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Foraging activity, diversity and abundance of bees on *Ricinus Communis* (castor plant) at Abu Road, Sirohi, Rajasthan

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Abstract
The *Ricinus communis*, commonly known as the castor bean or castor oil plant, is a perennial flowering shrub belonging to the family, Euphorbiaceae. The foraging activity, diversity and Abundance of bees was estimated from the flowering season in month of august and september from 2021 to 2024. A total of 10 bee species (Order Hymenoptera, Superfamily- Apoidea) *viz*. *Amegilla zonata, Apis cerana, Apis dorsata, Apis florea, Ceratina binghami, Tetragonula iridipennis, Xylocopa fenestrata, Pseudapis oxybeloides, Megachile lanata*, and *Nomia iridescens*) were documented on castor bean plant. It was observed that *Apis florea* was the most abundant (10.42 bees/m2/ 5 minutes) visitor while *Pseudapis oxybeloides* was the least abundant (0.32 bees/ m2/ 5 minutes). The foraging speed was highest observed in the morning between 8.00 am to 10 am. It was observed that *A. florea* spent the maximum average time (9.44 sec.) and *N. iridescens* the least average time (0.565) on the flowers. The Average times spent on the flower by bees were highest in the morning (4.876 in sec at 8-10 AM) and decreased throughout the day (2.702 at 2-4 PM). The ANOVA test results was F-statistic 0.871 and P-value= 0.4648. The p-value is greater than 0.05; there is no statistical significance in bee abundance across the different time intervals. The current study will be significance to understand pollinator's diversity, abundance and foraging activity on study plant.

Keywords: Bee, rajasthan, foraging activity, diversity

Introduction

Pollination, particularly by bees, is a cornerstone of global agriculture, sustaining both crop productivity and human nutrition. With their efficiency and adaptability, bees significantly enhance crop yield and quality, thereby supporting food security and strengthening the agricultural economy. Recognizing their indispensable role emphasizes the need to study bee diversity, distribution, and their pollination services, which are vital for ensuring ecological stability and sustainable agricultural practices (Khalifa *et al*. 2021) [7]. Pollination is a critical ecological service that ensures the reproduction of many angiosperms and is especially vital for crop plants. Among pollinators, bees play a decisive role in both wild and agricultural ecosystems, contributing not only to the diversity of flora but also to crop yield and quality (Klein *et al*. 2007 and Potts *et al*., 2010) [1, 2].

The castor plant (*Ricinus communis*) is an important non-edible oilseed crop grown in arid and semi-arid regions for its oil, which has multipurpose industrial applications including lubricants, soaps, cosmetics, and biofuels (Freitas *et al*. 2012) [3]. Although *R. communis* has often been described as anemophilous (wind-pollinated), increasing evidence suggests that insect, particularly bee, visitation can significantly enhance its fruit set and seed yield (Nayak *et al*. 2022) [4]. Bees visiting male and female flowers, moving between them, can contribute to pollen transfer and even trigger dehiscence of anthers, thereby increasing airborne pollen release and improving pollination efficiency. The studies in commercial plantations have shown that *Apis mellifera* and other bee species can increase *R. communis* productivity beyond what is achieved by wind alone (Nayak *et al*. 2020) [5, 6]. Aside from yield, understanding the diversity, abundance, and foraging activity of bees on *R. communis* is essential, especially in regions where climatic conditions and land use may impact pollinator communities. The recent studies in Haryana, India, for example, have documented that among insect visitors to castor, Hymenoptera - especially social bees like *Apis florea, A. cerana, A. mellifera*, and *A. dorsata* - dominate the visitor assemblage; non-Apis insects are present but comparatively rare. Further, foraging behaviour metrics such as visitation rate, foraging speed, and daily activity duration differ among bee species, with peak periods often occurring in mid-morning hours. Nectar sugar production, flower sex (male vs. female), hybrid type, and diurnal and climatic factors also influence foraging ((Nayak *et al*. 2020 and Nayak, 2020) [5, 6]. Birdshire *et al.* (2020) [10] observed that as urbanization increased, there was a decline in bee diversity and abundance. The economic implications are enormous; a 2025 global synthesis commissioned by Bayer assigns a market value of US $235 billion to US $577 billion annually to hymenopteran-mediated pollination, with specialty crops such as almonds, berries, and oilseeds most vulnerable to service deficits (Schindler *et al.,* 2025).

The Sirohi district, in southern Rajasthan, represents a semi-arid environment with unique floral ecology and land-use patterns. There is, however, a lack of focused studies examining the interaction of bees with *R. communis* in this region, particularly in terms of species richness, abundance, and foraging dynamics. Gaps also exist in understanding which bee species are most active, when they forage most intensely, and how these behaviors might affect the reproductive success of castor under local conditions. Therefore, this study aims to investigate the spatio-temporal foraging activities of bees, focusing on species diversity, foraging speed, and abundance.

Material and Methods

Study Area: Abu Road, located in Sirohi district at the foothills of the Aravalli ranges, supports a mosaic of habitats that contribute to its rich biodiversity. The region is characterized by dry deciduous forests on the hills and foothills, dominated by species such as *Anogeissus latifolia, Boswellia serrata* and *Butea monosperma*. In the lower plains, scrub and thorny vegetation, including *Acacia, Ziziphus* and *Capparis* species, is common, while riverine habitats along the Banas River and its tributaries sustain *Ficus, Tamarindus* and various reed communities. Agricultural landscapes with crops like mustard, wheat, maize and castor, along with adjoining grasslands. The diverse groups of flowering crops were prominently cultivated *viz.* Castor (*Ricinus communis*), Mustard (*Brassica nigra*), Marigold (*Tagetes erecta*), Radish (*Raphanus sativus*), Fennel (*Foeniculum vulgare*), Cucumber (*Cucumis sativus*) and Bitter Gourd (*Momordica charantia*). These crop species provided nectar and pollen resources.

Castor Bean: *R. communis*, commonly known as the castor bean or castor oil plant (Figure: 1). Typically growing to a height of 4-5 meters, the plant features an aerial, upright, and herbaceous stem. Its leaves are large, palmate, and arranged alternately. The species is monoecious, bearing both male and female flowers on the same plant. It reproduces through a mixed pollination system that includes both self-pollination and cross-pollination. The flowers are unisexual, incomplete, radially symmetrical (actinomorphic), and lack petals. This fast-growing, suckering shrub produces spiny capsules, which may be greenish to reddish-purple, containing large, shiny, oval seeds with mottled brown patterns. These seeds, which are highly toxic, have a warty outgrowth called a caruncle. Castor seeds are the primary source of castor oil, which is used in various applications.

In the study area, the average values of temperature, relative humidity, and wind velocity during the years 2021 to 2024 were 25.38 °C, 50.16%, and 3.16 m/s, respectively.

The foraging activity of bees has been estimated in flowering season (August to September) in between 2021 to 2024. The foraging speed has been estimated in terms of time spent by insect visitors on the flowers. Time spent by the bees on the flowers has been recorded from 8.00 am to 4.00 pm on the day of observation. Observations were primarily made through direct and with the help of videography through camera (Nikon D-5600, equipped with an 18- 5 mm lens) was used for photography. The observed bees were recorded along with their individuals during the sampling period. Initial year (2022), bees species were collected. Subsequent year (2023 and 2024) collection was of not made due to same species and conservation.

The collected specimens were placed in kill jars containing ethyl acetate and later transferred to airtight insect box. The collected specimens were pinned, labeled and identified based on morphological characteristics using taxonomic keys (Gupta, 1993; and Michener, 2007) [8, 9]. Identification was carried out by focused on diagnostic features such as body coloration, wing venation, and other morphological features *viz*. - mandibles, labrum, clypeus, malar space and tibial spur.

Fig 1: Foraging activities by Bees on a castor Plant and a castor Plant

Results

A total of 10 bee species (Table 1) have been observed on study plant. The observed species are belonging to the order Hymenoptera (Superfamily: Apoidea). A total of 10 bee species were observed, of which seven belonged to the family Apidae, two to Halictidae, and one to Megachilidae. It was observed that, *Apis florea* was the most abundant (10.42 bees/m^2/ 5 minutes) visitor while *Pseudapis oxybeloides* was the least abundant (0.32 bees/ m^2/ 5 minutes).

The Foraging Activity of Insect Pollinators on *Ricinus communis*

The foraging behavior and abundance of bee species on *Ricinus communis* were recorded across different time intervals of the day (08:00–16:00 h). A total of ten bee species belonging to different families were observed (Table 1). Foraging time per flower (he mean time spent per flower) varied considerably among species. The *Apis florea* exhibited the highest mean handling time (9.44 s/flower), followed by *Apis dorsata* (6.91 s/flower) and *Apis cerana* (5.95 s/flower). In contrast, solitary bees such as *Megachile lanata* (0.62 s/flower) and *Nomia iridescens* (0.57 s/flower) recorded the lowest values. The medium handling times were observed for *Ceratina binghami* (4.72 s/flower) and *Tetragonula iridipennis* (4.54 s/flower).

The abundance (individuals/m^2/5 min) also showed species-specific variation. Apis florea was the most abundant species (10.42/m^2/5 min), followed by *Apis cerana* (4.84/m^2/5 min) and *Apis dorsata* (2.56/m^2/5 min). The stingless bee *Tetragonula iridipennis* (1.82/m^2/5 min) and *Nomia iridescens* (0.84/m^2/5 min) also contributed noticeably. In contrast, species such as *Megachile lanata* (0.26/m^2/5 min), *Pseudapis oxybeloides* (0.32/m^2/5 min), and *Amegilla zonata* (0.40/m^2/5 min) showed very low abundance.

The effect of time duration of the day on the foraging activity was statistically analyzed. Average times spent on the flower by bees were highest in the morning (4.876 in sec at 8-10 AM) and decreased throughout the day (down to 2.702 at 2-4 PM) (Figure: 2).

For most bees species, peak foraging activity occurred during the morning hours (08:00-12:00 h), with a gradual decline toward the afternoon (12:00-16:00 h). This trend was most pronounced in *Apis dorsata* and *Apis cerana*, whereas *Apis florea* maintained relatively higher foraging activity throughout the day. Overall, *Apis florea* emerged as the dominant pollinator of *R. communis* in terms of both abundance and time spent per flower, whereas solitary bees such as *Megachile lanata* and *Pseudapis oxybeloides* played only a minor role. Pearson's correlation analysis revealed a strong positive relationship between mean time spent per flower and bee abundance ($r = 0.84$). This suggests that species investing more time per flower also tend to occur in greater abundance on *R. communis*. A one-way ANOVA test indicated no significant difference between the two variables ($F = 1.15$, $p = 0.30$), implying that while abundance and handling time are positively associated, variation among species may be influenced by additional ecological factors.

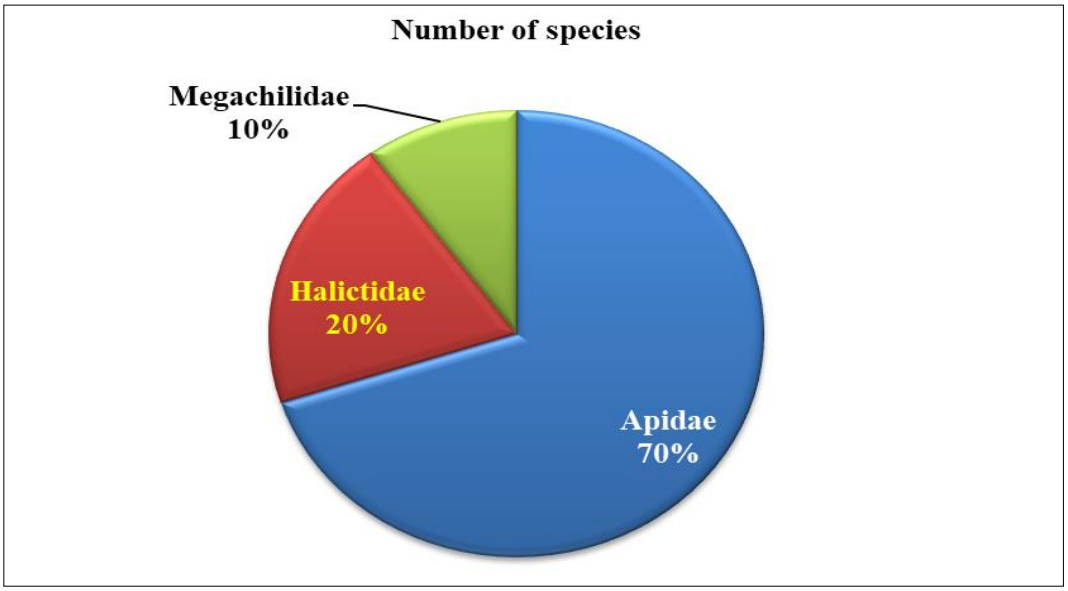

Fig 2: Representation of % of bees families on the study plant

Table 1: Time spent (in seconds) on per flower by the bees and Abundance of Bees (m^2/5 minutes) on castor Oil plant (*Ricinus communis*)

Sr. No.	Bee Species	8-10 AM	10-12 AM	12-02 PM	02-04 PM	Mean Time value	Average Abundance m^2/5 minutes
1	*Amegilla zonata* (Linnaeus, 1758)	01.80	01.20	01.00	00.46	01.115	00.40
2	*Apis cerana* (Fabricius, 1793)	07.28	06.40	05.26	04.88	05.955	04.840
3	*Apis dorsata* (Fabricius, 1793)	09.16	07.12	06.68	04.66	06.905	02.560
4	*Apis florea* (Fabricius, 1787)	12.12	09.24	08.60	07.80	09.44	10.420
5	*Ceratina binghami* (Cockerell, 1908)	06.26	05.20	04.20	03.20	04.715	00.580
6	*Tetragonula iridipennis* (Smith, 1854)	06.14	05.00	04.20	02.80	04.535	01.820
7	*Xylocopa fenestrata* (Fabricius, 1798)	02.20	02.00	01.40	01.00	01.65	00.440
8	*Pseudapis oxybeloides* (Smith, 1875)	02.24	02.20	02.00	01.40	01.96	00.320
9	*Megachile lanata* (Fabricius, 1775)	0.82	00.68	00.54	00.42	00.615	00.260
10	*Nomia iridescens* (Smith, 1853)	0.74	00.64	00.48	00.40	00.565	00.840

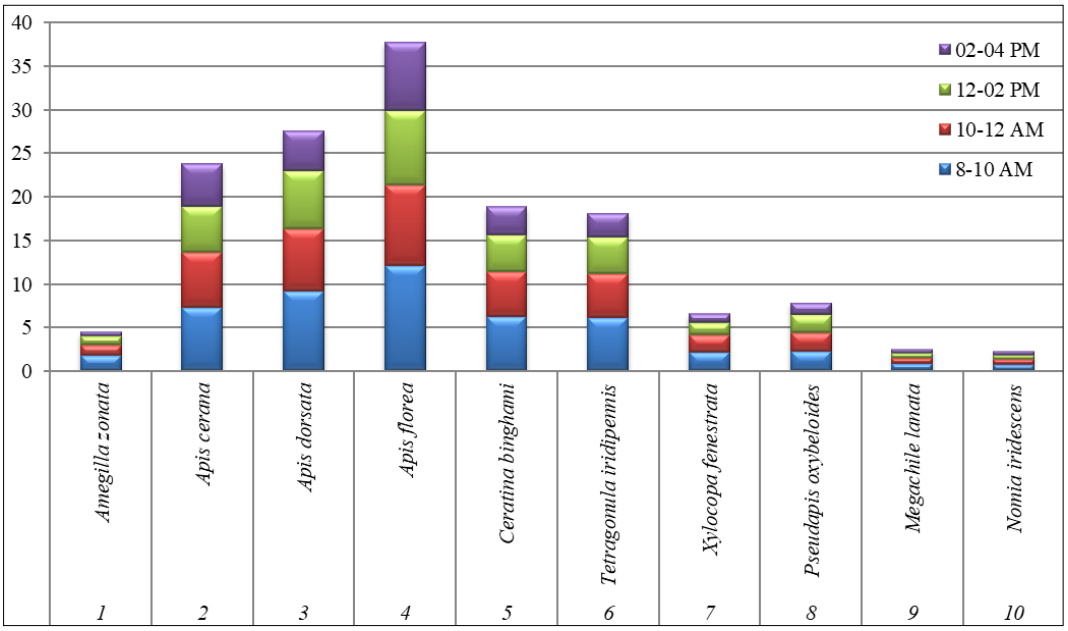

Fig 2: Foraging Activity (Time Spent per flower) of Bees at different Time Intervals on *Ricinus communis*

Discussion

The present study revealed that *Apis florea* was the most dominant pollinator of *R. communis*, showing both the highest abundance and longest handling time per flower. This observation is consistent with the findings of Sharma *et al*. (2019) [11], who reported that *A. florea* is an efficient pollinator of small-flowered crops in arid regions of India. A strong positive correlation (r = 0.84) between handling time and abundance suggests that species investing more time per flower tend to occur more frequently. However, the non-significant ANOVA indicates that variations among species may also be influenced by environmental and ecological factors. Kumar *et al*. (2017) [12] similarly highlighted the role of climatic variables and interspecific competition in shaping bee foraging behavior in semi-arid ecosystems. The diurnal activity of bees showed peak foraging during morning hours, gradually decreasing in the afternoon. This pattern aligns with the findings of Abrol (2012), who demonstrated that pollinator activity typically coincides with optimal temperature and nectar secretion. Interestingly, *A. florea* maintained relatively stable foraging throughout the day, suggesting better adaptation to fluctuating conditions.

Although solitary bees such as *Megachile lanata* and *Pseudapis oxybeloides* were less abundant, their role cannot be overlooked. Greenleaf and Kremen (2006) emphasized that solitary and wild bees enhance pollination efficiency by complementing honey bees, thereby contributing to ecosystem stability and crop yield.

Conclusion

The conclusion of current study is the *Apis florea* emerged as the dominant pollinator of *R. communis* in terms of both abundance and time spent per flower, whereas solitary bees such as *Megachile lanata* and *Pseudapis oxybeloides* played only a minor role. Understanding these interactions can inform efforts to enhance pollinator-friendly agricultural practices, improve castor yield, and contribute to biodiversity conservation in semi-arid landscapes. The availability of floral rewards significantly influenced pollinator visitation rates. Spatial foraging activities of bees refer to the way bees search for and collect resources like nectar, pollen, water, and resins across different ecosystems. *A. florea* emerged as the principal pollinator of R. communis, while other species played supplementary roles in maintaining pollinator diversity. These findings underscore the importance of conserving diverse bee communities for sustainable pollination services.

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