Mysore J. Agric. Sci., 57 (1) : 152-158 (2023)

Diversity of Floral Resources of Stingless Bee, *Tetragonula* nr. *pagdeni* (Hymenoptera : Apidae : Meliponini)

M. R. Moulya[1], K. S. Jagadish[2], V. V. Belavadi[3], G. Eswarappa[4] and A. N. Sringeswara[5]
[1&3]Department of Agricultural Entomology, [2&4]Department of Apiculture, [5] Department of Forestry and Environmental Sciences, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : moulyamr533@gmail.com

Authors Contribution

M. R. Moulya : Conceptualization, investigation, original draft preparation and analysis; K. S. Jagadish : Conceptualization, framing research proposal, data curation & draft correction ; V. V. Belavadi, G. Eswarappa & A. N. Sringeswara : Supervision and editing

Corresponding Author :
M. R. Moulya
Department of Agricultural Entomology,
College of Agriculture,
UAS, GKVK, Bengaluru

Received : September 2022
Accepted : January 2023

Abstract

Stingless bees, play an important role as pollinators of many flowering plants. The present study was aimed to know the floral resources foraged by stingless bee, *Tetragonula* nr. *Pagdeni* in Bengaluru, Karnataka through visual observations. Roving surveys were conducted and observation on the stingless bees visiting flowering plants were recorded from June 2021 to May 2022. A Total of 258 bee floral plant species, belonging to 68 different botanical families were documented. Most frequently foraged families were Asteraceae (28 species) and Fabaceae (27 species) followed by Bignoniaceae (14 species), Acanthaceae (11 species), Lamiaceae (10 species), Poaceae (10 species), Cucurbitaceae (9 species) and Solanaceae (8 species), besides 141 plant species coming under 60 other families. The flower colour, shape and size also influenced the foraging efficiency. Greater bee visitation was evident in white and yellow coloured flowers with open shape and small and medium sized flowers as compared to other. These results suggested that the studied site can provide floral resources to stingless bees throughout the year which is an important pre - requisite for maintaining stingless bee populations.

Keywords : Bee flora, Flower anatomy, Flowering period, Nectar source, Pollen source, Pollination, Stingless bees

The Mysore Journal of Agricultural Sciences

Pollinators have co-evolved with flowering plants and many species have a mutualistic relationship. Plant-pollinator interactions bind together food webs, within complex ecosystems and drive co-adaptive evolution among several insect-plant species (Gilbert and Raven, 1980; Williams *et al.,* 1983). Pollination is a crucial ecological service rendered by pollinators that indirectly determines the agricultural productivity (Robacker and Erickson, 1988). More than 85 per cent of the flowering plants depend on insects for pollination (Ollerton *et al*., 2011). Among non-*Apis* bee species, stingless bees, being eusocial, populated this planet 65 million years ago, are considered efficient pollinators of angiosperms with very small flowers, particularly in tropics. Stingless bees are amongst the longest evolved bees and have been found preserved inside pieces of 80-million-year old amber. 22 species of stingless bees belonging to 3 genera namely, *Tetragonula*, *Lepidotrigona* and *Lisotrigona* have been recorded in India (Viraktamath and Roy, 2022). In kannada, stingless bees are known as Nasarujenu or Mujentijenu or Ralajenu or Sollejenu. They are the smallest (4.0 to 5.0 mm length) of the honey bees, which are distributed in most parts of India and form an important group of pollinators in agricultural and natural ecosystems. Stingless bee forage in order to collect valuable floral resources needed for their survival and these include, nectar for energy requirement, pollen for protein and other nutritional needs, water for cooling hives and for metabolic processes, resins and other plant materials for nest

building (Vazhacharickal *et al.,* 2020). The stingless bees have a flight range of only around 500-800m radius from their nest for collecting pollen and nectar which makes them suitable for controlled conditions like green houses, poly houses and precision - horticultural ecosystems which often lack insect pollinators. These are potentially the most promising pollinator species because of their small size hence they can visit even the smallest flowers. They can survive under varying temperatures between 18-36 °C and can build their nest with low cost, easily available materials. Their hives could be placed hanging on the sunshades of houses, open porches or in the farm by using bee hive stands (Dollin and Heard, 1999).

The present study aims to understand the availability of various bee floral resources for stingless bees, their flowering period and source of rewards (pollen or nectar or both) and to know whether the shape, colour and size of flowers influence their foraging behaviour.

Material and Methods

The present study was conducted at the Gandhi Krishi Vigyana Kendra (GKVK) campus, UAS, Bengaluru (13.0713 - 13.0801^0 N, 77.5785 - 77.5905^0 E), which represents Eastern - Dry Zone of Karnataka, India during June 2021 to May 2022 with an objective to understand the diversity of floral resources available for stingless bees.

Periodic surveys on flowering plants was conducted and documented at fortnightly intervals for one year, with a view to identify the major nectar and pollen yielding plants in the study area. The plant samples were collected and their botanical features were documented, besides the bee flora was identified with the technical help of Botanist at the Department of Forestry and Environmental Sciences, UAS, GKVK, Bengaluru.

The plants were classified as a nectar source, when the bees insert the proboscis into the flower for sipping the nectar and as a pollen source, when the corbiculae got loaded with pollen during foraging. When both the activity was observed on the same plant, the plant was categorised as a source for both nectar and pollen. The richness of the source was judged by observing the number of bees involved and time spent by the bees to collect one load.

The plant was judged as bee flora based on field observations and as per the methodology suggested by Waykar and Baviskar (2015). Blooming periods of the plants were also recorded. In relation to the visitation by stingless bee foragers, data was recorded at fortnightly intervals for one-year period during June 2021 to May 2022 for construction of a floral calendar. This bee floral calendar comprising of flowering period, colour of the flower, shape and size of flower, its family and richness of the source (whether nectar source or pollen or both nectar and pollen source) was prepared in order to document the availability of food sources of stingless bees in the study area year round. Flower size was categorized based on visual observation: if the flower size was >3cm it was considered as large flower, if the flower size ranged from 1-3cm it was considered as medium flower and if it was <1 cm, then it was categorized into small flower group Waykar and Baviskar (2015).

Results and Discussion

The present study revealed that *Tetragonula* nr. *pagdeni* was found to forage on 258 bee floral species in UAS, GKVK, Bengaluru. The bee flora included 103 ornamental plant species (39.92%), 29 medicinal and aromatic plant species (11.24%), 21 vegetable crop species (8.14%), 13 fruit and plantation crop species (5.04%), 38 weed species (14.73%), 40 tree species (15.50%), 11 oilseed and pulse crop species (4.26%) and 3 field crops (1.16%) (Table 1 & Fig. 1). These findings are in accordance with those of Vijayakumar and Jeyaraaj (2016) who reported that 45 plant taxa belonging to 29 families and non-floral sources were utilized by *Tetragonula iridipennis* for pollen, nectar and resin. The families Arecaceae and Fabaceae had a significant importance amongst the samples. Coconut, sunflower and banana pollen types occurred most constantly among the samples collected from Nellithurai Village, Tamilnadu. About 140 plant species were recorded as bee forage sources in Dharwad, Karnataka, India,

The Mysore Journal of Agricultural Sciences

TABLE 1

Category-wise abundance and distribution of bee floral resources available for *Tetragonula* nr. *pagdeni*

Categories of the plant	No. of plants species foraged by *T.* nr. *pagdeni*	Percentage abundance
Vegetables	21	8.14
Oilseeds and Pulses	11	4.26
Field Crops	3	1.16
Weeds	38	14.73
Fruits and Plantations	13	5.04
Trees	40	15.50
Medicinal and Aromatic plants	29	11.24
Ornamentals	103	39.92
Total	258	

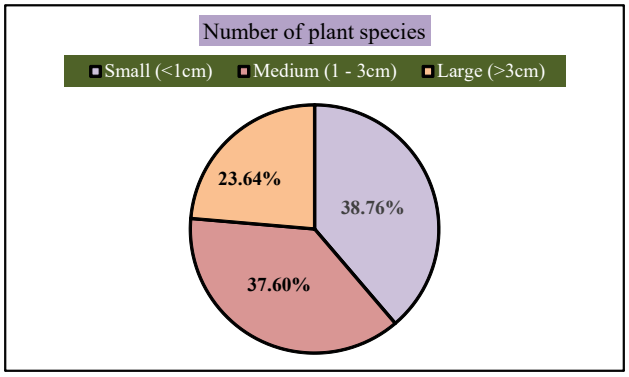

Fig. 1 : Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the size of the flowers

14 were identified as major food sources (Bhat *et al.,* 1990) who gave the details of their frequency of occurrence, whether nectar or pollen source and main flowering period.

Of the 68 botanical families recorded, Asteraceae topped the list accounting for 28 species, followed by the Fabaceae (27 species), Bignoniaceae (14 species), Acanthaceae (11 species), Lamiaceae (10 species), Poaceae (10 species), Cucurbitaceae (nine species), Solanaceae (eight species), Amaranthaceae , Euphorbiaceae and Myrtaceae 6 species each; Amaryllidaceae and Rubiaceae five species each; four species each of Apiaceae, Arecaceae, Asparagaceae and Moraceae, three species each of Anacardiaceae, Combretaceae, Convolvulaceae, Lythraceae, Malvaceae, Oleaceae and Rosaceae, two species each of Asclepiadaceae, Balsaminaceae, Brassicaceae, Cannaceae, Crassulaceae, Geraniaceae, Nyctaginaceae, Proteaceae, Verbanaceae and Vitaceae; one species each of Annonaceae, Apocyanaceae, Araceae, Araliaceae, Basellaceae, Berberidaceae, Bixaceae, Cacicaceae, Caprifoliaceae, Celestraceae, Chenopodiaceae, Commelinaceae, Costaceae, Dilleniaceae, Heliconiaceae, Magno laceae, Malpighiaceae, Meliaceae, Mimosaceae, Moringaceae, Muntingeaceae, Musaceae, Nymph aeceae, Papavaraceae, Passifloraceae, Pedaliaceae, Plumbaginaceae, Polygonaceae, Rutaceae, Sapota ceae, Scrophulariaceae, Simaroubaceae, Strelitziaceae and Zingiberaceae (Table 2). The present findings are also supported by those of Waykar and Baviskar (2015) who studied the diversity of bee flora and developed a floral calendar for Paithan taluka of Aurangabad district, Maharashtra, where 63 plant species were useful to honeybees as floral resources, out of which 41 were wild and 22 were agri-horticultural cultivated plant species. Vamshikrishna *et al.* (2021) conducted surveys at the College of Horticulture, Udyanagiri and Haveri Campus of University of Horticultural Sciences, Bagalkot, Karnataka and observed the stingless bees floraging on different flowering plant species from September 2019 to March 2020 during peak foraging time. They recorded a total of 30 plant species belonging to 20 different families of which the most preferred families included Apiaceae, Fabaceae, Asteraceae, Amaryllidaceae, Anacardiaceae and Euphorbiaceae.

Flower colour, shape and size acts as visual cues and a structure that allows a specific, co-evolved pollinator to contact the flower's anthers and stigma. In study area we have encountered various coloured flowers having different shapes and sizes and one or the other species of plants are present throughout the year which are rich sources of pollen and nectar and help in bee survival. The present studies revealed white coloured flowers (95 species) constituted about 31.35 per cent and was predominant, followed by flowers with

TABLE 2
Familywise distribution of bee pasturage resources of *Tetragonula* nr. *pagdeni*

Botanical family	No. of bee floral species
Asteraceae	28
Fabaceae	27
Bignoniaceae	14
Acanthaceae	11
Lamiaceae	10
Poaceae	10
Cucurbitaceae	9
Solanaceae	8
Amaranthacea	6
Euphorbiaceae	6
Myrtaceae	6
Amaryllidaceae	5
Rubiaceae	5
Apiaceae	4
Arecaceae	4
Asparagaceae	4
Moraceae	4
Anacardiaceae	3
Combretaceae	3
Convolvulaceae	3
Lythraceae	3
Malvaceae	3
Oleaceae	3
Rosaceae	3
Asclepiadaceae	2
Balsaminaceae	2
Brassicaceae	2
Cannaceae	2
Crassulaceae	2
Geraniaceae	2
Nyctaginaceae	2
Proteaceae	2
Verbanaceae	2
Vitaceae	2
Annonaceae	1
Apocyanaceae	1
Araceae	1
Araliaceae	1
Basellaceae	1
Berberidaceae	1
Bixaceae	1
Cacicaceae	1
Caprifoliaceae	1
Celestraceae	1
Chenopodiaceae	1
Commelinaceae	1
Costaceae	1
Dilleniaceae	1
Heliconiaceae	1
Magnoliaceae	1
Malpighiaceae	1
Meliaceae	1
Mimosaceae	1
Moringaceae	1
Muntingeaceae	1
Musaceae	1
Nymphaeceae	1
Papavaraceae	1
Passifloraceae	1
Pedaliaceae	1
Plumbaginaceae	1
Polygonaceae	1
Rutaceae	1
Sapotaceae	1
Scrophulariaceae	1
Simaroubaceae	1
Strelitziaceae	1
Zingiberaceae	1

yellow colour (65 species) which constituted 21.45 per cent, 45 species of red coloured flowers (14.85 %), 40 species of pink coloured flowers (13.20 %), 26 species of purple colour flowers (8.58 %), 23 species of orange colour flowers (7.59 per cent), violet colour (6 species) constituted 1.98 per cent and blue colour (3 species) contributed 0.99 per cent attracting stingless bee visitation (Table 3). Bosch *et al*. (1997) studied the flowering

TABLE 3

Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the colour of flowers

Colour of the flower	Number of plant species	Percentage
White	95	31.35
Yellow	65	21.45
Red	45	14.85
Pink	40	13.20
Purple	26	8.58
Orange	23	7.59
Violet	6	1.98
Blue	3	0.99

phenology, floral traits and pollinator composition in an herbaceous Mediterranean plant community and stated that yellow coloured flowers attracted more pollinators than the other colour flowers. Sajjanar and Eswarappa (2015) reported that stingless bee foraging in sesamum (2.26 bees / plant / 5min) increased the qualitative and quantitative parameters in sesamum when it has caged with bees as compared to open pollination.

Flower shapes create a distinct design when they bloom. It ranges from open, tubular, trumpet, funnel, bell, star and various other shapes. The shape of flowers is important in facilitating the pollinators they need. Out of 258 plants visited by stingless bees, open shape flowers constituted 58 bee floral species (22.48%), followed by tubular shaped flowers which constituted 31 species (12.02%), trumpet shaped flowers contributed 30 species (11.63%), 25 species had cup shaped flowers (9.69%), 20 species had star shaped flowers (7.75%), 18 species exhibited pea shaped flowers (6.98%), 15 species showed ligulate flowers (5.81%), 11 species each of funnel shaped and salverform shaped (4.26%), 10 species were labiate flowers (3.88%), seven species had bell shaped flowers (2.71%), five species of bee flora had urceolate and saucer shaped flowers and each contributed 1.94 per cent, each of the four species had campanulate and cruciform flowers which constituted 1.55 per cent, three species had bowl shaped flowers (1.16%) and one species of bee flora had coronate flowers contituting 0.39 per cent (Table 4).

TABLE 4

Foraging activity of *Tetragonula* nr. *pagdeni* in relation to the shape of the flowers

Shape of the flower foraged	Number of plant species	Percentage
Open	58	22.48
Tubular	31	12.02
Trumpet	30	11.63
Cup	25	9.69
Star	20	7.75
Pea	18	6.98
Ligulate	15	5.81
Funnel	11	4.26
Salverform	11	4.26
Labiate	10	3.88
Bell	7	2.71
Urceolate	5	1.94
Saucer	5	1.94
Campanulate	4	1.55
Cruciform	4	1.55
Bowl	3	1.16
Coronate	1	0.39
Total	258	100.00

Among the 258 plant species that were encountered, 100 species had smaller sized flowers (38.76 %), 97 plant species had medium sized flowers (37.60%) and 61 plant species had large sized flowers (23.64%) contributed stingless bee visitation. It clearly implied that > 70 per cent of the flowers which were small and medium sized ones were more preferred for visitation by stingless bees as compared to large sized flowers (Fig. 2).

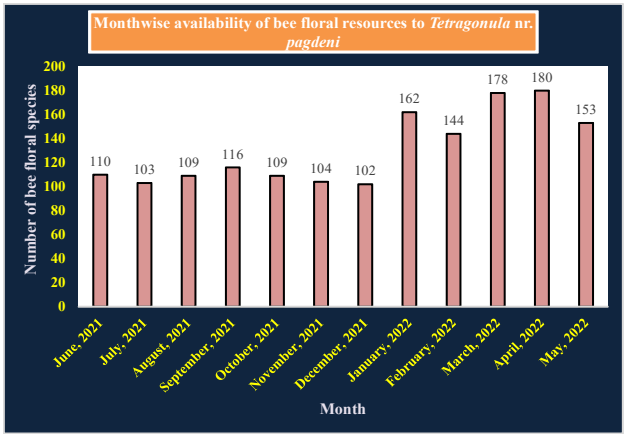

Fig. 2 : Monthwise availability of flowering plants for

Availability of nectar and pollen, the main food source for honey bees are the two chief nutritional resources affecting survival, abundance and distribution of bees. The plants which provide both nectar and pollen are known as 'bee floral plants' or 'bee pasturage'. The interaction between bees and the food plants needs to be properly understood for better management and commercial exploitation of bee colonies to fulfill the human needs. Among the forage plants, in vegetables three species offered only pollen and 18 species provided both; among ornamentals 24 species offered nectar, eight species provided pollen and the remaining 71 provided both; 21 species of medicinal and aromatic plants provided both nectar and pollen; seven species were offered nectar and only one species was a pollen source; 19 species of weeds provided both nectar and pollen, 11 weed species give only nectar and eight weed species provided only nectar; two species of field crops provided only pollen and only one species offered both pollen and nectar, 28 species of trees provided both pollen and nectar, four species gave only pollen and eight species provided only nectar; 10 species of fruit and plantation crops provided both pollen and nectar, two species of fruit and plantation crops gave only pollen and one species provided only nectar and 11 species of oilseeds and pulses provided both pollen and nectar to the stingless bee (Table 5).

TABLE 5

Floral rewards for *Tetragonula* nr. *pagdeni* from different bee flora

Bee floral category	Only pollen source (P)	Only nectar source (N)	Both P + N
Vegetables	3	0	18
Medicinal and Aromatic crops	1	7	21
Ornaments	8	24	71
Field Crops	2	0	1
Weeds	11	8	19
Trees	4	8	28
Fruits and Plantation	2	1	10
Oilseeds and Pulses	0	0	11

Bee pasturage was available for stingless bees throughout the year at GKVK, Bengaluru. From June 2021 to May 2022, 110, 103, 109, 116, 109, 104,102, 162, 144, 178, 180 and 153 bee floral were recorded, respectively. This figure indicated that the maximum visitation of stingless bees was during April, March, January, February and May, where the maximum sunshine hours and less rainfall conditions are present. These bees were active during sunny days. Due to the availability of bee flora during the entire year will be greatly congenial for maintaining stingless bee colonies at GKVK campus which in turn helps in pollination and ensuring the bio-diversity of this campus besides giving honey which is rich in medicinal value. The current findings are also supported by those of Basari *et al.* (2021) revealed that both nectar concentration and flower morphology are important factors for the bees in choosing their food sources. Gadhiya and Pastagia (2015) studied the flowers visited by stingless bees, *Tetragonula laeviceps* Smith and reported that 34 different plant species were visited by stingless bees including cucumber, onion, radish, cauliflower, tomato, brinjal and chilli, fruit crops like coconut, papaya, banana, mango, guava, muskmelon and watermelon; oilseed crops like mustard, castor, sunflower, niger and sunhemp; pulse crops namely greengram, blackgram and cowpea. The ornamental flower plants visited by stingless bees were hibiscus, hamelia, gardenia, ixora, chrysanthemum, turnera, gaillardia and gultora.

From the present study, it could be inferred that the stingless bees have an ability to visit a wide range of flowers like, vegetable crops, fruit crops, plantation crops, oilseed crops, pulse crops, ornamentals, weeds, trees, medicinal and aromatic crops. For bee visitation flower structure like shape, colour and size are one of the major criteria. The present findings prove that flower architecture is crucial while ensuring continuous availability of bee floral resources for sustenance of meliponiculture at a particular geographical location.

Acknowledgement : The authors are thankful to the Department of Agricultural Entomology/ Apiculture/ Forestry and Environmental Sciences, UAS,

Bangalore for providing research facilities, besides Department of Science and Technology for financial support in the form of DST-INSPIRE fellowship awarded to the first author to conduct this study.

References

Basari, N., Ramli, S. N., Abdul-Mutalid, N. A., Shaipulah, N. F. M. and Hashim, N. A., 2021, Flowers morphology and nectar concentration determine the preferred food source of stingless bee, *Heterotrigona itama*. *J. Asia Pac. Entomol.*, **24** (2) : 232 - 236.

Bhat, N. S., Manjunath, M. and Lingappa, S., 1990, Studies on bee flora of transitional zone of Karnataka. *Mysore J. Agric. Sci*., **24** (4) : 463 - 470.

Bosch, J., Retana, J. and Cerda, X., 1997, Flowering phenology, floral traits and pollinator composition in a herbaceous Mediterranean plant community. *Oecologia,* **109** (4) : 583 - 591.

Dollin, A. and Heard, T. A., 1999, Tips on stingless beekeeping by Australian beekeepers, *Native Bees of Australia,* **7** (1) : 1 - 17.

Gadhiya, V. C. and Pastagia, J. J., 2015, Flowers visited by stingless bees, *Tetragonula laeviceps* Smith. *AGRES,* **4** (4) : 323 - 330.

Gilbert, L. E. and Raven, P. H., 1980, Coevolution of animals and plants. *Symposium V, First Inter national Congress of Systematic and Evolutionary Biology*. University of Texas Press, 1973.

Ollerton, J., Winfree, R. and Tarrant, S., 2011, How many flowering plants are pollinated by animals? *Oikos*, **120** (3) : 321 - 326.

Robacker, D. C. and Erickson, E. H., 1988, Floral aroma: How far will plants go to attract pollinators? *Biosci.*, **38** (6) : 390 - 398.

Sajjanar, S. M. and Eswarappa, G., 2015, Bee pollination in crop production of sesame (*Sesamum indicum* L.). *Mysore J. Agric. Sci*., **49** (4) : 703 - 707.

Vamshikrishna, N., Vinaykumar, M. M., Venkateshalu, J. B. and Ajjappalavara, P. S., 2021, Foraging flora of stingless bees, *Tetragonula* spp. in Bagalkot, Karnataka, India. *J. Exp. Zool.,* **24** (2) : 1449 - 1453.

Vazhacharickal, P. J., Jagadish, K. S., Eswarappa, G. and Anil, G. B., 2020, An overview of global meliponi culture with a special focus to Kerala, India, *Int. J. Curr. Res.,* **8** : 2347 - 3215.

Vijayakumar, K. and Jeyaraaj, R., 2016, Floral sources for stingless bees in Nellithurai village, Tamilnadu, India. *Ambient. Sci.*, **3** (2) : 22 - 25.

Viraktamath, S. and Roy, J., 2022, Description of five new species of *Tetragonula* (Hymenoptera : Apidae : Meliponini) from India. *Biologia*, **77** : 1769 - 1793.

Waykar, B. and Baviskar, R. K., 2015, Diversity of bee foraging flora and floral calendar of Paithan taluka of Aurangabad district (Maharashtra), India. *J. Appl. Hortic.,* **17** (2) : 155 - 159.

Williams, K. S., Lincoln, D. E. and Ehrlich, P. R., 1983, The co-evolution of *Euphydryas chalcedona* butterflies and their larval host plants. *Oecologia,* **56** (2) : 323 - 329.