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SHORT NOTE

Non-Apis bee diversity in an experimental pollinator garden in Bengaluru – a Silicon Valley of India

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Abstract
Pollinators are important providers of ecosystem services through plant and crop pollination. However, pollinator population/colony decline has raised concern for their conservation in farm lands as well as in urban areas. Given the need for conservation of these pollinators, we developed a pollinator garden at Yelahanka Campus of ICAR-National Bureau of Agricultural Insect Resources in an area of one acre by planting over 50 plant species. Thirty-nine species of bees were documented from the flora of the pollinator garden. Out of the thirty-nine species of bees, nineteen species of bees belong to non-*Apis* families viz., Megachilidae and Halictidae. Apart from foraging on the flowers, the solitary bees like *Megachile* sp. were found nesting in the stems, fallen dried flowers in the pollinator garden. The bees were found year-round foraging upon the flora in the pollinator garden. Pollinator garden is a way to provide in-situ conservation of native bees while sustaining the valuable pollination service in various crop plants.

Pollinator insects in agricultural landscapes are dwindling over the years due to the use of agrochemicals, diseases, land fragmentation and rapid urbanization (Biesmeijer et al., 2006; Potts et al., 2010). The intensive agricultural practices make the pollinators and natural enemies devoid of nectar, pollen, shelter, and nesting sites (Cane 2008, Pywell et al., 2011). The easiest and feasible way for conservation of these pollinators could be the maintenance of flora attractive to pollinators such as small patches of pollinator gardens in urban and farmlands, which support them with food and shelter over time. The consequence of such efforts would be the resulting enhancement of pollination service to our food crops. These gardens not only serve as a reservoir of both pollinators and biological control agents like predators and parasitoids but also help in educating the public and enhancing the aesthetic value of the urban and farm ecosystems (Kells et al., 2001; Sheffield et al., 2008). Planting diverse flowering plants in the pollinator garden supports both bee diversity and density in addition to the provision of food and nesting sources for the native bees (Kremen et al., 2002).

An effort has been made to develop two patches (approximately one-acre area) of pollinator gardens in ICAR-NBAIR-Yelahanka Campus. The campus is spread over 8.5 ha area in the North of Bengaluru city (13° 5' 48.8724'' N 77° 33' 59.7168'' E). Over 50 species of plants belonging to diverse families (trees, shrubs, herbs and climbers) were brought from a local state recognized scientific nursery and planted during 2012 and nurtured and observed for their flowering and attractiveness to pollinator insects, especially bees.

We studied forty-six species of plants in the established pollinator gardens. Observations were made on the visitation of different species of bees at 15 days interval over a period of three years (2013-2015). The bees were collected using sweep nets and killed using ethyl acetate. The killed specimens

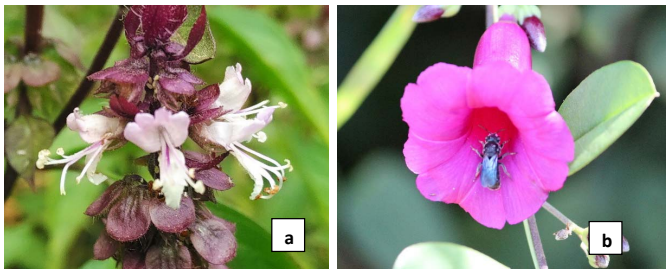
were relaxed and dry mounted for taxonomic identification. Some of the bee specimens were identified using taxonomic keys and others were identified by experts whose names are acknowledged in this publication elsewhere. The plant species were ranked into different categories based on the number of bee species attracted (Table 1, Fig 2) The reward (nectar or pollen) and other nest building materials collected by each species of the bees were recorded.

Thirty-nine species of bees were documented from different species of plants maintained in the pollinator garden (Table 2 & Fig 1). The major plant families attracting the bees in the increasing order of attraction were Lamiaceae (*Ocimum basilicum* and *O. gratissimum*), Convolvulaceae (*Argyreia cuneata* and *Jacquemontia violacea*), Acanthaceae *(Asystasia gangetica*), Asteraceae (*Gaillardia pulchella*), Passifloraceae (*Passiflora edulis*) and Lythraceae (*Woodfordia fruticosa*).

Fig 1. Diverse species of pollinators observed in the pollinator garden.

Argyreia cuneata (Convolvulaceae) was recorded to bloom between April to October, exhibiting attractive purple flowers. The bee activity on this plant was recorded from 0800 hrs to 1500 hrs, between May to October. There was a reduction in its population coinciding with the reduction in the blooming of *A. cuneata. Tetralonia* (*Thygatina*) *macroceps* (Anthophorinae: Apidae) was found to forage only on this species. Another congener, *Argyreia nervosa*, was found to be visited by *Xylocopa* sp. (Xylocopinae: Apidae) and *Lithurgus* sp. (Lithurginae: Megachilidae) but not by *Tetralonia*. The presence and absence of target flora as a determining factor for bee frequencies was reported by Frankie et al. (2009). This behavior shows the floral constancy of the bees. *Tetralonia* (*Thygatina*) sp. was reported to prefer the herbaceous plant *A. populifolia* (Convolvulaceae) (Inoka et al., 2002). Bees belonging to the genus *Thyreus* were recorded to frequently visit *Asystasia gangetica* (Acanthaceae). The tubular flowers present in this plant were found to attract long tongued bees as they have typical landing platform for the bees to rest and collect the reward. Carpenter bees belonging to the genus *Xylocopa* were found to forage on *Calotropis gigantea* (Apocynaceae), performing nectar robbing activity, a common behavior of carpenter bees according to Zhang et al. (2007).

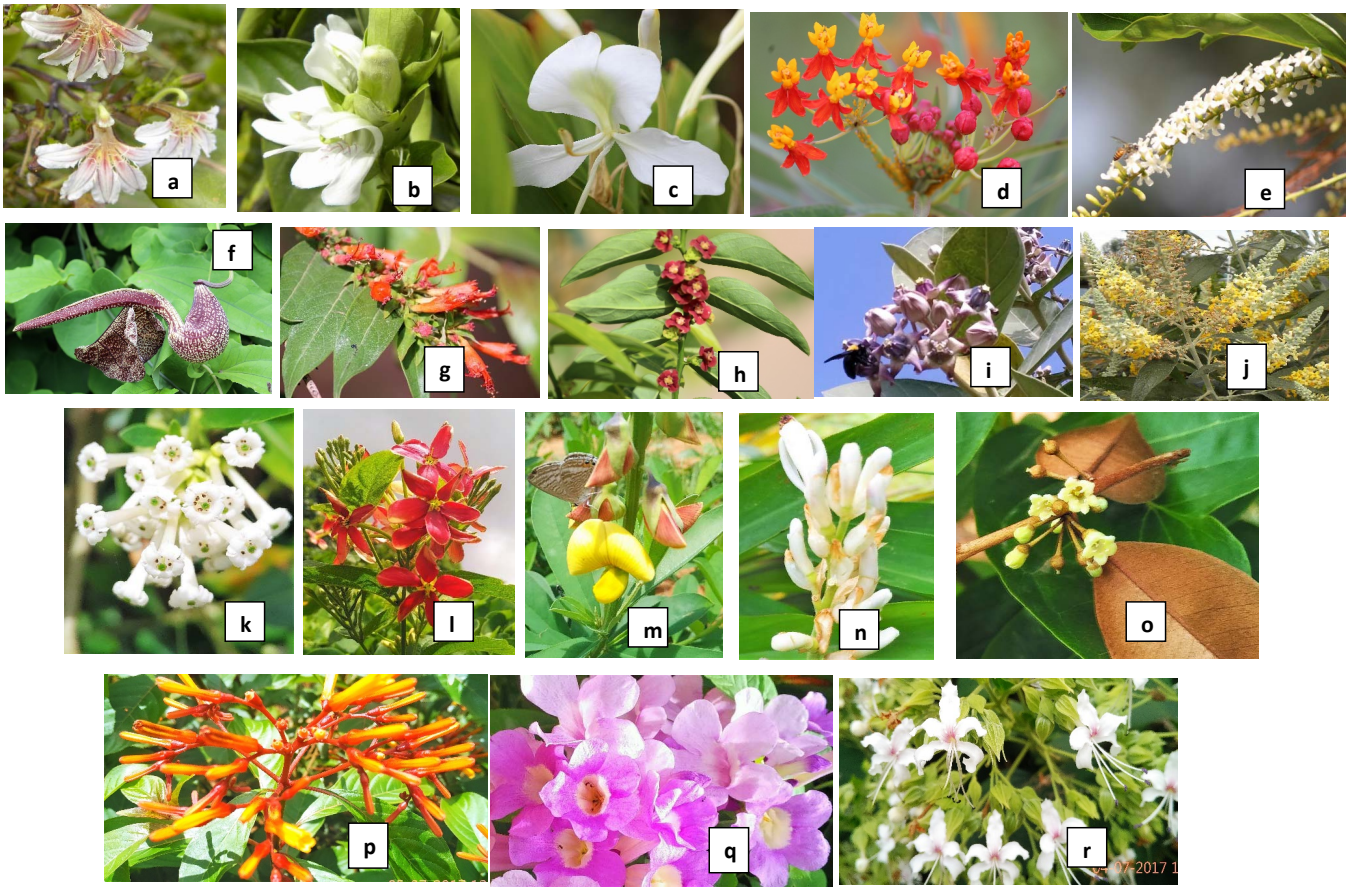
Woodfordia fruticosa (Lyrthaceae) was found to attract leaf cutting species *Megachile anthracina*, which was observed employing leaf bits as resources for nest construction. The nectar rich flowers of *W. fruticosa* were found to be actively foraged upon by the little bees *Apis florea* and *A. cerana. Apis florea* was found to build its nest in the branches of *W. fruticosa* with the ideal proximity of rich nectar source in the



Rank I : a. *Ocimum basilicum*, b. *Argyreia cuneata*

Rank II : a. *Asystasia gangetica*, b. *Adhatoda zeylanica*

Rank III : a. *Antigonon leptopus*, b. *Gaillardia pulchella*, c. *Ruta graveolans*



Rank IV: *a. Scaveola taccada*, b. *Adhatoda zeylanica*, c. *Hedychium coronaria*, d. *Asclepias curassavica*, e. *Citharexylum substratum*, f. *Aristolochia ringens*, g. *Woodfordia fruticosa*, h. *Sauropus androgynus*, i. *Calotropis gigantea*, j. *Budleja asiática*, k. *Cestrum diurnum*, l. *Quisqualis indica*, m. *Crotolaria retusa*, n. *Alpinia sp.*, o. *Chrysophyllum cainito*, p. *Hamelia patens*, q. *Mansoa Alliacea*, r. *Clerodendrum infortunatum*

Fig 2. Ranking of plants based on number of bees visited.

Table 1. Different plant species in the Pollinator garden along with ranking based on the number of bees visited.

Family	Plant Species	Rank
Lamiaceae	*Ocimum basilicum**	I
	Ocimum gratissimum	
	Strobilanthus barbatus	
	Strobilanthus hamiltoniana	
Convolvulaceae	*Argyreia nervosa*	I
	*Argyreia cuneata**	
	Ipomoea pescaprae	
	Jacquemontia violacea	
Acanthaceae	*Adhatoda zeylanica*	II
	Andrographis paniculata	
	*Asystasia gangetica**	
Polygonaceae	*Antigonon leptopus**	III
Asteraceae	*Gaillardia pulchella*	III
Passifloraceae	*Passiflora edulis*	III
Rutaceae	*Ruta graveolans*	III
Verbenaceae	*Citharexylum substratum*	IV
	*Clerodendrum viscosum**	
	Vitex negundo	
Elaeocarpaceae	*Elaeocarpus floribundus**	IV
	Elaeocarpus sphaericus	
Bignoniaceae	*Mansoa alliacea*	IV
	*Tecoma capensis**	
Solanaceae	*Cestrum diurnum**	IV
	Cestrum nocturnum	
Zingiberaceae	*Alpinia calcarata*	IV
Amaranthaceae	*Alternanthera sessilis*	IV
Aristolochiaceae	*Aristolochia ringens*	IV
Annonaceae	*Artabotrys odoratissimus**	IV
	Cananga odorata	
Apocynaceae	*Asclepias curassavica*	IV
Plantaginaceae	*Bacopa moniera*	IV
Scrophulariaceae	*Budleja asiatica*	IV
Fabaceae	*Butea monosperma*	IV
	*Crotolaria retusa**	
Apocynaceae	*Calotropis gigantea*	IV
Sapotaceae	*Chrysophyllum cainito*	IV
Vitaceae	*Cissus quadrangularis*	IV
Mimosaceae	*Adenanthera pavonina*	IV
Rubiaceae	*Hamelia patens*	IV
Zingiberaceae	*Hedychium coronaria*	IV
Malpighiaceae	*Hiptage benghalensis*	IV
Lythraceae	*Lagerstromia indica*	IV
	*Woodfordia fruticosa**	
Oleaceae	*Nyctanthes arbor-tristes*	IV
Phyllanthaceae	*Sauropus androgynus*	IV
Goodeniceae	*Scaevola taccada*	IV
Malpighiaceae	*Tristellateia australasiae*	IV

Ranking: I- 15-20 species of bees attracted to the plant, **II-** 10-15, **III-** 5-10 and **IV**-0-5

* The plant species which was more attractive compared with other species in the same families

flowers of the plant. The flowers of *W. fruticosa* are a major source of nectar and pollen visited by *Apis cerana* and *A. mellifera* in Shiwalik hills (Kaur & Mattu, 2016).

The pithy stems of *Clerodendrum viscosum* (Verbenaceae) was utilized by small carpenter bee, *Ceratina hieroglypica* for nest building activity. The destructive sampling of *C. viscosum* revealed the brood nests of the small carpenter bee *C. hieroglyphica* harbouring its life stages of pollen food. Pithy stems of *Caesalpinia pulcherrima* after pruning the branches were reported to be natural nesting sites of small carpenter bee, *C. binghami* (Amala & Shivalingaswamy, 2019). Continuous availability of flowers in the pollinator garden was found to sustain different species of bees from Spring to Summer. Plants like *Asystasia* sp. (Acanthaceae) and *Hamelia patens* (Rubiaceae) were found to have long blooming periods supporting the bee fauna with pollen and nectar rewards. Similar observations were recorded by Wojcik et al. (2008) and reported that flowers with long blooming periods sustained different species of bees in a seasonal sequence. The plant *Tristellateia australasiae* (Malpighiaceae) was found to be foraged upon by little bee *A. florea* in large numbers. The composite flowers of *Gaillardia pulchella* (Asteraceae) was found to be foraged by different species of halictid bees viz., *Nomia curvipes*, *Seladonia propinqua* in search for pollen. Blue banded bees *Amegilla zonata* (Anthphorinae: Apidae) and Sweat bees *Hoplonomia westwoodi* (Nominae: Halictidae) were recorded as some of the buzz pollinators of tomato and eggplant present in the pollinator garden.

Six different aromatic plants belonging to the family Lamiaceae were reported to attract and support many species of bees and hover flies (Barbir et al., 2016). Raju (2005) reported that three species of bees viz., *Apis cerana indica*, *Trigona iridipennis* and *Ceratina simillima* visited the flowers of *Woodfordia floribunda* Salisb. (Lythraceae) for the collection of pollen and nectar. Plants belonging to the family Convolvulaceae viz., *Argyreia populifolia*, *Ipomoea cairica*, *I. mauritiana* and *I. pescaprae* attracted five species of solitary bees *Lithurgus atratus*, *Lasioglossum halictoides*, *L. serenum*, *Systropha tropicalis* and *Tetralonia* sp.1 in Sri Lanka (Karunaratne et al., 2005). The flowers of the family Asteraceae with typical daisy like flower was reported to attract solitary bees, hoverflies, and 'other' flower-visiting insects (Rollings & Goulson, 2019). Peters (2014) reported that *Trigona fulviventris*, Halictids, *Ceratina* sp and *Bombus pullatus* visited the flowers of *Hamelia patens* (Rubiaceae) for pollen and nectar collection. The flowers of plant, *Asystasia chelonoides* (Acanthaceae) were reported to be visited by four different species of bees viz., *Amegilla comberi*, *A. puttalama*, *A. scintillans* and *Apis cerana* (Karunaratne et al., 2005). *Xylocopa latipes* and *X. pubescens* as a floral visitor and pollinator of *Calotropis gigantea* and *C. procera* was reported by Zafar et al. (2018).

Holistically, the plants and the flora in the pollinator garden were found to attract a diverse assemblage of bee

Table 2. Non-Apis bee and scolid wasp species recorded in the pollinator garden.

S. No.	Bee species	Family
1	*Amegilla confusa* (Smith, 1854)	Apidae
2	*Amegilla violacea* (Lepeletier, 1841)	Apidae
3	*Amegilla* sp. (*zonata* group):	Apidae
4	*Apis cerana* Fabricius, 1793	Apidae
5	*Apis dorsata* Fabricius, 1793	Apidae
6	*Apis florea* Fabricius, 1787	Apidae
7	*Braunsapis* sp.	Halictidae
8	*Ceratina binghami* Cockerell, 1908	Apidae
9	*Ceratina hieroglyphica* Smith, 1854	Apidae
10	*Ceratina smaragdula* (Fabricius, 1787)	Apidae
11	*Ceratina* sp.1	Apidae
12	*Ceratina* sp.2	Apidae
13	*Coelioxys basalis* Smith, 1875	Megachilidae
14	*Coelioxys confusus* Smith, 1854	Megachilidae
15	*Coelioxys* sp.	Megachilidae
16	*Hoplonomia westwoodi* (Gribodo, 1894)	Halictidae
17	*Lasioglossum* (*Ctenonomia*) sp. 1	Halictidae
18	*Lasioglossum* sp. 2	Halictidae
19	*Lithurgus atratus* Smith, 1853	Megachilidae
20	*Megachile anthracina* Smith, 1853	Megachilidae
21	*Megachile bicolor* (Fabricius, 1781)	Megachilidae
22	*Megachile cephalotes* Smith, 1853	Megachilidae
23	*Megachile disjuncta* (Fabricius, 1781)	Megachilidae
24	*Megachile lanata* (Fabricius, 1775)	Megachilidae
25	*Megachile* sp.1	Megachilidae
26	*Megachile* sp.2	Megachilidae
27	*Nomia curvipes* (Fabricius, 1793)	Halictidae
28	*Pachynomia* sp.	Halictidae
29	*Scolia affinis* Guérin-Méneville, 1830	Halictidae
30	*Seladonia propinqua* (Smith, 1853)	Halictidae
31	*Seladonia* sp.	Halictidae
32	*Tetralonia* (*Thygatina) macroceps* (Engel & Baker,2006)	Apidae
33	*Thyreus histrio* (Fabricius, 1775)	Apidae
34	*Thyreus massuri* (Radoszkowski, 1893)	Apidae
35	*Thyreus* sp.	Apidae
36	*Xylocopa aestuans* (Linnaeus, 1758)	Apidae
37	*Xylocopa amethystina* (Fabricius, 1793)	Apidae
38	*Xylocopa latipes* (Drury, 1773)	Apidae
39	*Xylocopa* sp.	Apidae

species belonging to the families Apidae, Megachilidae, and Halictidae. Plants belonging to the family Lamiaceae and Convolvulaceae could be ideally used to conserve native *Apis*/ non-*Apis* bees. The concept of pollinator garden is a vital tool to conserve the native pollinators by providing them food source (nectar and pollen) and habitat (nests construction). Pollinator gardens could be encouraged in urban habitats to enhance the aesthetic value, educative tool for school children and finally to sustain the ecosystem services provided by the pollinators.

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Authors' contribution

TMS conceptualized and coordinated the conduct of the study. AG identified the bee specimens. AR assisted in recording field observations. UA analyzed the data and drafted the manuscript. All authors have read and approved the manuscript.

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