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Research Article

Biodiversity of pollinators in four bee-friendly plant species

M. PRATHEEPA*, U. AMALA and T. M. SHIVALINGASWAMY
ICAR-National Bureau of Agricultural Insect Resources, Post Bag No. 2491, H. A. Farm Post, Hebbal, Bengaluru – 560024, Karnataka, India
Corresponding author E-mail: mpratheepa@gmail.com

ABSTRACT: Bees are the primary pollinators of many important agricultural crops. Enhancing the suitability of farm landscapes for native pollinators by growing flowering non crop plants is necessary for in-situ conservation of bee pollinators. A study has been conducted to find the role of four different plants, viz., *Hamelia patens, Ocimum basilicum, Asystesia* sp. and *Jacquemontia* sp. in the conservation of native bee pollinators. The different species of bees visiting the flowers were *Apis cerana, A. florea, Hoplonomia* sp., *Amegilla zonata*, *A. confusa* and *Ceratina hieroglyphica*. The diversity indices were higher during morning hours than the afternoon. The number of bees visited per flower, time spent and numbers of flowers visited on *Jacquemontia* sp. were more compared to other plant species. Biodiversity indices were calculated by using Insect Biodiversity Analysis Portal, which is an online tool to carry out biodiversity analysis and hosted at https://www.nbair.res.in/Biodiversity. The planting of bee-friendly plant species as identified in this study will help support healthy, diverse pollinator and other beneficial insect communities..

KEY WORDS: Bee pollinators, biodiversity indices, in-situ conservation, non-crop plants

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INTRODUCTION

Bees are the primary pollinators of many important agricultural crops. Honey bees provide the majority of pollination services on most farms, but native bees serve as an important component of a sustainable pollination strategy. Native pollinators need undisturbed nesting sites and access to nectar and pollen when the crop is not in bloom. Native bee community alone could provide sufficient pollination services (Kremen, 2002). Restoring pollination services in areas of greatest agricultural intensity would require both reducing insecticide use and restoring native or surrogate vegetation to provide nesting habitat and floral resources for bees when they are not using crops (Fussell and Corbet, 1992). Similarly, more information is needed on how to manage this habitat to maximize the provision of pollen and nectar resources whilst protecting breeding habitat for butterflies (Pywell, 2011). There is increasing interest in the role of urban environments as habitats for wildlife, including species of conservation concern (Jones, 2012). Enhancing the suitability of farm landscapes for native pollinators by growing flowering non crop plants will act as a diversified strategy for achieving better crop yields in pollination-dependent crops year after year. Hence, this study has been proposed to find the role of four different plants, *viz*., *Hamelia patens*, *Ocimum basilicum*, *Asystesia* sp. and *Jacquemontia* sp. for the nesting sites of native pollinators, *viz.*, *Apis cerana, A. florea, Hoplonomia* sp., *Amegilla zonata*, *A. confusa* and *Ceratina hieroglyphica*.

MATERIALS AND METHODS

The present study was conducted in the experimental farm of ICAR-National Bureau of Agricultural Insect Resources, Yelahanka Campus, Bengaluru. The number of bees visiting per flower per minute, time spent by the bees per flower was observed and recorded in four different plants, *viz.*, *Hamelia patens*, *Ocimum basilicum*, *Asystesia* sp. and *Jacquemontia* sp. on four different timings 10-11 am, 12-1 pm, 2-3 pm, and 4-5 pm. The different species of the bees visiting each plant were also recorded. The different bee species visited were *Apis cerana, A. florea, Hoplonomia* sp., *Amegilla zonata*, *A. confusa* and *Ceratina hieroglyphica*. The mean number of bees visited/plant/minute, time spent by the bees in each flower and diversity indices of bees visiting each plant was worked out. The mean number of bees visited per plant/flower per minute during the period 10-11 am, 12-1 pm and 2-3 pm given in Table 1 and Table 2. Similarly, the duration of time spent in seconds by bees has been recorded and given in Table 3.

Biodiversity indices is a quantitative measure to calculate species richness and species evenness in a community.There are several diversity indices like Shannon diversity index (H'), Simpson index (D_1), Brillouin index (H_B), Berger Parker index (D), McIntosh index and Evenness based on Shannon (E_S) index, Simpson index and McIntosh index (E_M) are being used.Shannon-weiner index is represented as in Equation (i).

$$H' = \sum_{i=1}^{S} p_i \log p_i \qquad \text{--------- (i)}$$

p_i can be estimated by n_i/N which is proportion of individuals in the i^{th} species. 'S' refers total no. of species in the community and 'N' represents total no. of individuals.

Brillouin index is calculated based on the Formula (ii)

$$H_B = \frac{\ln(N!) - (\sum_{i=}^{s} \ln(n_1!))}{N} \qquad \text{--------- (ii)}$$

Where 'N' is the total no. of individuals in the sample, n_i is the number of individuals in the i^{th} species and S is total no. of species and N is total no. of individuals.

Berger-Parker Index can be used to find the dominance of the species within the community and the formula is given in Equation (iii).

$$D = \frac{\max(n_i)}{N} \qquad \text{--------- (iii)}$$

Evenness indices required to find the relative abundance of the species within the community. Lower number indicates one or a few species dominate and high value indicates that most of the species distributed equally within the community. Hence, evenness based on Shannon index and McIntosh were calculated based on the Formulae (iv) and (v).

$$E_S = \frac{H'}{\ln(S)} \qquad \text{--------- (iv)}$$

$$E_m = \frac{(N-U)}{\left(N - \left(\frac{N}{\sqrt{S}}\right)\right)} \qquad \text{--------- (v)}$$

and 'U' is calculated based on the Formula (vi).

$$U = \sqrt{\sum_{i=1}^{s} n_i^2} \qquad \text{--------- (vi)}$$

The diversity indices were calculated for (i) no. of bees visited per plant per minute (ii) no. of bees visited no. of flowers and (iii) the time spent (in seconds) in all four different plants during 10-11 am and mentioned in Table 4, Table 6 and Table 7, respectively. Diversity indices for no. of bees visited per plant per minute during 2-3 pm was given in Table 5.

RESULTS AND DISCUSSION

The mean number of bees visited per plant/flower per minute during the period 10-11 am, 12-1 pm, 2-3 pm and 4-5 pm is given in Table 1 and Table 2. It has been observed that during the morning hours between 10-11 am and 12-1 pm, more no. of bees visited on four different plants and its flowers. Similarly, the duration of time spent in seconds by bees has been recorded and given in Table 3. It has been observed that *Apis cerana* and *A.florea* were not visited during 2-3 pm and 4-5 pm, but other bees like *Hoplonomia* sp., *Amegilla zonata*, *A. confusa* and *Ceratina hieroglyphica* visited during 10-11 am, 12-1 pm and 2-3 pm. But none of the bees visited during 4-5 pm. These results confirm earlier reports of Duffy *et al*. (2014), according to them the bees always foraged for pollen during the morning and early afternoon, but switched

Table 1. Number of bees visited per plant per minute on different timings

Bee species	Time duration			
	10-11am	12-1pm	2-3 pm	4-5 pm
Apis cerana	5.75	1.5	0	0
Apis florea	4	2.75	0	0
Hoplonomia sp.	5	2.75	2	0
Amegilla zonata	3	0.75	1.25	0
Amegilla confusa	2.25	3	2.75	0
Ceratina hieroglyphica	4.25	3.5	3.25	0

Table 2. Number of flowers visited on different timings by different bee species

	Time duration			
Bee species	10-11 am	12-1 pm	2-3 pm	4-5 pm
Apis cerana	5.25	3.5	0	0
Apis florea	4.75	4.25	0	0
Hoplonomia sp.	4	5	4.25	0
Amegilla zonata	6.25	1.25	4	0
Amegilla confusa	6.25	4.5	5.5	0
Ceratina hieroglyphica	4.5	4.75	4	0

to nectar in the late afternoon.

Biodiversity indices are numerical value to know about species richness and evenness. Several diversity indices like Shannon diversity index (H'), Simpson index (D_1), Brillouin index (H_B), Berger Parker index (D), McIntosh index and Evenness based on the Shannon index (E_S), Simpson index and McIntosh index (E_M) have been calculated for the (i) no. of bees visited per plant per minute (ii) no. of bees visited no. of flowers and (iii) the time spent (in seconds) in all four different plants during 10-11 am and given in Table 4, Table 6 and Table 7, respectively. The Shannon diversity index, Simpson index and Brillouin index were high on *Jacquemontia* sp. and descending order of four plants was, *viz*., *Jacquemontia>Ocimum>Asystesia>H. patens* (Table 4). Diversity indices were calculated for no. of bees visited per plant per minute during 2-3 pm was calculated and given in Table 5. In comparison of diversity indices during 10-11 am and during 2-3 pm, it has been observed that the diversity indices were higher during morning hours than the afternoon (Table 4 and Table 5). The diversity indices have a higher value on *Jacquemontia* sp. The descending order of four plants based on Shannon and Simpson indices is *Jacquemontia < Asystesia* sp. *<Hamelia patens<Ocimum basilicum* which denotes that more flowering happened in *Jacquemontia* sp. (Table 4 and Table 6). Berger-Parker index helps to find the dominance of the species which denotes the bee species spent more time on *Jacquemontia* sp. (Table 7).

Table 3. Time spent (in seconds) by different bee species on different timings

	Time duration			
Bee species	10-11 am	12-1pm	2-3 pm	4-5 pm
Apis cerana	7	5	0	0
Apis florea	6.75	8	0	0
Hoplonomia sp.	7	8.75	5.75	0
Amegilla zonata	1.5	0.75	1	0
Amegilla confusa	1.5	1.75	1.5	0
Ceratina hiero-glyphica	6	5.75	7.5	0

The bees were found to collect both pollen and nectar reward from the flowers during their foraging activity. Planting diverse flowering plants in the pollinator garden supports both bee diversity and density in addition to food and nesting sources for the native bees (Kremen *et al*., 2002). Plants like *Asystesia* sp, and *Hamelia patens* were found to have long blooming periods supporting the bee fauna with pollen and nectar rewards. The flowers of *Jacquemontia multiflora* were reported, and visited by butterflies and especially by bees,

Table 4. Diversity indices of number of bees visited per plant per minute on four different plants during 10-11 am

Indices	*Hamelia patens*	*Ocimum basilicum*	*Asystesia* sp.	*Jacquemontia* sp.
Shannon diversity index	1.661	1.745	1.707	1.707
Simpson index	0.813	0.857	0.839	0.839
Brillouin D HB	1.433	1.429	1.395	1.395
Berger-Parker Index	0.294	0.227	0.318	0.318
McIntosh	0.653	0.729	0.705	0.705
Shannon Evenness	0.927	0.973	0.953	0.953
Simpsons evenness	0.205	0.194	0.198	0.198
McIntosh Evenness	0.914	0.969	0.937	0.937

Table 5. Diversity indices of number of bees visited per plant per minute on four different plants during 2-3 pm

Indices	*Hamelia patens*	*Ocimum basilicum*	*Asystesia* sp.	*Jacquemontia* sp.
Shannon diversity index	0.69	0.67	0.77	0.69
Simpson index	0.65	0.82	0.81	0.69
Brillouin D HB	0.77	1.01	0.86	0.81
Berger-Parker Index	0.55	0.30	0.43	0.56
McIntosh	0.52	0.72	0.72	0.57
Shannon Evenness	0.38	0.37	0.43	0.39
Simpsons evenness	0.25	0.20	0.21	0.24
McIntosh Evenness	0.61	0.83	0.75	0.64

Table 6. Diversity indices of number of bees visited number of flowers on four different plants during 10-11 am

Indices	*Hamelia patens*	*Ocimum basilicum*	*Asystesia* sp.	*Jacquemontia* sp.
Shannon diversity index	0.33	0.18	0.81	0.47
Simpson index	0.84	0.85	0.84	0.86
Brillouin D HB	1.50	1.55	1.45	1.50
Berger-Parker Index	0.26	0.22	0.30	0.21
McIntosh	0.68	0.70	0.70	0.72
Shannon Evenness	0.18	0.10	0.45	0.26
Simpsons evenness	0.20	0.20	0.20	0.19
McIntosh Evenness	0.96	0.99	0.95	0.99

Table 7. Diversity indices of time spent (in seconds) by bees on four different plants during 10-11 am

Indices	*Hamelia patens*	*Ocimum basilicum*	*Asystesia* sp.	*Jacquemontia* sp.
Shannon diversity index	0.18	0.22	0.47	0.56
Simpson index	0.81	0.82	0.82	0.81
Brillouin D HB	1.42	1.43	1.34	1.33
Berger-Parker Index	0.27	0.24	0.25	0.28
McIntosh	0.64	0.67	0.67	0.66
Shannon Evenness	0.10	0.12	0.26	0.31
Simpsons evenness	0.21	0.20	0.20	0.20
McIntosh Evenness	0.91	0.93	0.91	0.90

including the introduced *A. mellifera*, in northeastern Brazil (Piedade-Kiill and Ranga, 2000). Higher frequency of flower visiting by a neotropical bee, *Ancyloscelis apiformis* in the ephemeral flowers of *Jacquemontia bracteosa* was reported by Santos and Gimenes (2016).

SOFTWARE

Biodiversity indices were calculated by using Insect Biodiversity Analysis Portal, which is an online tool to carry out biodiversity analysis and hosted at http://www.nbair.res.in/Biodiversity. On uploading MS-Excel file as input to this portal diversity indices like Shannon, Simpson, Berger-Parker, McIntosh, etc., have been calculated. Other than the diversity indices, Evenness, Formulation of contingency table by using presence/absence of species X and species Y, Calculation of chi-square (χ^2) value and Iwao's spatial association analysis between the species X and Species Y can be calculated by using this portal.The home page of 'Insect Biodiversity Analysis Portal', has been given in Fig. 1.

The diversity indices were higher during morning hours than the afternoon. The number of bees visited, time spent and number of flowers visited on *Jacquemontia* sp. were more compared to other plant species *Asystesia* sp. < *Ocimum basilicum* < *Hamelia patens*. The different bee species visiting

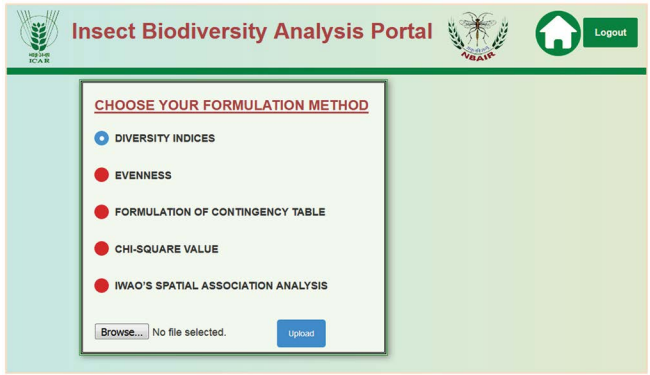

Fig. 1. Home page of insect biodiviersity analysis portal at http://www.nbair.res.in/Biodiversity

the flowers were *A. cerana, Amegilla zonata, A. confusa, Ceratina hieroglyphica* and *Hoplonomia* sp. Time spent by the sonicating bees like *A. zonata* and *A. confusa* was found to be relatively lower compared to other species of bees. The results showed the role of four plants with pollen and nectar rewards attracts the bees could be a candidate species in gardens for in-situ conservation of bee pollinators. Year-round blooming flora could be planted in urban habitats for an aesthetic value to sustain the ecosystem services provided by the pollinators.

Ecological requirements of pollinators and beneficial insects in the form of food, nests, overwintering habitat etc., mostly overlap. Bees are our main pollinators and they need diverse and abundant pollen and nectar supply throughout their flight season so as to nourish their developing larvae. Adequate availability of nectar and alternate prey species will help natural enemies to flourish in such complex habitats (Emile May, 2018). The planting of bee-friendly plant species as identified in this study will help support healthy, diverse pollinator and other beneficial insect communities.

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