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Assessment of Bee Diversity and Abundance (*Hymenoptera*: *Apoidea*) on *Caesalpinia bonduc* L. during the Flowering Season in the Southwestern Aravalli Region (Abu Road), Sirohi, Rajasthan, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The aim of the present study was to document the diversity and abundance of bee species visiting *Caesalpinia bonduc* (Family: Fabaceae), a plant species found in the foothills of the Aravalli range, in the south-western Rajasthan area of Abu Road Tehsil, Rajasthan, India. The surveys were

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conducted during the flowering period from July 2021 to September 2021 and again from July 2022 to September 2022. A comprehensive analysis revealed the presence of sixteen bee species (Hymenoptera: Apoidea) visiting *Caesalpinia bonduc*, belonging to nine different genera and categorized under four families: Apidae, Andrenidae, Halictidae, and Megachilidae. Among these families, Apidae recorded the highest number of bee species, with 11 in total: *Amegilla dizona, A. violacea, A. zonata, Apis cerana, A. dorsata, A. florea, Ceratina binghami, Tetragonula iridipennis, Xylocopa aestuans, X. pubescens*, and *X. fenestrata*. The families Megachilidae and Halictidae were each represented by two species: *Megachile bicolor, M. cephalotes* and *Nomia crassipes, Pseudapis oxybeloides* respectivily. The highest abundance of all Bee species was recorded between 12.00- 2:00 pm across various time intervals. The highest abundance of *Apis florea* (13.4 bees/m²/5 minutes) was recorded between 12:00 and 2:00 PM, making it the most abundant species among the 16 bee species observed. At different time intervals, Apis florea consistently recorded the highest number of individuals in each interval. Other entomofauna observed on *C. bonduc* included *Spoladea recurvalis* (Fabricius, 1775), *Suastus gremius* (Fabricius, 1798), *Hasora chromus* (Cramer, 1780), and *Spindasis ictis* (Hewitson, 1865), which belong to the order Lepidoptera. Additionally, *Poekilocerus pictus* (Fabricius, 1775) from the order Orthoptera and *Gametis versicolor* (Fabricius, 1775) from the order Coleoptera were also recorded.

Keywords: Bees; Caesalpinia bonduc; Abu Road; Aravalli; Rajasthan.

1. INTRODUCTION

Bees are categorized in the superfamily Apoidea within the order Hymenoptera. As pollinators, they visit flowers in search of food, including nectar and pollen, while also collecting pollen. During these floral visits, bees may unintentionally brush against the reproductive components of flowers, transferring pollen from one flower to another. This process is essential for the plant's reproduction, as it facilitates the conversion of pollen into fruit or seeds. Bees possess distinctive anatomical features, such as hairy bodies and specialized brushes or pockets on their legs, which aid in the collection and transportation of pollen. Identifying bees can be challenging because they vary in size, color, and shape, and there are over 20,000 species worldwide. Here are some general Physical Characteristics traits and ways to identify bees:

1. Hairy Bodies: Most bees have fuzzy, hairy bodies that help them collect pollen. The density and length of hair vary by species.
2. Body Shape: They usually have a robust, round body, though some species like carpenter bees are more elongated.
3. Wings: Bees typically have two pairs of wings, though these pairs may look like one set.
4. Antennae: Their antennae are usually long and segmented.
5. Leg Pouches: Many female bees have pollen baskets, or ‘scopa,’ on their hind legs for collecting pollen.

Bees utilize ultraviolet vision to guide them to flowers (Laurence, 2015), enhancing their effectiveness as pollinators. They represent an important group of pollinators, with approximately 20,000 described species worldwide (Michener, 2007). Bees play a crucial role in improving fruit quality, contributing to characteristics such as increased redness, reduced sugar-acid ratios, firmer texture, fewer malformations, higher weight, and greater commercial value in crops like strawberries (Klatt *et al*., 2015). Seven families of bees are recognized, including Apidae, Andrenidae, Colletidae, Halictidae, Megachilidae, Melittidae, and Stenotritidae, with five of these families found in Australia.

The Apoidea superfamily (Order: Hymenoptera) comprises seven families: Apidae, Megachilidae, Halictidae, Andrenidae, Colletidae, Melittidae, and Stenotritidae (the latter only found in Australia). In India, six bee families have been reported, while only five families have been recognized in Rajasthan, as the Melittidae family is predominantly found at higher altitudes. Hymenopterans were the most common visitors to C. crista flowers, accounting for over 90% of all visitors. Carpenter bees (*Xylocopa sp*.) are particularly significant pollinators, as they are the largest, visit most frequently, and transport the highest number of pollen grains per visit to *C. crista* flowers (Shi-Jin et al., 2004).

Bee diversity documentation is critical for understanding and preserving healthy ecosystems. Bees have an important function as pollinators, promoting plant reproduction and

biodiversity. This data sheds light on ecosystem health and enables researchers to monitor environmental changes that may affect bee populations (Potts et al., 2010). In agriculture, recording bee variety can help to increase food security by determining which bee species are most successful at pollinating crops. In addition, bee documentation helps conservation efforts. Many bee species are threatened by habitat loss, pesticides, and climate change, therefore tracking diversity can assist identify at-risk species and guide conservation initiatives (IPBES, 2016). It also provides essential data for study and policy, allowing governments and organizations to make more informed decisions to safeguard biodiversity. Finally, bee diversity is an indication of climate change consequences because fluctuations in populations and behaviors reflect larger environmental changes (Garibaldi et al., 2013).

Medicinal plants hold great significance for the overall well-being of people worldwide. *Caesalpinia bonduc* (L.) is a large, thorny shrub widely distributed across India, belonging to the family Caesalpiniaceae. The plant is found in various countries, including Sumatra, Borneo, Thailand, Malaysia, Indonesia, the Philippines, Brunei, Singapore, Papua New Guinea, and India (Alvin Francis, 2011). It has been extensively utilized in traditional medicine systems such as Ayurveda, Siddha, homeopathy, and Unani. The components of the *C. bonduc* plant possess numerous properties, including antioxidant, antiviral, antifungal, anticancer, antipyretic, antimalarial, anti-filarial, neuroprotective, diuretic, anti-fertility, and nutritional benefits (Kandasamy and Balasundaram, 2021). Known as "fever nut," *C. bonduc* has been used in India for many years to treat cancer, diabetes, heart disease, inflammation, fever, and other conditions, as well as for birth control. The seeds of this plant are commonly used to address menstrual abnormalities associated with polycystic ovarian syndrome (PCOS), a prevalent endocrinological disorder affecting women of reproductive age globally (Gadakh *et al.,* 2020).

In Indian traditional herbal medicine, *Caesalpinia bonduc* plays a significant role in the treatment of various diseases. According to Khare (2007), different parts of the plant, including the seed, leaf, bark, and root, are utilized for their antiperiodic, antirheumatic, antidiabetic, emmenagogue, anthelmintic, and anticoagulant properties. The plant is considered a top remedy for chronic fever in homeopathy. Additionally, the seeds of *Caesalpinia bonduc* contain alkaloids, bitter compounds, saponins, and fixed oil, contributing to their medicinal value.

According to Vogel (1990), the genus *Caesalpinia* features four flower varieties, each suited to a distinct pollinator—bees, butterflies, moths, and hummingbirds—highlighting the importance of pollination in its reproductive success. The fitness of a *Caesalpinia* flower may be closely linked to the type of pollinator it attracts. However, studies indicate that bee abundance and diversity decline with increasing urbanization, suggesting that urban areas negatively impact bee populations. This underscores the need for a greater diversity of floral resources to mitigate the adverse effects of urbanization on pollinators (Birdshire et al., 2020).

Caesalpinia bonducella (Fever Nut) is a plant having important ecological and medicinal properties. Ecologically, it flourishes in tropical and subtropical settings, helping to stabilize soil and maintain local biodiversity. Pharmacologically, this plant is known for its many therapeutic effects. It has neuroprotective properties, as evidenced by research that suggest it can prevent oxidative damage to the neurological system. It is also renowned for its diuretic, hepatoprotective, and anti-inflammatory qualities, which make it useful for treating a variety of health issues. Furthermore, its immunomodulatory properties boost both innate and acquired immunity, which might help manage autoimmune disorders. Furthermore, C. bonducella has demonstrated promise in blood sugar regulation, indicating its prospective application in diabetic care (IARJSET, 2024).

Makkar and Chhuneja (2015) reported a total of 724 bee species in India, detailing the distribution of various bee families: Stenotritidae (0 species), Melittidae (4 species), Colletidae (31 species), Andrenidae (20 species), Halictidae (214 species), Megachilidae (237 species), and Apidae (218 species). Additionally, Gupta (2011) recorded a total of 50 bee species from the family Halictidae in Rajasthan. The role of bees in the pollination of the Khejari plant (Prosopis cineraria) was documented by Gorain et al. (2012). Notably, a total of 55 bee species from the Apidae family have been recorded in Rajasthan. This study represents the first investigation into the diversity and abundance of bees visiting the study plant.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the forested region of Abu Road in Rajasthan's Sirohi district, which is located in the Aravalli foothills. Bee observations were conducted at two distinct sites: Soorpagla and Deldar village, located in Abu Road Tehsil within the foothill region of the Aravalli range in Sirohi, Rajasthan, India. These sites are characterized by mountainous terrain and are traversed by two rivers, the Ambaji River and the Battisa River (Fig. 3). Rivers such as the Ambaji and Battisa flow across the rocky, subtropical forest-covered terrain that defines this area. The forest environment is an ecologically important area for biodiversity studies because it supports a diverse range of flora and fauna, including pollinators and medicinal plants such as *Caesalpinia bonduc*. The forest cover surrounding the study area is of a subtropical type.

2.2 Methodology

The studied sites were visited for bee observations two times in a month from July 2021 to September 2021 and again from July 2022 to September 2022 at each site. Bees were observed, and samples were collected within a one-meter length and one-meter width area during five-minute intervals throughout the day to assess abundance. A sweeping insect net (with a 12 inch ring diameter, 24-inch net depth, and 59-inch handle length) was used to collect bees flying above the flowers. Collected bees can be examined closely and returned to the environment and, if necessary they were killed in a killing bottle using ethyl acetate, and then bee spread on a spreading board, pinned, and finally placed in an insect preservation box for further studies.

Characteristics of *C. bonduc*:

Flowers: Covered with fine hair, yellowish in color.

Seeds: Dicotyledonous.

Plant Form: Shrub and perennial.

Fruits: Egg-shaped, grey in color, found in dehiscent pods that split open to release their seeds, and covered with hair.

Flowering Time: From July to September.

Environmental parameters, including temperature and average relative humidity, were measured during each survey at different time intervals using an HTC digital thermo-hygrometer. Bees were observed and collected during the blooming stage of the flowers. Limited sampling occurred from 6:00 AM to 6:00 PM on sunny days during the peak flowering period. Field photographs were taken with a Nikon digital camera (D-5600) equipped with an 18-55 mm lens, while pinned specimen photographs were captured using a mobile phone model OPPO A-78, featuring a 50 MP camera. For the assessment of bee abundance, photographs, video recordings, and a stopwatch were utilized.

Bee Identification: Specimens were collected and brought to the laboratory for identification. A stereo-zoom microscope was employed for bee identification on basis of morphological characters, following the identification guide by Michener (2000). Assistant Professor Jagdish Kumar Saini of the University of Allahabad, Prayagraj, gave great help in determining bee species, therefore guaranteeing correct recognition for the study.

Fig. 1. Whole Plant (Flower and whole Plant)

Fig. 2. Landscape of study area

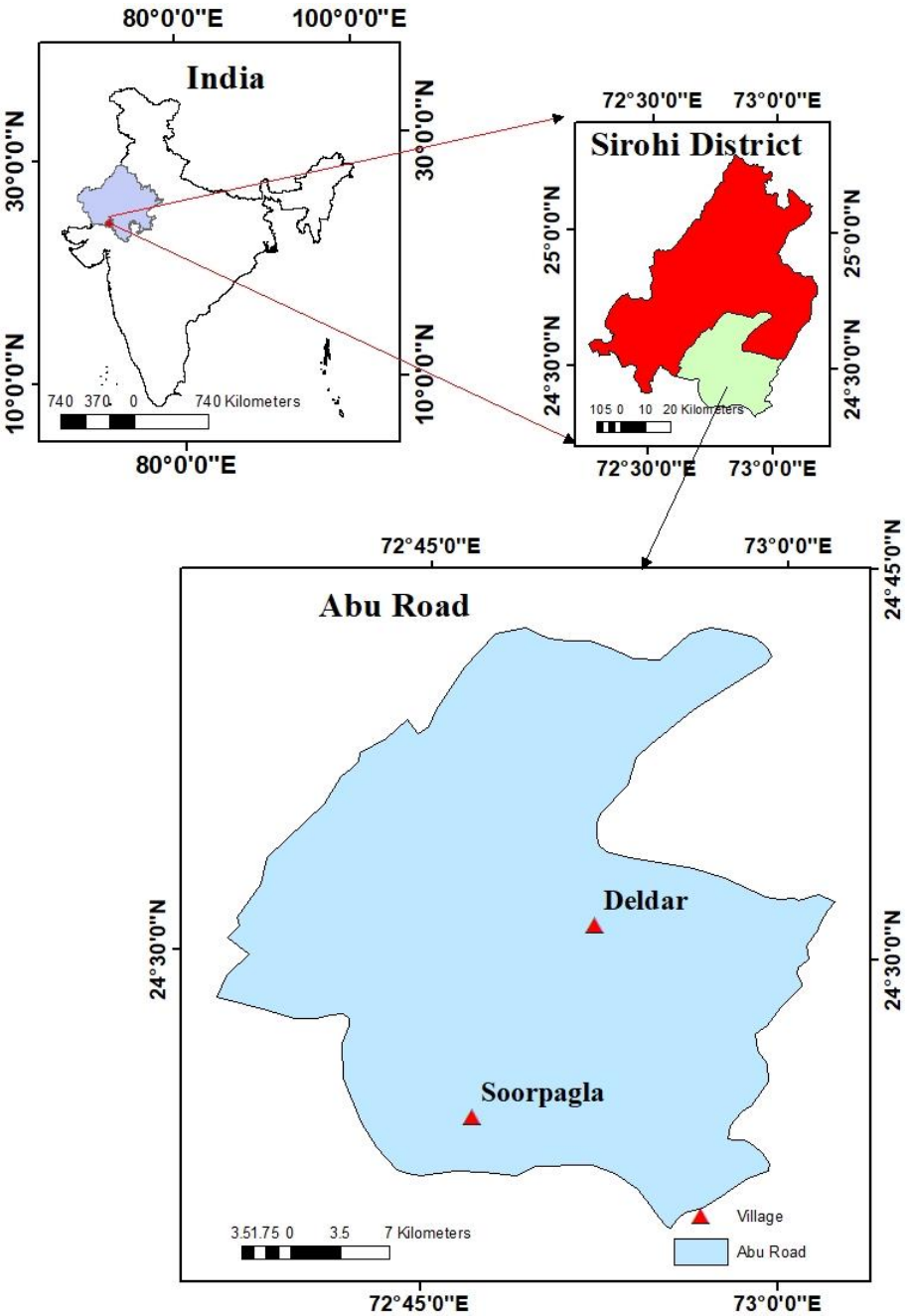

Fig. 3. Map showing Study area (Source: ARC Map 10.5).

3. RESULTS AND DISCUSSION

The present study was conducted to explore the diversity and abundance of bees, as well as their environmental factors, in Abu Road, Sirohi, Rajasthan, India.

Bee Diversity: An extensive study revealed that sixteen bee species (Hymenoptera: Apoidea) from nine different genera were identified, grouped into four families: Apidae, Andrenidae, Halictidae, and Megachilidae. The family Apidae had the highest number of species, with eleven total, including *Amegilla dizona, A. violacea, A. zonata, Apis cerana, A. dorsata, A. florea, Ceratina binghami, Tetragonula iridipennis, Xylocopa aestuans, X. pubescens*, and *X. fenestrata*. Additionally, two species each from the families Halictidae and Megachilidae were observed: *Nomia crassipes* and *Pseudapis oxybeloides* from Halictidae, and Megachile bicolor and M. cephalotes from Megachilidae.

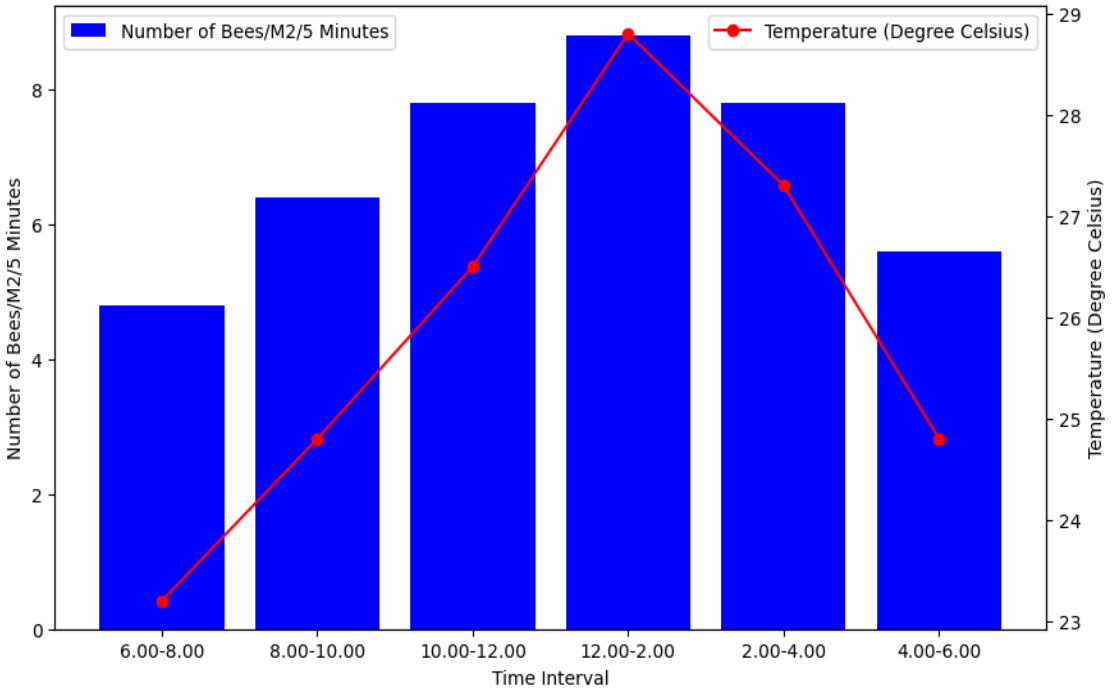

Fig. 4. Relationship between number of bees/m^2/5 minutes and temperature

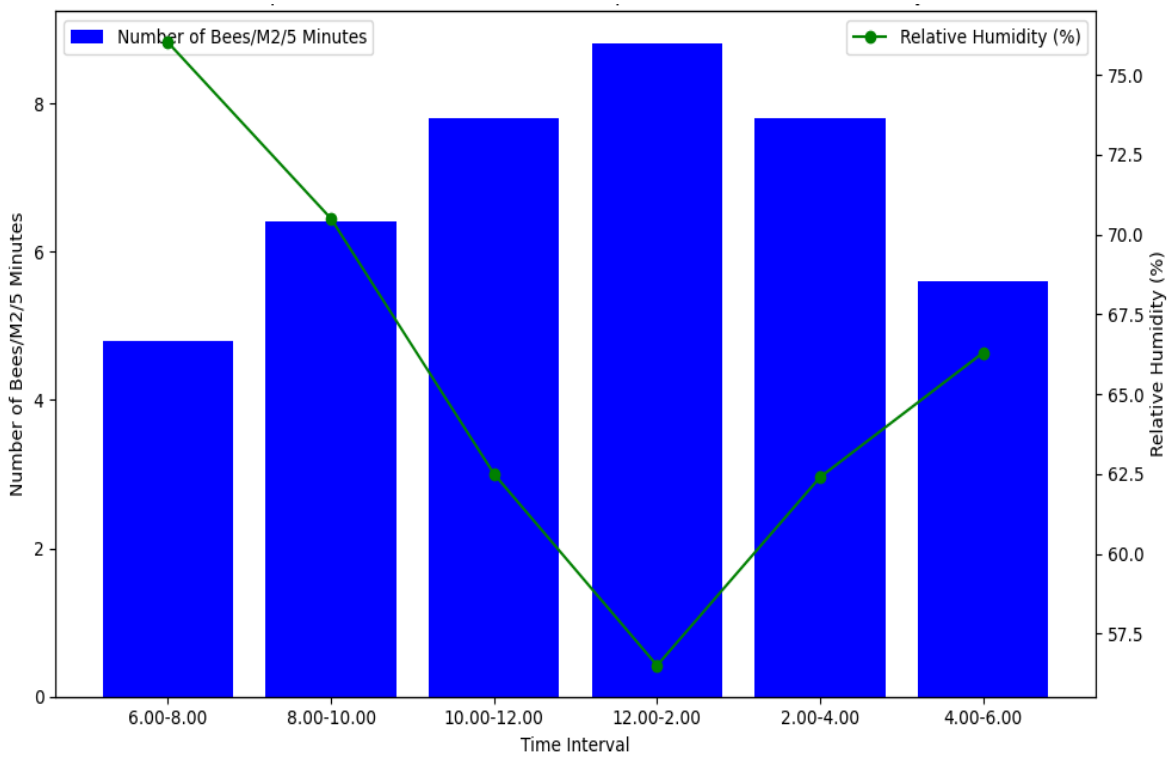

Fig. 5. Relationship b/w number of Bees/m2/5 minutes and Humidity (in Relative %)

Data of relative humidity and temperature is based on the average of July to September month of 2021 and 2022

Table 1. Bee species recorded on *C. bonduc* during the study

Sl. No.	Scientific Name	Family	Super-family: Order
1	*Amegilla dizona* (Engel, 2009)	Apidae	Apoidea: Hymenoptera
2	*Amegilla violacea* (Lepeletier, 1841)		
3	*Amegilla zonata* (Linnaeus, 1758)		
4	*Apis cerana* (Fabricius, 1793)		
5	*Apis dorsata* (Fabricius, 1793)		
6	*Apis florea* (Fabricius, 1787)		
7	*Ceratina binghami* (Cockerell, 1908)		
8	*Tetragonula iridipennis* (Smith, 1854)		
9	*Xylocopa aestuans* (Linnaeus, 1758)		
10	*Xylocopa pubescens* (Spinola, 1838)		
11	*Xylocopa fenestrata* (Fabricius, 1798)		
12	*Megachile bicolor* (Fabricius, 1781)	Megachilidae	
13	*Megachile cephalotes* (Smith, 1853)		
14	*Nomia crassipes* (Fabricius, 1789)	Halictidae	
15	*Pseudapis oxybeloides* (Smith, 1875)		
16	*Andrena sp.* (Fabricius, 1775)	Andrenidae	

Table 2. Abundance of Bess species on *Caesalpinia bonduc* L at different hours of the day during the study period (July-September, 2021-2022) at Abu Road Tehsil, Rajasthan, India

Sl. No.	Bee Species	Number of Bees/m²/5minutes						
		6.00-8.00	8.000-10.00	10.00-12.00	12.00-14.00	14.00-16.00	16.00-18.00	Average
1	*Amegilla dizona* (Engel, 2009)	05	5.8	7.8	8.4	7.4	5.2	6.6
2	*Amegilla violacea* (Lepeletier, 1841)	4.4	6.2	7.2	8.4	7.4	5.8	6.5
3	*Amegilla zonata* (Linnaeus, 1758)	4.8	5.8	7.2	8.4	7.4	5.6	6.5
4	*Apis cerana* (Fabricius, 1793)	5.6	6.4	8.4	9.8	6.8	5.4	7.0
5	*Apis dorsata* (Fabricius, 1793)	6.2	9.4	11.2	13.8	12.6	8.4	10.2
6	*Apis florea* (Fabricius, 1787)	8.4	10.6	12.8	13.4	12.2	8.8	11.0
7	*Ceratina binghami* (Cockerell, 1908)	6.8	8.8	9.6	10.6	9.8	7.6	8.8
8	*Tetragonula iridipennis* (Smith, 1854)	5.8	6.6	8.8	10.8	9.2	6.2	7.9
9	*Xylocopa aestuans* (Linnaeus, 1758)	5.4	7.6	9.6	9.8	8.8	7.2	8.0
10	*Xylocopa pubescens* (Spinola, 1838)	4.2	6.8	7.4	8.8	7.8	6.2	6.8
11	*Xylocopa fenestrata* (Fabricius, 1798)	4.2	6.4	7.6	8.2	7.4	5.4	6.5
12	*Megachile bicolor* (Fabricius, 1781)	4.2	5.6	6.8	7.6	7.2	4.8	6.0
13	*Megachile cephalotes* (Smith, 1853)	3.4	4.8	5.8	6.8	6.2	3.6	5.1
14	*Nomia crassipes* (Fabricius, 1789)	4.2	5.4	6.6	6.2	6.8	4.8	5.6
15	*Pseudapis oxybeloides* (Smith, 1875)	2.2	2.9	4.2	5.4	4.8	2.6	3.6
16	*Andrena sp.* (Fabricius, 1775)	2.2	3.6	4.2	4.8	4.4	3.4	3.7

Table 3. List of others insect found the study plant

Sl. No.	Scientific Name	Common Name	Family	Order
1.	*Spoladea recurvalis* (Fabricius, 1775)	Beet Webworm Moth	Crambidae	
2.	*Suastus gremius* (Fabricius, 1798)	Indian palm bob		
3.	*Hasora chromus* (Cramer, 1782)	Common Banded Awl	Hesperiidae	
4.	*Spindasis ictis* (Hewitson, 1865)	Common shot silverline	Lycaenidae	Lepidoptera
5.	*Poekilocerus pictus* (Fabricius, 1775)	Painted Grasshopper	Pyrgomorphidae	Orthoptera
6.	*Gametis versicolor* (Fabricius, 1775)	Flower chafer beetle	Scarabaeidae	Coleoptera

Photographs of Bee Species (picture. 1-16):

1. *Amegilla dizona* (Engel, 2009)

2. *Amegilla violacea* (Lepeletier, 1841)

3. *Amegilla zonata* (Linnaeus, 1758)

4. *Apis cerana* (Fabricius, 1793)

5. *Apis dorsata* (Fabricius, 1793)

6. *Apis florea* (Fabricius, 1787)

7. *Ceratina binghami* (Cockerell, 1908)

8. *Tetragonula iridipennis* (Smith, 1854)

9. *Xylocopa aestuans* (Linnaeus, 1758)

10. *Xylocopa pubescens* (Spinola, 1838)

11. *Xylocopa fenestrata* (Fabricius, 1798)

12. *Megachile bicolor* (Fabricius, 1781)

13. *Megachile cephalotes* (Smith, 1853)

14. *Nomia crassipes* (Fabricius, 1789)

15. *Pseudapis oxybeloides* (Smith, 1875)

16. *Andrena sp.* (Fabricius, 1775)

1. *Spoladea recurvalis* (Fabricius, 1775)

2. *Suastus gremius* (Fabricius, 1798)

3. *Hasora chromus* (Cramer, 1782)

4. *Spindasis ictis* (Hewitson, 1865)

5. *Poekilocerus pictus* (Fabricius, 1775): A pest

6. *Gametis versicolor* (Fabricius, 1775): A pest

Plate 1. Other Insect faunal species on the Study plant (1-6)

Abundance of Bees: The average abundance of various bee species on *C. bonduc* flowers varied across different time intervals from 6:00 AM to 6:00 PM. Among the observed species, *Pseudapis oxybeloides* had the lowest average abundance at 3.6 bees, while *Apis florea* had the highest average abundance at 10.9 bees.

Among the sixteen species, *A. florea* exhibited higher abundances of 13.4, 12.8, 12.2, 10.6, 8.4, and 8.4 bees/m²/5 minutes during different hours of the day: from 12:00-2:00 PM, 10:00-12:00 PM, 2:00-4:00 PM, 8:00-10:00 AM, 6:00-8:00 AM, and 4:00-6:00 PM, respectively. The average abundance of bee species ranked from lowest to highest was as follows: *Pseudapis oxybeloides* (3.6), *Andrena sp.* (3.7), *Megachile cephalotes* (5.1), *Nomia crassipes* (5.6), *M. bicolor* (6.0), *Amegilla violacea* (6.5), *A. zonata* (6.5), *Xylocopa fenestrata* (6.5), *A. dizona* (6.6), *X.* pubescens (6.8), Apis cerana (7.0), Tetragonula iridipennis (7.9), X. aestuans (8.0), Ceratina binghami (8.8), *A. dorsata* (10.3), *A. florea* (10.9). The highest overall abundance of all species was recorded between 12:00-2:00 PM. notably; *A. florea* had the peak abundance of 13.4 bees/m²/5 minutes during this time.

Other Observations: During the study period, one moth species, *Spoladea recurvalis* (Fabricius, 1775), and three butterfly species—*Suastus gremius* (Fabricius, 1798), *Hasora chromus* (Cramer, 1782), and *Spindasis ictis* (Hewitson, 1865)—were also reported. Additionally, two feeding foliage insect species, *Poekilocerus pictus* (Fabricius, 1775) and *Gametis versicolor* (Fabricius, 1775), were observed. Overall, a total of 22 different entomofauna were documented visiting the flowers of *C. bonduc*.

4. CONCLUSION

The research of bee diversity and abundance on Caesalpinia bonduc discovered a diverse range of pollinators, including 16 species from four families. The most diversity was seen in the Apidae family, notably Apis florea, which also had the highest abundance throughout the day. This emphasizes the importance of C. bonduc as a pollinator-friendly plant in the Aravalli foothills region, sustaining not just bees but also other entomofauna. The findings highlight the ecological relevance of this plant species and its role in preserving local biodiversity. Further research on its pollination ecology might improve our knowledge of its importance in local ecosystems and influence conservation initiatives.

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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