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Diversity of Bees on Sweet Basil in Bihar

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation aims to study the diversity of insect pollinators rendering pollination services to sweet basil. Sweet basil (*Ocimum basilicum* L.) is a significant culinary and medicinal herb used for curing renal problems, warts, worms, diarrhea, migraines, etc. Secondary metabolites from *Ocimum* sp. have excellent biological activity being bactericidal; anti-microbial and antioxidant. The important bee pollinators of sweet basil flowers were recorded in a square meter of the experimental plot that had been randomly designated. Throughout the whole flowering season, the experimental plot was kept free from spray. More research is needed to better understand the precise functions that different bee species play in sweet basil pollination, as well as their effects on

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this process in relation to other factors that influence their populations. Such findings can be used to develop targeted strategies for conservation or sustainable agriculture that promote both crop production and pollinator health.

Keywords: Ocimum basilicum; secondary metabolites; pollination; biological activity.

1. INTRODUCTION

Insects render more than 80 percent of pollination services. Pollination by insects is crucial and one of the key ecosystem services offered by the insects to humankind. The importance of pollination in crop plants by insect species has increased in the last few years [1]. Among all insects, hymenopteran pollinators are the most efficient and effective plant pollinators of cultivated and non-cultivated plants. In Hymenoptera, bees alone provide 80 % of pollination rewards to plants due to their robust and hairy body (except *Hileaus* and *Nomada* – slender and sparsely haired). According to Greenleaf and Kremen [2] pollinating bees are essential to produce around 15-30 percent of crops i.e. about one-third of the human diet supply. The worth of pollination service provided by bees is about 143 times that of honey production [3].

Basil, also known as sacred Tulsi (*Ocimum sanctum),* is a great herb because it is considered the “queen of herbs”. It belongs to the family “Lamiaceae”. Sweet basil has more medicinal properties which makes it more useful. However, in the plains of north India, south India, and Assam, it can be grown both as Kharif and Rabi crops. This species gives about 30-35 Kg/ha of oil i.e., 12–13 kg of flower oil and 18–22 Kg of whole herb oil [4]. Basil is cultivated in Bihar on an area of about 3.0 acres with an annual production of 1.2 metric tonnes [5]. In Bihar Nalanda, Muzaffarpur, Samastipur, Vaishali, Begusarai, East Champaran and West Champaran are major sweet basil growing districts.

Sweet basil (*Ocimum basilicum* L.) is a significant culinary and medicinal herb used for curing renal problems, warts, worms, diarrhea, migraines etcetera. Secondary metabolites from Ocimum species have excellent biological activity being bactericidal; anti-microbial and antioxidant [6].

The top five states in the nation for basil production are Rajasthan, Madhya Pradesh, Karnataka, Tamil Nadu, and Uttar Pradesh (*Ocimum* spp.). The *Ocimum* genus essential oils have a wide range of applications in the fragrance and cosmetics sectors as well as in traditional medicine. On a 25,000-hectare farm in India, basil is grown for its annual oil production of between 250 and 300 tonnes [7]. The present investigation aims to study the diversity of insect pollinators rendering pollination services to these crops.

2. MATERIALS AND METHODS

2.1 location

The experimental area is very even. It has a deep sandy loam soil that drains well. The experiment was conducted in the Samastipur district of Bihar on the western and southern banks of river Budhi Gandak at latitude 25.980 N, longitude 85.670 E and altitude of 52.92 m above sea level. This place experiences a sub-tropical climate with mild winters and hot dry summers.

2.2 Collection of Bee Pollinators

The important bee pollinators of sweet basil flowers were recorded in a square meter of the experimental plot that had been randomly designated. Throughout the whole flowering season, the experimental plot was kept free from spray. Bee visitors were collected using a sweeping net during the whole time of blooming season at different times of the day.

2.3 Sweep Net Collection

Using an insect sweep net, flower visitors were also collected at frequent intervals and throughout the day. Samples from sweep nets were taken on various days with various bloom densities. In order to preserve them for future identification, flower visitors were gathered, transferred to a collecting jar, executed, mounted with insect pins, and thoroughly dried. Using the available keys [8] and the expertise at the Department of Entomology, bee species were identified.

2.4 Preservation

Bees were captured and exterminated during the survey, and they were brought to the Department of Entomology, RPCAU, Pusa. Bees were separated, and pinned through the thorax using nickel-coated entomological pins of sizes No. 1, 0, and 00, and all specimen components, particularly significant taxonomic features like wings, mouth parts, legs, and antenna, were stretched appropriately on setting boards made of thermacole. Small bees were mounted using paper points and water-based glue. For a week, the preparations were allowed to settle. The appropriate labels are subsequently applied to the set specimens. The scientific name, family, order, location, date, and collector name were all printed on the 2 cm×1 cm white paper collection label. A second label of the same size, with the host plant's details, was adhered beneath the collecting label. A wooden insect storage box of 30 x 45 x 10 cm3 was then used to keep the labeled bees, and it was filled with naphthalene balls or para-dichloro-benzene to serve as a repellant against ants and other museum insects.

2.5 Identification of Bee Pollinators

The collected and preserved bees were identified up to species level, with some up to genus level using the identification keys provided by [9-26] and characters of the bee were observed by using a sterozoom microscope.

2.6 Diversity & Evenness Index

Species diversity was calculated using Shannon–Wiener (Shannon Index) H'. & SDI or Simpsons diversity index (D)

From the equation, the Shannon Index is determined.

$$H' = -\sum PilnPi$$

Where Pi is the proportion of individuals in the i^{th} species.

$$D = \sum Pi\ 2$$

The evenness of non-Apis among the sites was assessed using the Pielou's (J') [27,28].

$$J' = H'\ Hmax = H'\ lnS$$

Where,

H 1 = information content of the sample,
Pi = Proportion of total sample belonging to i^{th} species,
S = total number of species in habitat.

3. RESULTS AND DISCUSSION

These studies were carried out from December 2021 to January 2022 on "Diversity of Bee pollinators in sweet basil'' at RPCAU, Pusa with the objective of diversity of bee pollinators, foraging behavior and impact of weather on the population of Bee pollinators had been recorded.

3.1 Commonness of Species on Sweet Basil

The species documented during the study were categorized based on their frequency of sightings. Less than five specimens in each species collected during the survey period are considered rare bees and which was designated as singleton species (single individual/species), doubleton species (two individual/species), tripleton species (three individual/species), and so on. The rest of the others (>5 individuals/species) are considered as common or occasional species.

So after the documentation of bee pollinators in sweet basil, we found 5 rare bee pollinators namely *Braunsapis* (reed bees), *Nomia westwoodi*, *Steganomus* (sweat bees), *Heriades,* and *Coelioxys* (cuckoo or sharp-tailed bee). The remaining 12 bee pollinators (*Apis dorsata, Apis mellifera, Apis cerana, Apis florea, Amegilla, Ceratina* (*Pithis*) sp., *Ceratina* (*Ceratinidia*) sp, *Thyreus* sp., *Lassioglossum albescens, Pseudapis oxybeloides, Lipotriches* sp., *Megachile disjuncta*) are categorized under common species. The common species are mostly dominated by the family Apidae. The species which represents singleton are considered as very rare compared to other bees in this category. The rarity of these bee species is possibly due to various biotic and abiotic factors. Much attention is needed to study their habitat, behavior, and host plants to conserve them.

3.2 Species Categorization of Sweet Basil

The latest findings are consistent with Banjo et al.'s [29] earlier research that found Hymenoptera to be the most abundant order of *Ocimum basilicum*. In the same vein, our results indicate that Apidae is the most common family under the classification of commonness as shown in Table 1.

Table 1. Species categorization of sweet basil

Sl. No	Scientific Name	Common Name	Status
1	*Apis dorsata*	Rock/Giant bee	Common
2	*Apis mellifera*	Italian/European bee	Common
3	*Apis cerana indica*	Indian bee	Common
4	*Apis florea*	Little bee	Common
5	*Amegilla* sp.	Blue-banded bee	Common
6	*Ceratina* (*Pithis*)sp.	Green metallic bees	Common
7	*Ceratina* (*Ceratinidia*)sp.	Small carpenter bees	Common
8	*Braunsapis* sp.	Reed bees	Common
9	*Thyreus* sp.	Neon cuckoo bees	Common
10	*Lassioglossum albescens*	Sweat bees	Common
11	*Nomia westwoodi*	Unknown	Common
12	*Steganomus* sp.	Sweat bees	Common
13	*Pseudapis oxybeloides*	Unknown	Common
14	*Lipotriches* sp.	Sweat bees	Common
15	*Heriades* sp.	Resin bees	Common
16	*Coelioxys* sp.	Cuckoo or sharp-tailed bees	Common
17	*Megachile disjuncta*	Leafcutter bees	Common

Table 2. Diversity of bee pollinators collected from sweet basil

Sl. No	Scientific Name	Common Name	Family	Sub family
1	*Apis dorsata*	Rock/Giant bee	Apidae	Apinae
2	*Apis mellifera*	Italian/European bee	Apidae	Apinae
3	*Apis cerana*	Indian bee	Apidae	Apinae
4	*Apis florea*	Little bee	Apidae	Apinae
5	*Amegilla* sp.	Blue-banded bee	Apidae	Apinae
6	*Ceratina* (*Pithis*)sp.	Green metallic bees	Apidae	Xylocopinae
7	*Ceratina* (*Ceratinidia*)sp.	Small carpenter bees	Apidae	Xylocopinae
8	*Braunsapis*	Reed bees	Apidae	Xylocopinae
9	*Thyreus* sp.	Neon cuckoo bees	Apidae	Apinae
10	*Lassioglossum albescens*	Sweat bees	Halictidae	Halictinae
11	*Nomia westwoodi*	Unknown	Halictidae	Dieunomiini
12	*Steganomus*	Sweat bees	Halictidae	Nomiinae
13	*Pseudapis oxybeloides*	Unknown	Halictidae	Nomiinae
14	*Lipotriches* sp.	Sweat bees	Halictidae	Nomiinae
15	*Heriades*sp.	Unknown	Megachilidae	Megachilinae
16	*Coelioxys* sp.	Cuckoo or sharp-tailed bees	Megachilidae	Megachilinae
17	*Megachile disjuncta*	Leafcutter bees	Megachilidae	Megachilinae

Pannure [30] recorded 26 species of bees as rare bees at GKVK Bangalore which constituted 36.92 per cent of the total recorded bees. Most of the rare species in that study were single individuals (singletons) and double individuals (doubletons). The present study's result was in line with Pannure's [30] findings.

3.3 Diversity of Bee Pollinators Collected from Sweet Basil

The collected diversified Bee pollinators showing their taxonomical position are represented in below Table 2.

A total of 17 Bee pollinators belonging to 3 families which include Apidae**,** Halcitidae, and Andrenidae were recorded during the study period from the sweet basil during the blooming period. Out of all the above 3 families, Apidae leads in the majority with 53% followed by Halictidae (29%), and at last stands the Megachilidae with 18%.

The current results closely align with earlier research by Banjo et al. [29], who discovered that Hymenoptera were the most prevalent order of *Ocimum basilicum* and accounted for 50.7% of all pollinators.

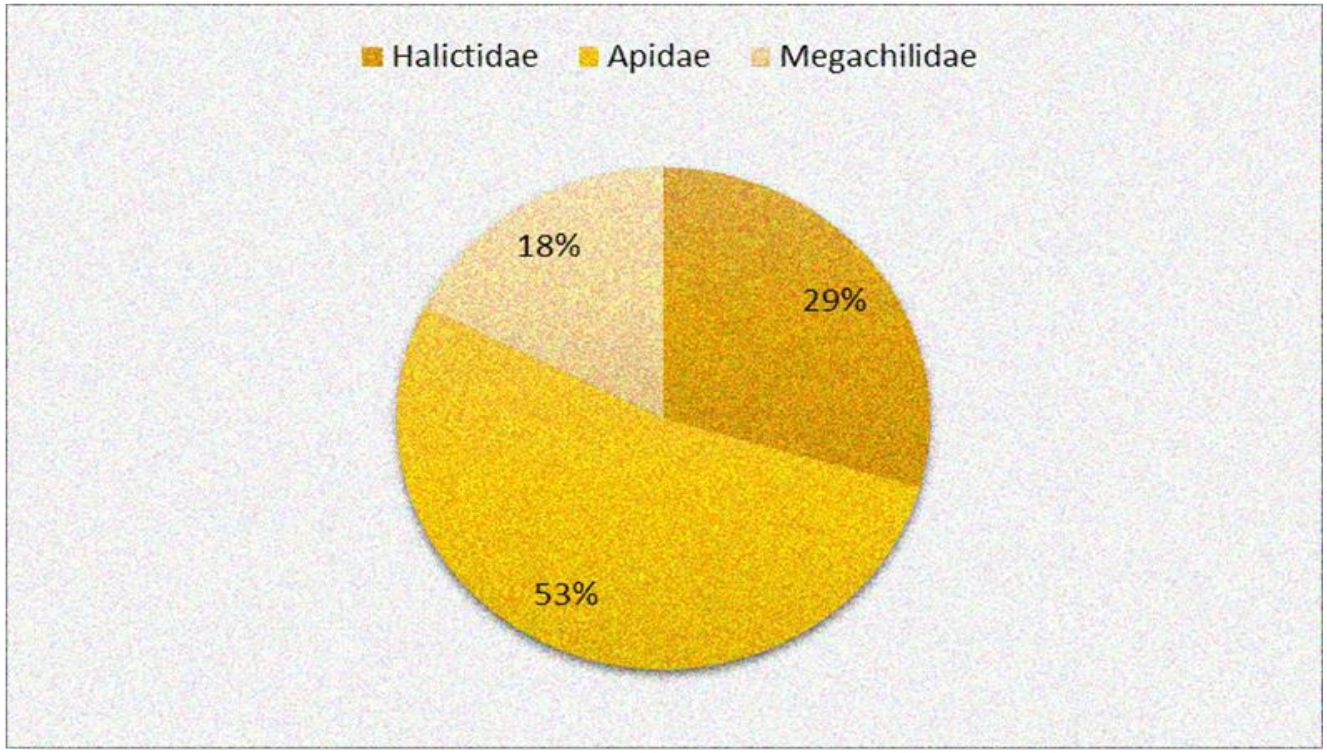


Plate 1. Percentage shared by bee families in *Ocimum*

Apis dorsata

Apis mellifera

***Ceratina* sp.**

***Lassioglossum* sp.**

***Braunsapis* sp.**

***Andrena* sp.**

Megachile lanata

Nomia westwoodi

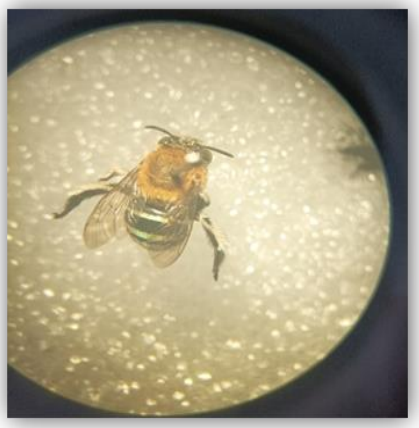
Plate 2. Diversity of bee pollinators on sweet basil

Indian Epaulette - *Pseudapis oxybeloides*

Asian Honey Bee - *Apis cerana*

Striped Carpenter Bee – *Ceratina* (*Ceratinidia*) sp

Elliot's Pronged-Nomia *Nomia elliotii*



Blue-banded bee - *Amegilla* sp.

Disjunct Resin Bee - *Megachile disjuncta*

***Steganomus* sp.**

Mining Bee - *Andrena* sp.

Cloak-and-Dagger Bee - *Thyreus* sp.

Armored-Resin Bee - *Heriades* sp.

Sharptail Bee - *Coelioxys* sp.

Plate 3. Diversity of bee pollinators in sweet basil

Table 3. Sample size of bee pollinators for assessing the Shannon & Simpson index

Sl. No	Date of observation	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
1	20.12.2021	26	33	29	5	0	0	0	0	0	0	0	0	0	0	0	0	0
2	23.12.2021	33	39	33	9	0	0	0	0	0	0	0	0	1	0	0	1	1
3	26.12.2021	30	35	31	17	0	0	0	0	0	1	0	1	0	2	0	0	0
4	29.12.2021	20	20	18	25	1	2	1	1	0	0	1	0	0	0	0	0	7
5	01.01.2022	17	16	13	20	0	0	0	2	3	3	0	0	0	3	1	0	3
6	04.01.2022	18	18	17	17	0	0	4	0	0	1	0	2	3	0	0	1	6
7	07.01.2022	35	39	32	13	0	0	0	0	2	7	2	0	1	1	1	0	0
8	10.01.2022	40	45	35	13	1	3	0	0	0	2	0	0	2	0	0	1	3
9	13.01.2022	30	36	30	10	5	1	3	1	1	4	0	1	1	1	0	0	0
10	16.01.2022	20	20	27	7	2	0	0	0	1	0	1	0	0	0	0	0	0
11	19.01.2022	16	17	14	5	0	0	2	0	0	0	0	0	0	0	0	0	0
12	22.01.2022	28	23	29	4	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: 1- Apis mellifera; 2-Apis dorsata; 3-Apis cerana; 4-Apis florea; 5- Amegilla sp.; 6-Ceratina (Pithitis) sp; 7- Ceratina (Ceratinidia) sp; 8- Braunsapis sp; 9-Thyreus sp.; 10-Lassioglossum albescens; 11- Nomia westwoodi; 12- Steganomus; 13- Psuedapis oxybeloides; 14- Lipotriches sp.; 15- Heriades sp.; 16- Coelioxys sp. 17- Megachile disjuncta

Table 4. Diversity indices for bee pollinators on sweet basil

Crop	Shannon-Weiner index	Simpson diversity Index	Evenness index
Sweet basil	1.72	0.77	0.606

The findings by DP Abrol and Devinder Sharma [31] discovered that insects from 8 families, 4 orders, and 14 species pollinate *Ocimum,* a significant medicinal plant native to Jammu and Kashmir, India. *Amegilla zonata*, followed by *Apis dorsata* and *A. cerana*, made frequent visits to the blossoms of *O. kilimandscharicum*.

Mandela et al. [32] reported, 35 species of bees and a total of 645 individual flower visitors from 4 families were gathered from all of the study sites. The Apidae family contained the most species (17) and individuals (516), followed by the Megachilidae family (60 individuals, 9 species), and the Halictidae family (68 individuals, 8 species). Our research on sweet basil obtained partial results with Mandela et al. [32].

We observed Apidae had the highest number of individuals. According to [33] 's research, 318 bees of *O. basilicum* were found in Eastern Rajasthan, mostly in the town of Sarmathura in the Dholpur district. These were determined to belong to 10 genera, 16 species, and 04 families of Apoidea (Megachilidae, Halictidae, Apidae, and Andrenidae). On *O. basilicum*, Colletidae bees have never been observed. Seven different species belonging to the Megachilidae family were discovered in all. So our research shows a similar pattern to [33]

3.4 Diversity and Evenness Indices on Sweet Basil

Diversity was calculated for the Shannon-Weiner index, Simpson diversity Index & evenness index. Simpson's index was a direct reflection of several species documented in a particular study site. We obtained a total of 1209 individuals as shown in Table 3 & estimated the Shannon, Simpson, and evenness index as represented in Table 4. The results showed a Shannon index of 1.72, a Simpson index of 0.77, and an evenness index of 0.606.

According to research by [34] on the variety of insect pollinators used to pollinate sweet basil, the Shannon Weiner diversity index was highest (1.20) between 16:00 and 18:00 and lowest (0.94) between 10:00 and 12:00. our findings obtained a higher Shannon diversity index in comparison with [34]. So by this, we can state that we obtained closer results with the above research.

4. CONCLUSION

This research is very important because it shows how diverse and important bee pollinators are for sweet basil (*Ocimum basilicum)* in Bihar, India. It identified 17 species of bees from three families with Apidae being the most dominant. The study showed that there was a relatively high level of bee diversity which means that conservation efforts should be focused on rare species. Bee pollination is vital for crop yield, quality, and global food production as well as contributing significantly to biodiversity and ecosystem health. However, bees face many threats such as habitat loss, climate change, pesticides, and diseases. In order to address these challenges the research recommends protecting bee-friendly habitats, reducing pesticide use and raising awareness about pollinator importance. More studies are needed to better understand the specific roles of different bee species in sweet basil pollination and develop targeted strategies for conservation and sustainable agriculture that promote both crop production and pollinator health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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