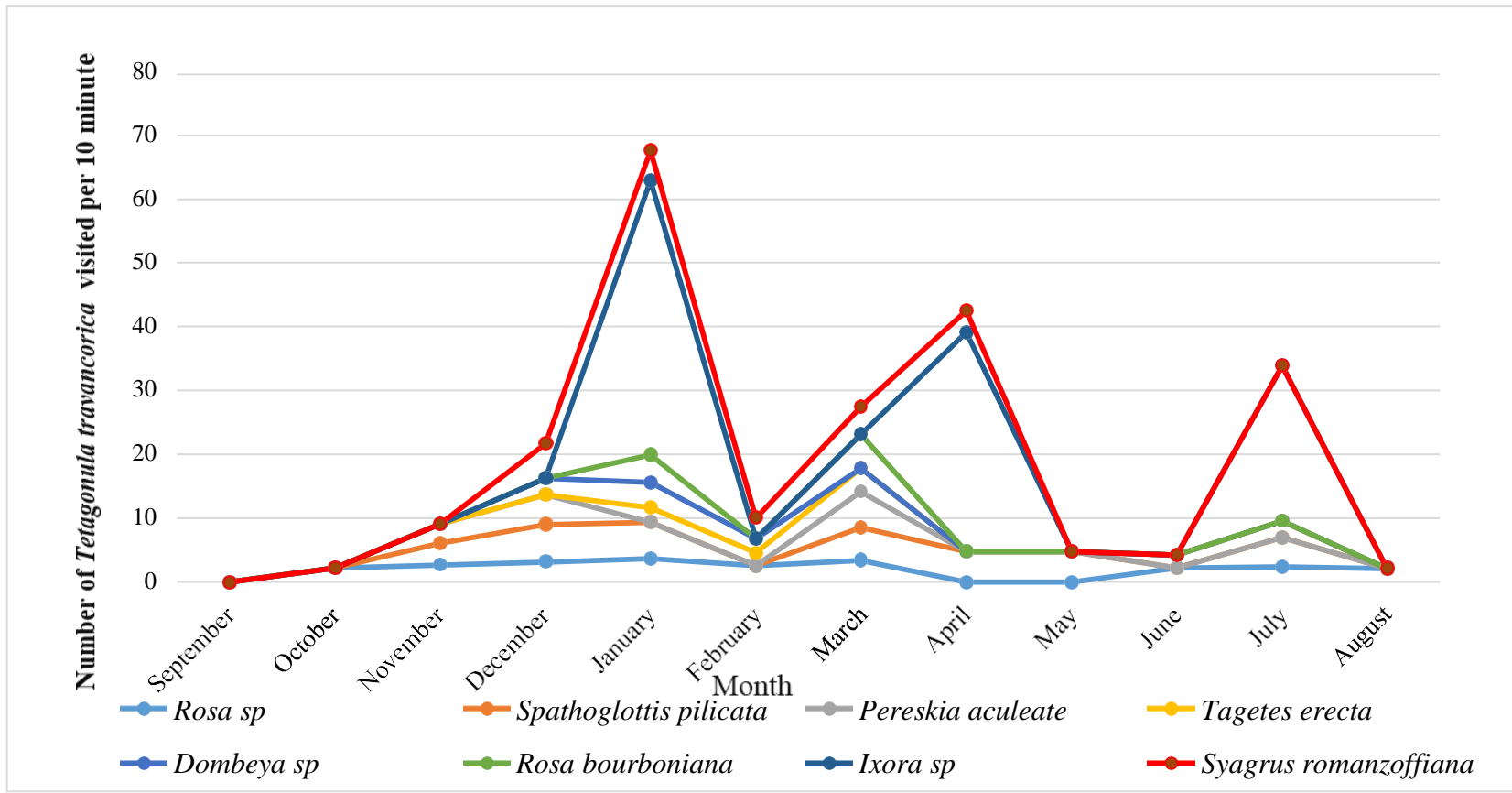


Fig 14: Foraging rate of *Tetragonula travancorica* in pollen providing flowering plants

Foraging speed by bee was recorded between 2.51 to 30.44 sec during 1000-1200 h of the day. Maximum time spent was observed in *Nymphaea* sp. (28.54 sec) and *M. arboreus* (26.47sec). It was observed that they spent more time in a single flower for collecting more resources and visited only less number of flowers. Bomfim *et al.* (2014) reported that the length of each time visit by a stingless bee forager varied between 2.27 to 43.95 sec. Maximum foraging speed of stingless bee in cucumber were seen between 1000 h and 1200 h with 17.89 – 22.75 sec (Tej *et al.*, 2017)

In this experiment, it was found that among the various year round flowering plants producing nectar and pollen, maximum foraging activity was observed during the month of January to March. This result is in line with the findings of Vijayan *et al.* (2018) reported that maximum foraging activity was observed in the month of January to March.

### 5.3. RELATIONSHIP BETWEEN FORAGING RATE AND WEATHER PARAMETERS

The study revealed that weather parameters had a crucial impact on the foraging behaviour of stingless bees and foraging activity was affected by temperature, relative humidity, rainfall and sunshine hours and the activity was not affected by wind velocity. Anthesis timing in some plant species may be affected by the prevailing weather conditions which in turn affects foraging activity. Significant positive correlation was observed with temperature and foraging rate ( $R= 0.213$  to  $0.454$ ) and significant negative correlation was observed between relative humidity and number of foragers ( $R= -0.157$  to  $-0.401$ ). Significant negative correlation was found between rainfall and foraging rate ( $R= -0.068$  to  $-0.675$ ) whereas significant positive correlation was recorded with sunshine hours and foraging rate ( $R= 0.384$  to  $0.652$ )

The results confirm with the report of Kumar *et al.* (2015) and Bharath *et al.* (2020) who found that among all climatic factors, rainfall hampered the foraging activity while wind speed was found to have no remarkable effect. In many studies, it has been revealed that with increase in day temperature, the activities of bees greatly reduce. Kaur and Sihag (1994) also observed that activity of foragers was positively and highly significantly correlated with the temperature and negatively and highly significantly with the relative humidity.

### 5.4. FLORAL CALENDAR PREPARATION

The floral calendar has considerably facilitated the standardization of routine management practices in apiaries. The knowledge of blooming season is important factor for sustainable management of bee colonies and for good honey harvest. Singh (2005), reported that floral calendar is a time table that indicates the appropriate date and duration of the blossoming period of the important nectar and pollen producing plants in the area. Such information may enable beekeepers to utilize beekeeping at the maximum level, so that they can harvest a good yield of honey and other bee products.

In this study, based on the availability of different plants along with their flowering time, a bee floral calendar has been developed. *T. travancorica* visited 20 plant species and collected nectar or pollen or both from these flowers. Among these, *T. travancorica* collected nectar from two floras; *A. leptopus* and *H. patens* whereas bees collected pollen from 10 floras; *P. grandiflora*, *Nymphaea* sp, *R. bourboniana*, *Rosa* spp, *S. romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. erecta* and *E. mili* and both nectar and pollen were collected from 8 bee floras; *M. arboreus*, *C. pulcherrima*, *C. constrictum*, *J. pandurifolia*, *T. capensis* *I. chinensis* and *T. capensis*. The observation data revealed that the floral calendar, the maximum reported bee flora was observed during the honey flow season, January to March. The minimum stingless bee flora blooms during dearth season, July to September. This result was in accordance with the report of Jaiswal and Thakur (2016) highest bee flora's flowering was recorded during January to May, and therefore, this period can be considered as honey flow period. The minimum stingless bee flora blooms during July to September, therefore, this period considered as floral dearth period. Similarly, Taha (2015) also found that highest numbers of flowering species were recorded during March.

During dearth period, shortage of pollen and nectar floral resources will result in weakening of colony performance and strength. Occasionally prolonged dearth of bee flora may lead to perishing of the bee colonies. This experiment found that, in order to overcome the scarcity of pollen and nectar, different ornamental plants can be cultivated based on the flowering time. The nectar providing plants that can be included during dearth period were *A. leptopus* and *H. patens*, pollen providing plants include *P. grandiflora*, *Nymphaea* sp, *R. bourboniana* and *Z. rosea*. The plants that provide both nectar and pollen during dearth period were, *M. arboreus*, *C. pulcherrima*, *J. pandurifolia*, *C. constrictum*.

Waykar and Baviskar (2015) prepared floral calendar for Paithan taluk of Aurangabad district which recorded peak periods of honeybee foraging during mid-October to mid-

December and dearth period as mid -June to mid-August. Kumari (2004) prepared floral calendar for bees for Visakhapatnam, Andhra Pradesh, India and recorded 74 different plant species belonging to 35 families as honey bee forage plants. Of the total plant species in the floral calendar, 18 plant species bloom throughout the year and they included ornamentals, fruit trees, medicinal herbs and weeds: the remaining plant species were either uniseasonal or biseasonal bloomers.

## ***SUMMARY***

## 6. SUMMARY

Stingless bees could be successfully integrated into the urban farming systems without much complications especially in balcony, terrace as well as kitchen gardens. The stingless bees need minimum space and attention and could be easily handled by women, children and aged persons without any difficulty. Moreover, they could utilize the existing gardens, parks, open spaces as appropriate locations for their bee hives and enrich such areas with sufficient nectar and pollen producing plants. Hence the present investigation on “Stingless bee foraging pattern in ornamental plants” was carried out at College of Agriculture, Vellayani from September 2021 to August 2022. The objective was documentation of the foraging pattern of stingless bees in nectariferous and polleniferous ornamental plants and preparation of floral calendar. The results are summarised here.

Stingless bee, *T. travancorica* visited a wide range of flowers. In present study, 20 ornamental plants were visited by stingless bee. The nectar producing flowers were, *A. leptopus*, *H. patens* and pollen producing plants were, *P. grandiflora*, *Nymphaea* sp, *R. bourboniana*, *Rosa* spp, *S. romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. erecta* and *E. mili*. Both nectar and pollen providing plants were *M. arboreus*, *C. pulcherrima*, *C. constrictum*, *J. pandurifolia*, *T. capensis* and *I. chinensis*.

Among the nectar providing plants, *A. leptopus* produce larger cluster of flowers more number of flowers with high nectar refill ratio and in *H. patens*, the plant which produce bright coloured flowers in aggregated form, availability of nectar was found throughout the year. *P. grandiflora* and *Nymphaea* sp. produce huge amount of pollen throughout the year. In the flower of *S. romanzoffiana*, a seasonal pollen providing plants more number of stingless bees were attracted because the plants are having branched inflorescence with abundant pollen. In *R. bourboniana*, highest bee foraging was observed due to the fragrance nature of the flower.

Among different types of hibiscus, maximum foraging rate was observed in *M. arboreus* which may be due to the high availability of the energetically rewarding nectar source (8.47µl). Among different types of ixora, highest bee population was noticed in red coloured ixora among different ixora types. It was mainly due to the high volume (1.73µl) and concentration (16.73%) of nectar present in the flower. Also these two plants produce enough pollen to attract bees.

The foraging activity were observed from 0700 h in the morning and continued till evening 0600 h. Observation on foraging intensity in different ornamental plants, it was

highest (9.91 flowers 10 min<sup>-1</sup>) during 1000 – 1200 h and was least (0.15 flowers 10 min<sup>-1</sup>) during 0500 – 0600 h. Maximum foraging activity in *A. leptopus*, and *R. bourboniana* was during 1100 h to 1200 h and *Nymphaea* sp. was 1000 h to 0100 h.

Maximum foraging rate was observed among different ornamental plants, during 1000-0100 h. Among the year round flowering plants, *A. leptopus* (5.02) was showing highest foraging rate followed by *M. arboreus* (4.87). In nectar and pollen providing plants maximum foraging rate was observed in *M. arboreus* (4.87). Foraging activity of pollen foragers was highest in *S. romanzoffiana* (51.83) followed by *R. bourboniana*. Maximum foraging rate in *A. leptopus* was observed during 1100 h to 1200 h and *M. arboreus* was during 1000 - 1200 h. Maximum foraging speed was observed in *Nymphaea* sp (28.54 sec) and *M. arboreus* (26.47sec) and peak foraging speed was recorded during 1000 – 1200 h (2.51 to 30.44 sec).

Significant positive correlation was observed with temperature and number of foragers in case of *A. leptopus*, *C. pulcherrima*, *P. grandiflora*, *J. pandurifolia*, *S. romanzoffiana*, *R. bourboniana* and *E. mili* (R= 0.213 to 0.454). Significant negative correlation was observed between relative humidity and number of foragers in case of *A. leptopus*, *H. patens*, *Nymphaea* sp, *C. pulcherrima*, *P. grandiflora*, *J. pandurifolia*, *M. arboreus*, *C. constrictum*, *S. romanzoffiana* and *Rosa* spp (R= -0.157 to -0.401).

Significant negative correlation was found between rainfall and number of foragers in case of *A. leptopus*, *H. patens*, *J. pandurifolia*, *S. romanzoffiana*, *R. bourboniana*, (R= -0.068 to -0.675) whereas significant positive correlation was observed in *Nymphaea* sp, *C. constrictum*, *E. mili*, *P. grandiflora*, *I. chinensis*, *T. erecta*. Significant positive correlation was recorded with sunshine hours and foraging rate in *A. leptopus*, *H. patens*, *C. pulcherrima*, *J. pandurifolia*, *C. constrictum*, *M. arboreus*, *Rosa* spp, and *R. bourboniana* (R= 0.384 to 0.652) while significant negative correlation was found between sunshine hours and number of foragers in case of *I. chinensis* (R= -0.523).

Floral calendar was prepared on the basis of availability of nectariferous and polleniferous plants. Ornamental plants available throughout the year were, *A. leptopus*, *H. patens*, *P. grandiflora*, *Nymphaea* sp, *M. arboreus*, *C. pulcherrima*, *C. constrictum* and *J. pandurifolia* and *R. bourboniana*, *Rosa* spp, *S. romanzoffiana*, *P. aculeate*, *H. annuus*, *Z. elegans*, *T. capensis*, *I. chinensis*, *T. erecta* and *E. mili* were seasonal plants. The maximum reported bee flora was observed during the honey flow season, January to March and the

minimum stingless bee flora blooms during dearth season, July to September. The nectar providing plants that can be included during dearth period are *A. leptopus* and *H. patens*, and pollen providing plants to be included were *P. grandiflora*, *Nymphaea* sp, *R. bourboniana* and *Z. rosea*. The plants that provide both nectar and pollen during dearth period are *M. arboreus*, *C. pulcherrima*, *J. pandurifolia*, *C. constrictum*.

This study revealed that *T. travancorica* collected nectar from two ornamental plants whereas bees collected pollen from 10 plant species, and both nectar and pollen were collected from 8 floras. Among the various year round flowering plants producing nectar and pollen, peak foraging activity was observed during the month of January to March and the foraging activity of bees varied in a day with the peak foraging activity during 1000 h to 0100 h. Bee floral calendar was prepared using data from year-round observation which is helpful for bee keepers to have a map of nectar and pollen ornamental sources in their area.

## ***REFERENCES***

## 7. REFERENCES

- Abou-Shaara, H. F. 2013. Foraging behavior of honey bee. *Veterinari Medicina*. 59 (1): 1–10.
- Adhikari, S. and Ranabhat, N.B. 2011. Bee flora in mid hills of Central Nepal. *J. Plant Sci.* 8 (4):45-56.
- Ahmed, B. and Rehman, A. 2002. Population dynamics of insect foragers and their effect on seed yield of rapeseed (*Brassica campestris* L. var. *toria*). *Indian Bee J.* 64(3-4):1-5.
- Akter, A., Biella, P. and Klecka, J. 2017. Effects of small-scale clustering of flowers on pollinator, foraging behaviour and flower visitation rate. *PloS one*. 12(11):76.
- Aleixo, K.P., de Faria, L.B., Garofalo, C.A., Fonseca, V.L.I. and da Silva, C.I. 2013. Pollen collected and foraging activities of *Frieseomelitta varia* (Lepeletier) (Hymenoptera: Apidae) in an urban landscape. *Sociobiology*, 60(3):266-276.
- Aleixo, K.P., Menezes, C., Imperatriz Fonseca, V.L. and da Silva, C.I. 2017. Seasonal availability of floral resources and ambient temperature shape stingless bee foraging behavior (*Scaptotrigona* aff. *depilis*). *Apidologie*. 6(1): 117-127.
- Alqarni, A.S. 2006. Tolerance of summer temperature in imported and indigenous honeybee *Apis mellifera* L. races in central Saudi Arabia. *J. Biol. Sci.* 13(2):123-127.
- Azmi, W.A., Zulqurnain, N.S. and Ghazi, R. 2015. Melissopalynology and foraging activity of stingless bees, *Lepidotrigona terminata* (Hymenoptera: Apidae) *J. Sustain. Sci. Manag.* 10(1): 27-35.
- Azuma, H., Toyota, M., Asakawa, Y., Takaso, T. and Tobe, H. 2002. Floral scent chemistry of mangrove plants. *J. Plant. Res.* 115: 47-53.
- Bhargava, H.R., Jyothi, J.V.A., Bhushanam, M. and Surendra, N.S. 2009. Pollen analysis of *Apis* honey, Karnataka, India. *Apiacta*, 44(5):14-19.
- Bhalchandra, W., Baviskar, R.K. and Nikam, T.B. 2014. Diversity of nectariferous and polleniferous bee flora at Anjaneri and Dugarwadi hills of Western Ghats of Nasik district (MS) India. *J. Entomol. Zool. Stud.* 2(4): 244-249.
- Bharath, M.P., Chinniah, C., Jayaraj, J., Suresh, K., Balamohan, T.N. and Vellaikumar, S. 2020. Foraging activity of stingless bee, *Tetragonula iridipennis* smith (Hymenoptera: Apidae) during summer season in Madurai district of Tamil Nadu, India. *J. pharmacogn. Phytochem.* 9(1): 144-148.

- Biesmeijer, J.C., Smeets, M.J., Richter, J.A. and Sommeijer, M.J. 1999. Nectar foraging by stingless bees in Costa Rica: botanical and climatological influences on sugar concentration of nectar collected by *Melipona*. *Apidologie*. 30(1):43-55.
- Biesmeijer, J.C. and de Vries, H. 2001. Exploration and exploitation of food sources by social insect colonies: a revision of the scout-recruit concept. *Behav. Ecol. Sociobiol.* 49(2): 89-99.
- Bomfim, I.G.A., de Melo Bezerra, A.D., Nunes, A.C., de Aragao, F.A.S. and Freitas, B.M. 2014. Adaptive and foraging behavior of two stingless bee species in greenhouse mini watermelon pollination. *Sociobiology*, 61(4):502-509.
- Campos, M., Markham, K.R., Mitchell, K.A. and da Cunha, A.P. 1997. An approach to the characterization of bee pollens via their flavonoid/phenolic profiles. *Int.J. Plan. Chem. Biochem. Technol.* 8(4):181-185.
- Chaudhary, O.P. 2001. Bee forage and floral calendar of India. In *Yadav PR* (eds), *Recent advances in Apiculture*. Haryana Agricultural University, Hisar. 61-65p.
- Cooper, P. D. and Schaffer, W.M. 1985. Temperature regulation of honey bees (*Apis mellifera*) foraging in the Sonoran desert. *J. Exp Bio.* 114:1-1.
- Corbet S.A., Fussell, M., Ake, R., Fraser, A., Gunson, C., Savage, A. and Smith, K. 1993. Temperature and the pollination activity of social bees. *Ecol. Entomol.* 1(8): 17-30.
- Dalio, J. S. 2013. Foraging activity of *Apis mellifera* on *Parthenium hysterophorous*. *J. Pharmacy Biol. Sci.* 7(5):01-04.
- Danaraddi, C.S. 2007. Studies on stingless bee, *Trigona iridipennis* Smith with special reference to foraging behaviour and melissopalynology at Dharwad, Karnataka. M.Sc. thesis. College of Agricultural Science. Dharwad. 202p
- Denisow, B., Strzałkowska-Abramek, M., Bożek, M. and Jeżak, A. 2014. Ornamental representatives of the genus *Centaurea* L. as a pollen source for bee friendly gardens. *J. Apic. Res.* 58(2): 49-58.
- Devanesan, S., Nisha, M.M., Bennet, R. and Shailaja, K.K. 2002. Foraging behavior of stingless bee, *Trigona iridipennis* Smith. *Insect Environment*, 8(3):131-133.
- Devanesan, S., Shailaja, K. K. and Pramila, K.S. 2009. Status paper on stingless bee *Trigona iridipennis* Smith. *All India Coordinated Research Project on Honeybee and Pollinators. KAU, Vellayani, 80.*
- Dobson, H.E. and Bergström, G. 2000. The ecology and evolution of pollen odors. *Plant Syst. Evol.* 222:63-87.

- Dudareva, N. and Pichersky, E. 2006. Floral scent metabolic pathways: their regulation and evolution. *Bio. Flora.* 5: 55-78.
- Dyer, A.G., Boyd-Gerny, S., Shrestha, M., Garcia, J.E., van der Kooi, C.J. and Wong, B.B. 2019. Colour preferences of *Tetragonula carbonaria* Sm. stingless bees for colour morphs of the Australian native orchid *Caladenia carnea* *J. Comp. Physiol.*, 205(3): 347-361.
- Evans, E. and Needham, D. 1987. Physical properties of surfactant bilayer membranes: thermal transitions, elasticity, rigidity, cohesion and colloidal interactions. *J. Phys. Chem.* 91(16): 4219-4228.
- Faegri, K. and Van Der Pijl, L. 2013. Principles of pollination ecology. Elsevier Sci. 256p.
- Flower shapes – The seed site Available: <http://theseedsite.co.uk/flowershapes.html>
- Free, J. B. (ed.).1993. *Insect pollination of crops*. Academic press, New York, 555p.
- Free, J.B.1970. *Insect pollination of crops*. Academic Press, London and New York, 684p
- Gadhiya, V.C. and Pastagia, J.J. 2015. Flowers visited by stingless bees, *Tetragonula laeviceps* Smith. 4(4):323-330.
- Gadhiya, V.C. and Pastagia, J.J. 2019. Time spent by stingless bees, *Tetragonula laeviceps* for nectar and pollen collection from musk melon flower. *J. Entomol. Zool. Stud.* 7(1): 498-500.
- Galetto, L., Bernardello, G. and Sosa, C.A. 1998. The relationship between floral nectar composition and visitors in *Lycium* (Solanaceae) from Argentina and Chile: *Flora.* 193(3):303-314.
- Ghazi, R., Azmi, W.A., Jaapar, M.F. and Hassan, N.B. 2014. Foraging Activities of Stingless Bee (Hymenoptera: Apidae: *Hetrotrigona itama*). *Int. Sym. Insec.* 4:21-28.
- Ghosh, S., Jeon, H. and Jung, C. 2020. Foraging behaviour and preference of pollen sources by honey bee (*Apis mellifera*) relative to protein contents. *J. Ecol. Environ.* 44 (2):1-7.
- Gopinath, P.P., Parsad, R., Joseph, B., and Adarsh, V.S.2021. Grapes Agril: Collection of shiny apps for data analysis in agriculture. *J. Open source Software* 6(63):3437-3441.
- Hemalatha, D., Jayaraj, J., Murugan, M., Balamohan, T.N., Senthil, N., Chinniah, C. and Suresh, K. 2018. Foraging performance of Indian honey bee *Apis cerena indica* (F.), during winter in Madurai district of Tamil Nadu, India. *J. Entomol. Zool. Stud.* 6(3): 224-227.
- Hilario, S.D., Imperatriz-Fonseca, V.L. and Kleinert, A.D.M.P. 2001. Responses to climatic factors by foragers of *Plebeia pugnax* Moure (in litt.)(Apidae, Meliponinae). *Revista Brasileira de Biologia.* 61(1):191-196.
- Hosamani, V., Kattimani, K.N., Nidagundi, R., Gangadharappa, P.M. and Lokesh, M.S.2018.

Diversity of nectariferous and polleniferous bee flora and floral calendar of

- honey bees in dryland regions of Koppal District. *J. Pharm. Phytochem*, 7(3): 362-366.
- Jaiswal, A.S.D.K. and Thakur, H.S.R.2016. Diversity of Bee flora and Floral Calendar of Native Honeybees in Nagaland, India. *Advances*, 2285 p.
- Joshi, N. C. and Joshi, P.C.2010. Foraging behaviour of *Apis* spp. on Apple flowers in a subtropical environment. *New York J.*3:71-76
- Kajobe, R. 2007. Botanical sources and sugar concentration of the nectar collected by two stingless bee species in a tropical African rain forest. *Apidologie*. 38(1):110-121.
- Kaur, G. and Sihag, R.C.1994. Effects of weather factors on the colony of honeybee. *Apis mellifera*, 1:3-4.
- Kevan, P.G. and Baker, H.G. 1983. Insects as flower visitors and pollinators. *Annu. Rev. Entomol.* 28(1):407-453.
- Kim, W., Gilet, T. and Bush, J.W. 2011. Optimal concentrations in nectar feeding. *Proc. Natl. Acad. Sci.* 108(40):16618-16621.
- Kovac, H. and Stabentheiner, A. 2011. Thermoregulation of foraging honeybees on flowering plants: seasonal variability and influence of radiative heat gain. *Ecol. Entomol.* 36(6):686-699.
- Kumar, R., Rajput, G.S., Mishra, R.C. and Agrawal, O.P. 2013. A study on assessment of duration of dearth period for Honey bees in Haryana, India. *Entomol. Zool.* 8(1): 434-437.
- Kumar, D., Sharma, V. and Bharti, U.2015. Mapping of medicinal flora as honey bee forage. *J. Entomol. Zool. Stud* 3(6): 235-248.
- Kumari, P.K. 2004. Floral resources of honeybee plant species at Visakhapatnam, Andhra Pradesh, India. *J. Apic.* 19(1):43-50
- Layek, U. and Karmakar, P. 2018. Nesting characteristics, floral resources, and foraging activity of *Trigona iridipennis* Smith in Bankura district of West Bengal, India. *Insectes sociaux*. 6(5):117-132.
- Liu, F.L., Zhang, X.W., Chai, J.P. and Yang, D.R. 2006. Pollen phenolics and regulation of pollen foraging in honeybee colony. *sociobiology*, 582-588p.
- Lorenzon, M.C.A., Rodrigues, A.G. and Desouza, J. 1993. Behavior of *Trigona-spinipes* (Hymenoptera, Apidae) on flowering onion fields. *J. Agric. Res.* 28(2):217-221.
- Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the Folin phenol reagent. *J. Biol. Chem.* 193: 265-275.

- Maity, A., Chakrabarty, S.K. and Yadav, J.B. 2014. Foraging behaviour of honeybees (*Apis* spp.)(Hymenoptera: Apidae) in hybrid seed production of Indian mustard (*Brassica juncea*). *Indian J Agric Sci.* 84(11):1389-1394.
- Melendez-Ramirez, V., Magana-Rueda, S., Parra-Tabla, V., Ayala, R. and Navarro, J. 2002. Diversity of native bee visitors of cucurbit crops (Cucurbitaceae) in Yucatan, Mexico. *J. Insect Conserv.* 4:135-147.
- Michener, C. 2000. *The Bees of the World*. Baltimore & London, Maryland, The John Hopkins University Press, 913p.
- Mishra, R. C. and S. K. Sharma. 1997. Technology for management of *Apis mellifera* in India. In: R. C. Mishra (eds.) *Perspectives in Indian Apiculture*. 131-148 p.
- Muthuraman, M., Sanjay Jose, K., Mohankumar, S. and Vijay Kumar, K. 2013. Bio ecology of stingless bee *Trigona irridipenis* Sm. and evolving improved meliponiculture techniques. In Virektmath S., Fakrudin B., Vastval A. S. and Mohankumar S. (eds) *Coordinator Network Project on honeybees and stingless bees*, Dharwad, Karnataka, 172-188p.
- Nunez Avellaneda, L.A. and Carreno, J.I. 2017. Polinization on *Syagrus orinocensis* (Arecaceae). *Biologica*, 22(2):221-233.
- Nunes-Silva, P., Hrcncir, M., da Silva, C.I., Roldao, Y.S. and Imperatriz-Fonseca, V.L. 2013. Stingless bees, *Melipona fasciculata*, as efficient pollinators of eggplant (*Solanum melongena*) in greenhouses. *Apidologie*, 44:537-546.
- Oliveira-Abreu, C., Hilario, S.D., Luz, C.F.P. and dos Santos, I.A. 2014. Pollen and nectar foraging by *Melipona quadrifasciata* (Hymenoptera: Apidae: Meliponini) in natural habitat. *Sociobiology*, 61(4):441-448.
- Ordonez, A.A.L., Gomez, J.D. and Vattuone, M.A. 2006. Antioxidant activities of *Sechium edule* (Jacq.). *Food chemistry*. 97(3): 452-458.
- Pacini, E. 2000. Anther and pollen ripening to pollen presentation. In: Dafni A., Hesse M., Pacini E. (eds) *Pollen and pollination*, Springer, Vienna.19-43p.
- Painkra, G.P. and Kumaranag, K.M., 2019. Foraging activity of stingless bee, *Tetragonula iridipennis* Smith (Hymenoptera-Apidae-Meliponinae) in sunflower. *J.plant. dev. Sci.* 11(8): 463-466.
- Panda, P., Sontakke, B.K. and Panda, B. 1993. Effect of different modes of pollination on yield of sunflower and niger. *J. Insect Sci.*6: 75-77
- Pernal, S.F. and Currie, R.W. 2001. The influence of pollen quality on foraging behavior in honeybees (*Apis mellifera* L.). *Behav. Ecol. Sociobiol.*51:53-68.

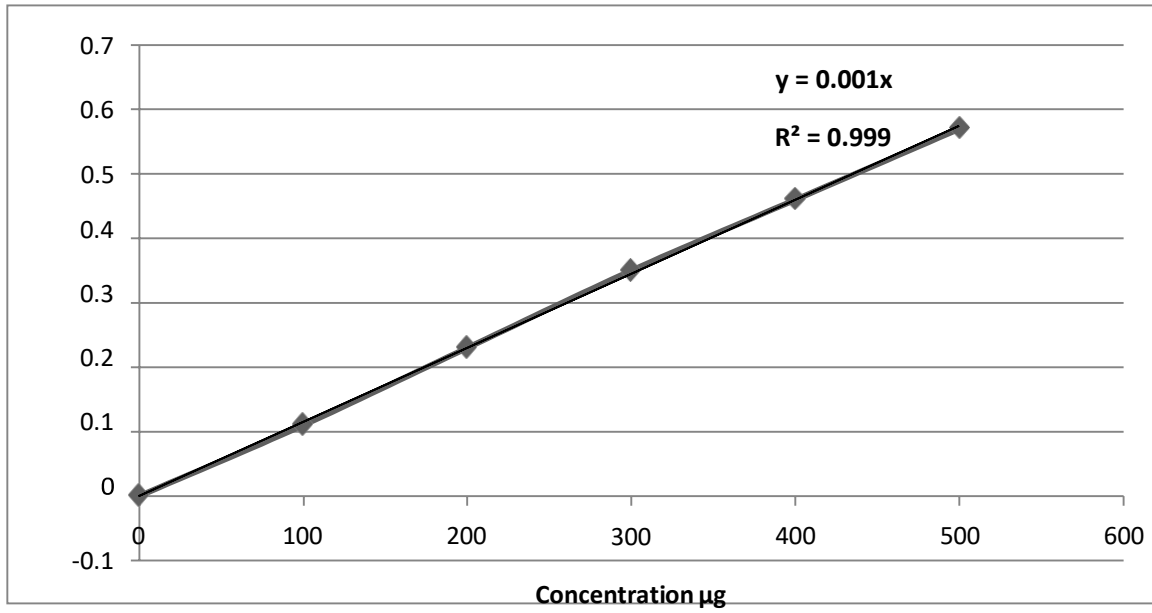
- Ponnuchamy, R., Bonhomme, V., Prasad, S., Das, L., Patel, P., Gaucherel, C., Pragasam, A. and Anupama, K. 2014. Honey pollen: using melissopalynology to understand foraging preferences of bees in tropical South India. *PLoS One*, 9(7): 1-11.
- Premila, K. S., Devanesan, S., Arthur Jacob, J. and Shailaja, K. K. 2007, September. Foraging plants of stingless bee, *Trigona iridipennis* Smith *All India Coordinated Research Project on Honeybee and Pollinators*. KAU, Vellayani, 80p.
- Raju, A.S., Muthuraman, M., Viraktamath, S., Devanesan, S., Abrol, D.P. and Rahman, A. 2013. Foraging sources of honey bees and stingless bees. *Monograph on Morphometry and phylogeography of honey bees and stingless bees in India* 158p.
- Raju, A.J.S., Raju, V.K., Victor, P. and Naidu, S.A. 2001. Floral ecology, breeding system and pollination in *Antigonon leptopus* L. (Polygonaceae). *Plant Species Biology*, 16(2):159-164.
- Ramalho, M., 2004. Stingless bees and mass flowering trees in the canopy of Atlantic Forest: a tight relationship. *Acta Botanica Brasilica*, 18:37-47.
- Reddy, P.R., Rashmi, T. and Verghese, A. 2015. Foraging activity of Indian honey bee *Apis cerana*, in relation to ambient climate variables under tropical conditions. *J. Environ. Bio.* 36: 577-581.
- Reyes-Carrillo, J.L., Eischen, F.A., Cano-Rios, P., Rodriguez-Martinez, R. and Nava Camberos, U. 2007. Pollen collection and honey bee forager distribution in cantaloupe. *Acta Zool. Mex.* 23(1): 29-36.
- Robertson, C., 1889. Flowers and insects. I. *Botanical Gazette*, 14(5):120-126.
- Roubik, D.W. 1979. Nest and colony characteristics of stingless bees from French Guiana (Hymenoptera: Apidae). *J. Kansas. Entomol. Soci.* 443-470p.
- Roubik, D.W. 1980. Foraging behavior of competing Africanized honeybees and stingless bees. *Ecology*, 61(4): 836-845.
- Roubik, D.W. 2006. Stingless bee nesting biology. *Apidologie*. 37(2):124-143.
- Roubik, D.W., Yanega, D., Buchmann, S.L. and Inouye, D.W. 1995. On optimal nectar foraging by some tropical bees (Hymenoptera: Apidae). *Apidologie*. 26(3): 197-211.
- Said, F., Inayatullah, M., Ahmad, S, Iqbal, T., Shah, R. A., Shah, R. A., Usman, A., Zaman, M. and Haq, S. U. 2015. Foraging behavior of the Himalayan Honey bee, *Apis cerana* (Hymenoptera: Apidae) associated with sunflower (*Helianthus annuus*

- L.) at Peshawar District of Khyber Pakhtunkhwa (KP). *J. Entomol. Zool. Stud.* 3(3):203-207.
- Saravanan, P.A. and Alagar, M. 2007. Foraging activity of stingless bee, *Trigona iridipennis* Smith. *J. Plant Prot. Environ.* 4(2): 65-69.
- Singleton, V.L. and Rossi, J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. enol. Vitic.* 16(3): 144-158.
- Silva, D.P., Moisan-De Serres, J., Souza, D.R., Hilgert-Moreira, S.B., Fernandes, M.Z., Kevan, P.G. and Freitas, B.M. 2013. Efficiency in pollen foraging by honey bees: Time, motion and pollen depletion on flowers of *Sisyrinchium palmifolium* L (Asparagales: Iridaceae). *J. Pollinat. Ecol.* 11(3):27-32.
- Singh, S.T. 2005. Bee plant diversity in Southern Peninsular India. Ph. D. thesis, University of Pune, India 101p.
- Sommeijer, M.J., De Rooy, G.A., Punt, W. and De Bruijn, L.L.M. 1983. A comparative study of foraging behavior and pollen resources of various stingless bees (Hymenoptera: Meliponinae) and honeybees (Hymenoptera: Apinae) in Trinidad, West-Indies. *Apidologie.* 14(3):205-224.
- Suryanarayana, M.C., Rao, G.M. and Singh, T.S.M.S. 1992. Studies on pollen sources for *Apis cerana* Fabr and *Apis mellifera* L bees at Muzaffarpur, Bihar, India. *Apidologie.* 23(1):33-46.
- Sushil, S.N., Stanley, J., Hedau, N.K. and Bhatt, J.C. 2013. Enhancing seed production of three Brassica vegetables by honey bee pollination in north-western Himalayas of India. *Univers. j. agric. res.* 1(3):49-53.
- Taha, E.K.A. 2015. Chemical composition and amounts of mineral elements in honeybee collected pollen in relation to botanical origin. *J. Apicul. Sci.* 59(1): 75-81.
- Tej, M.K., Srinivasan, M.R., Vijayakumar, K., Natarajan, N. and Kumar, S.M. 2017. Morphometry analysis of stingless bee *Tetragonula iridipennis* Smith (1854). *Inter. J. Current Micro. Sci.* 6(10): 2963-2970.
- Terrab, A., Diez, M.J. and Heredia, F.J. 2002. Characterisation of Moroccan unifloral honeys by their physicochemical characteristics. *Food chemistry*, 79(3):373-379.
- Thakur, M. and Nanda, V. 2020. Composition and functionality of bee pollen: A review. *Trends Food Sci Technol.* 98: 82-106.
- Vamshikrishna, M. M., Vinaykumar., Venkateshalu, J. B., Gopali, P. S., Ajjappalavara, B. B. Patil. and Prashant. 2021. Foraging flora of stingless bees, *Tetragonula* spp. in

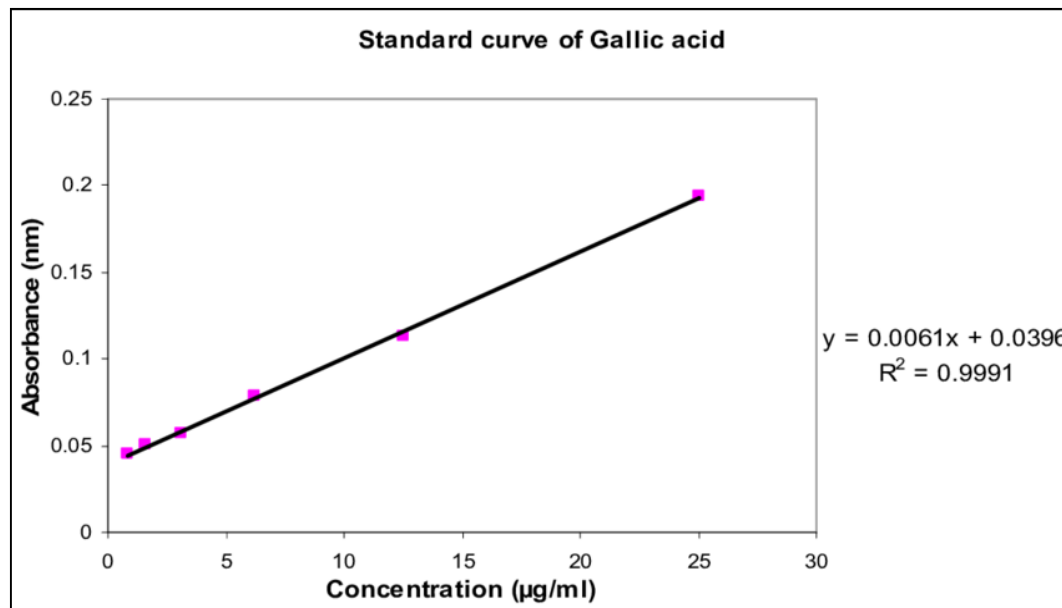
- Bagalkot, Karnataka, India. *J. Exp. Zool. India* 24, 1449-1453. DocID: <https://connectjournals.com/03895.2021.24.1449>.
- Vaudo, A.D., Tooker, J.F., Grozinger, C.M. and Patch, H.M. 2015. Bee nutrition and floral resource restoration. *Current opinion in insect science*, 10 (1): 133-141.
- Vaudo, A.D., Tooker, J.F., Patch, H.M., Biddinger, D.J., Coccia, M., Crone, M.K., Fiely, M., Francis, J.S., Hines, H.M., Hodges, M. and Jackson, S.W. 2020. Pollen protein: lipid macronutrient ratios may guide broad patterns of bee species floral preferences. *Insects*. 11(2):13:2.
- Verma, L.R. 1990. Beekeeping in integrated mountain development: *Economic and scientific perspectives*. 118p.
- Vijayakumar, K. and Jayaraj, R. 2013. Geometric morphometry analysis of three species of stingless bees in India. *International J. Sci. Edu.* 1(2): 91-95.
- Vijayakumar, K. and Jeyaraaj, R. 2016. Floral sources for stingless bees in Nellithurai Village, Tamilnadu, India. *Ambient Science*, 3(2):69-74.
- Vijayan, M., Saravanan, P.A. and Srinivasan, M.R. 2018. Effect of season and timings on the foraging behaviour of stingless Bee, *Tetragonula iridipennis* Smith (Hymenoptera: Apidae). *Madras Agri. J.* 105(7-9):286-90.
- Waykar, B. and Baviskar, R.K. 2015. Diversity of bee foraging flora and floral calendar of Paithan taluka of Aurangabad district (Maharashtra), India. *J. Applied. Hortic.* 1:7-12.
- Wilms, W., Imperatriz-Fonseca. V.L., and Engels, W. 1996. Resource partitioning between highly eusocial bees and possible impact of the introduced Africanized honey bee on native stingless bees in the Brazilian Atlantic rainforest. *Stud. Neotrop. Fauna Environ.* 31(3-4): 137-151.
- Wolff, D. 2006. Nectar sugar composition and volumes of 47 species of Gentianales from a southern Ecuadorian montane forest. *Ann. Bot.* 97(5):767-777.
- Yucel, B. and Duman, I. 2005. Effects of foraging activity of honeybees (*Apis mellifera* L.) on onion (*Allium cepa*) seed production and quality. *J. Bio. Sci.* 8(1):123-126.
- Yadav, G. and Kaushik, H. 2012. Studies on *Apis mellifera* L. Colonies Performance at Hisar, Haryana, India. *Advances*, 725p.
- Zhang, H., Wu, H., Zhou, Q., Zhao, R., Sheng, Q. and Zhu, Z. 2021. Flowering characteristics and reproductive biology of *Nymphaea* hybrid, a precious water lily. *Scientia Horticulturae*, 287p.

## ***APPENDICES***

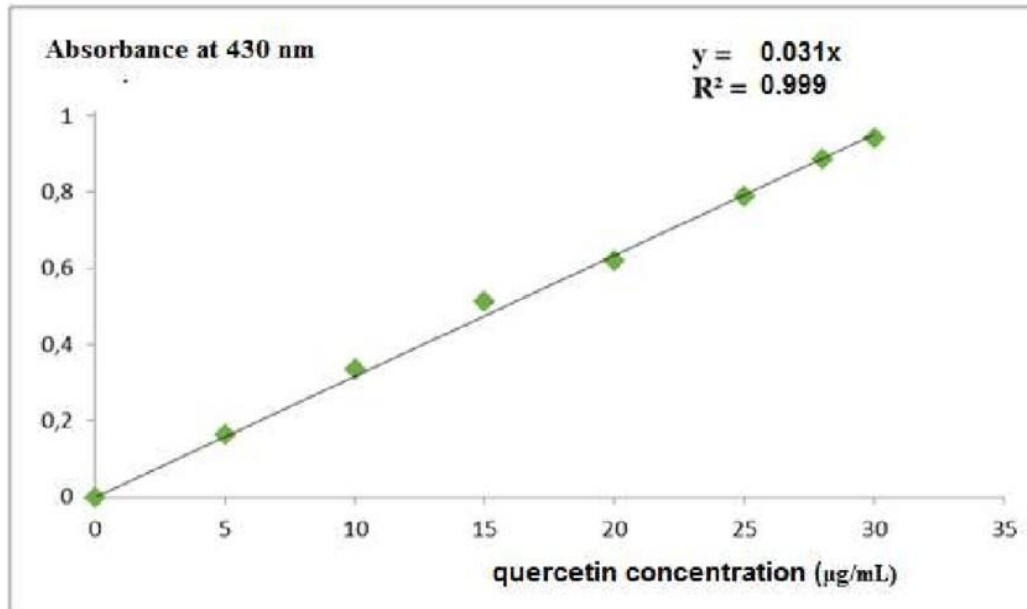
Standard Curve of Bovine Serum Albumin (BSA) for protein estimation



Standard curve for Gallic acid for phenol estimation



Standard curve for Quercetin for flavonoid estimation



## ***ABSTRACT***

## ABSTRACT

The present investigation on “Stingless bee foraging pattern in ornamental plants” was conducted at the Department of Agricultural Entomology, College of Agriculture, Vellayani, during 2020-2022. The objective of the study was documentation of the foraging pattern of stingless bees in nectariferous and polleniferous ornamental plants and preparation of floral calendar. Flowers were observed from identified ornamental plants at full bloom stage and their flowering period and floral characteristics were studied. Foraging activity of stingless bees was studied and observations were recorded from 0700 h to 1800 h from September 2021 to August 2022.

A total of 20 ornamental plant species were identified on the basis of stingless bee foraging for nectar and pollen of which, 9 plant species were found producing flowers year round and remaining as seasonal. Major nectar producing plants were identified as coral vine (*Antigonon leptopus* Hook. and Arn) and scarlet bush (*Hamelia patens* Jacq). Pollen producing plants were identified as moss rose/sun plant (*Portulaca grandiflora* L), water lily (*Nymphaea* sp), rose (*Rosa* spp), scented rose (*Rosa bourboniana* L), ornamental palm (*Syagrus romanzoffiana* cham), lemon vine (*Pereskia aculeate* L), marigold (*Tagetes erecta* L) and sunflower (*Helianthus annuus* I). The ornamental plants providing both nectar and pollen were found to be hibiscus (*Malvaviscus arboreus* B, *Hibiscus rosa-sinensis* L), peacock plant (*Caesalpinia pulcherrima* L), chinese powder puff (*Combretum constrictum* L), chinese ixora (*Ixora chinensis* L), cape honey suckle (*Tecoma capensis* L), peregrina/ spicy jatropha (*Jatropha Pandurifolia* L) and euphorbia (*Euphorbia mili* L).

Among the ornamental plants foraged by bees, the predominant family was Asteraceae followed by Rubiaceae, Malvaceae and Euphorbiaceae. The majority of bee flora were of strong orange, yellowish white followed by strong red and vivid reddish orange and tubular and cup-like shapes.

Studies on foraging activity of stingless bee revealed that the peak activity was recorded during January and March with peak foraging activity from 1000 h to 0100 h. Among the year round flowering plants, maximum foraging rate was observed in *Antigonon leptopus* and among seasonal flowering plants, it was *Syagrus romanzoffiana*. Longest time spent by

foragers was recorded as 30.44 sec during 1000-1200h of the day. Maximum time spent was observed in *Nymphaea* sp. followed by *Malvaviscus arboreus*.

Relationship between foraging rate and weather parameters viz temperature, relative humidity, wind velocity, rainfall and sunshine hours were done. Significant positive correlation was observed with temperature and number of foragers in case of *Antigonon leptopus* (0.221), *Caesalpinia pulcherrima* (0.271), *Portulaca grandiflora* (0.402), *Jatropha pandurifolia* (0.454) and *Syagrus romansoffiana* (0.213). Significant negative correlation was observed between relative humidity and number of foragers in case of *Antigonon leptopus* (-0.157), *Hamelia patens* (-0.216), *Nymphaea* sp. (-0.356), *Caesalpinia pulcherrima* (-0.256), *Portulaca grandiflora* (-0.295), *Jatropha pandurifolia* (-0.311), *Malvaviscus arboreus* (-0.142), *Combretum constrictum* (-0.293) and *Syagru sromansoffiana* (-0.401). Significant negative correlation was found between rainfall whereas significant positive correlation was recorded with sunshine hours and foraging rate.

Thus in this study two nectar producing plants, eight pollen providing plants and 10 nectar and pollen producing ornamental plant species were identified. The foraging activity of bees varied in a day with the peak foraging activity during 1000 h to 0100 h. Bee floral calendar was prepared by using data of year round observation which can aid the farmers in providing the identified bee flora in particular month so that the bees can exploit these resources available in their surroundings