



## Seasonal dynamics of honey bee foraging and floral calendar development in Semi-Arid Region of North-Eastern Rajasthan

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### Abstract

The present study was conducted from 2021 to 2023 in the intensively cultivated agricultural landscapes of Sikar district, located in the semi-arid north-eastern region of Rajasthan, India. The research aimed to assess the diversity of honey bee species, document their floral preferences, and develop a comprehensive floral calendar to understand the honey flow and dearth periods critical to beekeeping and crop pollination. Four honey bee species, *Apis dorsata*, *Apis florea*, *Apis cerana indica*, and *Apis mellifera*, were identified. Observations revealed a seasonal pattern in floral resource availability, closely tied to crop cycles, influencing bee foraging behavior and pollination dynamics. Major honey flow periods occurred during winter (November–March) and post-monsoon months (September–October), driven by crops such as mustard (*Brassica campestris*), onion (*Allium cepa*), and ber (*Ziziphus mauritiana*). Conversely, dearth periods were observed during late summer (May–June) due to limited blooming. The study highlighted the importance of crop diversity and strategic flowering to support sustainable pollinator populations and optimize both pollination services and honey production in the region. An annual beekeeping calendar was developed to guide local apiculture practices aligned with floral availability.

**Keywords:** Honey bee, floral calendar, pollination, honey flow, dearth period

### Introduction

Insects represent one of the most diverse and abundant groups in the animal kingdom, playing critical roles in ecosystem functionality. They contribute to plant growth, seed dispersal, and the decomposition of organic matter. Among these ecological services, insect-mediated pollination stands out as a key process that underpins global food security. The relationship between pollinators and flowering plants is an essential mutualistic interaction that ensures biodiversity, ecosystem health, and agricultural productivity. Alarming, the decline of pollinator populations threatens not only ecosystem balance but also the sustainability of agricultural systems that rely on them.

Among all insect pollinators, honey bees (particularly *A. mellifera* and *A. cerana*) are regarded as the most efficient due to their social behavior, foraging range, and adaptability to diverse crop systems. Studies estimated that nearly 73% of global cultivated crops depend, to varying degrees, on animal pollinators, with bees contributing the largest share. Other pollinating agents include flies (19%), bats (6.5%), wasps (5%), beetles (5%), birds (4%), and butterflies (4%) (Klein *et al.*, 2007; Potts *et al.*, 2010)<sup>[6, 12]</sup>.

In the context of agriculture, pollination by honey bees significantly enhances both crop quantity and quality. Integrating managed bee colonies into farming systems has been shown to increase yields across a wide array of crops, fruits, vegetables, oilseeds, and nuts, while simultaneously improving crop uniformity and overall market value (Garibaldi *et al.*, 2013)<sup>[4]</sup>. This is particularly relevant in the context of climate change, land degradation, and the rising global demand for food. However, the decline in honey bee populations due to habitat loss, pesticide exposure, and disease presents a major challenge to modern agriculture and calls for the implementation of pollination management strategies.

India, with its rapidly growing population and diverse agro-climatic zones, faces the dual challenge of increasing food

production while managing environmental stress. Honey bee pollination, especially through apiculture of species such as *Apis mellifera*, *A. cerana indica*, and stingless bees, offers a sustainable and eco-friendly strategy to enhance agricultural output. Empirical studies have demonstrated that bee-mediated pollination improves fruit set, seed production, and overall crop market value (Abrol, 2011; Kumar *et al.*, 2012)<sup>[1, 8]</sup>.

In northwestern Indian states such as Punjab, Haryana, and Rajasthan, key contributors to vegetable production in India, honey bees play a pivotal role in enhancing the productivity of crops like cucurbits, tomato, brinjal, and okra. Even with the adoption of hybrid seeds and fertilizers, insufficient pollination remains a limiting factor for yield. Integrating apiculture-based pollination can address this gap effectively and sustainably. While Punjab and Haryana benefit from strong irrigation infrastructure and progressive farming communities, Rajasthan, despite its harsher agro-climatic conditions, also shows significant promise, especially in districts like Sikar where irrigated zones support vegetable cultivation.

Promoting honey bee pollination not only enhances agricultural returns but also diversifies income of farmers through honey, beeswax, and other bee products (Verma, 1990; Morse and Calderone, 2000)<sup>[10, 13]</sup>. This paper explores the diversity of honey bee species in the Sikar district of Rajasthan, their role as floral visitors in major crops, and the broader implications of honey bee pollination on crop productivity and agricultural sustainability.

### Materials and Methods

The present study was conducted in the Sikar district, located in the north eastern region of Rajasthan, India. Geographically, the district lies between 27.21° to 28.12° North latitude and 74.44° to 75.25° East longitude, with an average elevation of approximately 427 meters (1,401 feet)

above sea level. The research was carried out from 2021 to 2023 in intensively cultivated agricultural areas of the district; selection was based on crop diversity and bee activity. During the study period, Systematic field observations during peak foraging hours (usually 8:00–11:00 am and 3:00–5:00 pm) were conducted across various crop fields to identify various honey bees’ activities, floral plant species visited and pollinated by honey bees. The cumulative records of bee activity and floral resources across seasons were compiled to prepare floral calendar with dearth and honey Flow period.

Plant and bee specimens were collected for further identification. Crops were identified with the help of local famers. Honey bee specimens were preserved in 70% ethanol and deposited in the Department of Zoology for taxonomic identification. Identification of bee species was carried out using standard taxonomic keys given by Michener, (2007) [9] and with support from the Entomology Laboratory at the University of Rajasthan

**Results**

In the Sikar district, a semi-arid agro climatic zone, of Rajasthan, the presence of diverse flowering crops throughout the year provides a consistent yet seasonal foraging base for multiple species of honey bees. Total four species of honey bees were observed in the agricultural crop fields of the Sikar region. These included *A. dorsata*, *A. cerana*, *A. mellifera*, and *A. florae*, belonging to the order Hymenoptera, superfamily Apoidea, and family Apidae. It is noteworthy that *Apis mellifera* is not indigenous to the Sikar region but has been introduced for commercial beekeeping purposes. The region exhibited a distinct pattern of nectar and pollen availability based on crop flowering cycles, which directly influenced honey bee activity and pollination dynamics.

During the winter season (November to February), major

honey flow was supported by crops such as Indian mustard (*Brassica campestris*), fenugreek (*Trigonella foenum-graecum*), and chickpea (*Cicer arietinum*) (Table 1). Mustard and fenugreek provided both nectar and pollen, while chickpea served as a pollen source. In early spring (February to April), crops like onion (*Allium cepa*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*) flower, offered vital resources like onion contributed nectar and pollen, while wheat and barley offered pollen. This period supported continued bee activity and transitions into a brief dearth period.

As temperatures rise in late spring and early summer (March to May), watermelon (*Citrullus lanatus*) emerged as a significant crop offering both nectar and pollen, which is essential during a time of limited floral diversity. The onset of the monsoon (July to October) brought renewed minor and major honey flows, marked by the flowering of ber (*Ziziphus mauritiana*), guava (*Psidium guajava*), green gram (*Vigna radiata*), cluster bean (*Cyamopsis tetragonoloba*), and sunflower (*Helianthus annuus*). Green gram and guava provided both nectar and pollen, while ber and pearl millet (*Pennisetum glaucum*) served primarily as pollen sources. Sunflower, despite being a minor resource in some varieties, contributed to both nectar and pollen availability in cultivated hybrids.

This year-round sequence of floral resources underlined the importance of maintaining crop diversity and seasonal flowering for sustaining bee populations in the Sikar region. Native bees, especially *A. dorsata* played a significant role in pollinating both cultivated and wild flora, whereas managed *A. mellifera* colonies were primarily utilized to exploit peak nectar flows from mustard and onion crops. The dynamic interplay between agricultural practices and pollinator ecology in Sikar highlighted the need for integrated pollination management to optimize both crop yield and honey production.

**Table 1:** Plant Flowers visited by Honey Bees and Foraging Purpose

Botanical Name	Common Name	Family	Flowering Period	Nectar	Pollen	Nectar + Pollen
<i>Brassica campestris</i>	Indian Mustard	Brassicaceae	November–February	✓	✓	✓
<i>Cicer arietinum</i>	Chickpea	Fabaceae	December–March	-	✓	-
<i>Allium cepa</i>	Onion	Amaryllidaceae	February–April	✓	✓	✓
<i>Triticum aestivum</i>	Wheat	Poaceae	February–March	-	✓	-
<i>Ziziphus mauritiana</i>	Ber (Jujube)	Rhamnaceae	July–October	-	✓	-
<i>Vigna radiata</i>	Green Gram (Moong)	Fabaceae	August–September	✓	✓	✓
<i>Cyamopsis tetragonoloba</i>	Cluster Bean	Fabaceae	August–October	✓	-	-
<i>Citrullus lanatus</i>	Watermelon	Cucurbitaceae	March–May	✓	✓	✓
<i>Hordeum vulgare</i>	Barley	Poaceae	February – March		✓	
<i>Pennisetum glaucum</i>	Pearl Millet	Poaceae	July – September		✓	
<i>Sorghum bicolor</i>	Sorghum	Poaceae	August – October		✓	
<i>Trigonella foenum</i>	Fenugreek	Fabaceae	December – February	✓	✓	✓
<i>Helianthus annuus</i> L.	Sunflower	Asteraceae	July – September	✓	✓	✓
<i>Psidium guajava</i>	Guava	Myrtaceae	July–October	✓	-	-

**Annual Floral Calendar & Honey Flow Pattern-** The yearly cycle of flowering crops and pollination activity reflected a dynamic pattern of honey flow, ranging from

peak seasons of abundance to challenging dearth periods. Table 2 shows a month-wise description of crop flowering, bee activity, and honey flow status.

**Table 2:** Annual floral Calendar with Honey Flow status

Month	Major Flowering Crops	Pollination Activity	Status
January	Mustard ( <i>Brassica spp.</i> ), Chickpea (early)	High bee activity	Major Honey Flow
February	Mustard (peak), Barley, Chickpea, Onion	Peak bee visitation	Major Honey Flow

March	Wheat, Onion, Barley	Strong bee foraging	Major Honey Flow
April	Onion (late), Summer vegetables (okra, cucurbits)	Moderate–low forage	Transition
May	Few crops, cucurbits like watermelon	Low bee activity	Dearth Period
June	Sparse flowering; monsoon starts, scattered wild bloom	Very low activity	Dearth Period
July	Onset of monsoon flowering (wild shrubs, cucurbits), Ber, Pearl Millet, Guava	Low to moderate	Beginning Flow
August	Ber, Sunflower (early), Green Gram, Pearl Millet, cluster Bean, Sorghum	Moderate bee activity	Minor Flow
September	Ber, Sunflower (early), Green Gram, Pearl Millet, cluster Bean, Sorghum	High activity	Major Honey Flow
October	Ber, Sunflower (early), Green Gram, Pearl Millet, cluster Bean, Sorghum	Peak pollination	Major Honey Flow
November	Mustard (early), Chickpea, Fenugreek Sunflower (late)	Moderate to high	Minor Flow
December	Mustard (early), Chickpea, Fenugreek	Activity increases	Early Flow Start

## Discussion

The findings from the Sikar district presented a comprehensive view of the intricate relationship between seasonal floral availability, agricultural cropping patterns, and honey bee foraging dynamics in a semi-arid environment. The year-round but seasonally fluctuating availability of nectar and pollen resources underscored the ecological interdependence between pollinators and crops. The alternating cycles of major, minor, and dearth honey flow periods aligned closely with the cropping calendar, highlighting the importance of floral continuity for sustaining healthy bee populations and optimizing apicultural productivity.

Native bee species, particularly *A. dorsata* and *A. florea*, emerged as key pollinators in the region, each exhibiting unique foraging behaviors and ecological roles. *A. dorsata*, being a highly migratory and long-distance forager, capitalized on mass flowering events such as the mustard bloom, a major nectar source in the winter season (November to March). Its dominance during this period aligned with findings from other semi-arid regions in India (Nair *et al.*, 2015)<sup>[11]</sup> and reinforced its critical role in large-scale pollination services. In contrast, *A. florea*, with its smaller foraging range, thrived in fragmented landscapes, making significant contributions to pollination in small-scale farms and home gardens (Koeniger and Koeniger, 2000)<sup>[7]</sup>.

The limited presence of *A. cerana indica* in Sikar, possibly due to competition and displacement by the introduced *A. mellifera*, reflected broader trends observed across India. While *A. mellifera* was favored for its high honey yield and was successfully managed in mustard and onion fields, its dependence on human intervention and continuous floral resources rendered it less resilient in harsh, resource-scarce periods (Gogoi *et al.*, 2020)<sup>[5]</sup>. Thus, while beneficial for commercial honey production, *A. mellifera* posed ecological concerns regarding the displacement of native species and long-term sustainability.

The floral calendar of Sikar revealed two major honey flow periods, winter (November–March) and late monsoon to early autumn (September–October), interspersed with minor flows and dearth periods. Winter crops such as mustard, chickpea, fenugreek, and onion provided abundant nectar and pollen, supporting robust colony development and peak honey production (Kumar *et al.*, 2012; Chauhan *et al.*, 2019)<sup>[2, 8]</sup>. The mustard bloom, in particular, served as a cornerstone of regional apiculture due to its dense flowering and nectar richness.

The dearth period during April–June presented a critical challenge, marked by reduced forage availability and heightened stress on colonies. This period, common in arid and semi-arid zones, required strategic interventions such as supplemental feeding or migratory beekeeping to more

resource-rich areas (Gogoi *et al.*, 2020)<sup>[5]</sup>. Interestingly, crops like watermelon during early summer and cereal grained like wheat, barley, and pearl millet, though primarily wind-pollinated, still offered opportunistic foraging resources, particularly pollen, which can help in mitigating nutritional gaps.

With the onset of the monsoon, resurgence in blooming occurred through crops such as green gram, ber, guava, and sunflower. These provided a bridge in forage availability, contributing to minor flows and maintaining colony vitality. The period of September–October marked the second major honey flow, benefiting from overlapping blooms of multiple crops, which enhanced pollination efficiency and bee colony performance (Garibaldi *et al.*, 2013)<sup>[4]</sup>.

The observed seasonal synergy between crop phenology and bee biology emphasized the need for diversified cropping systems and staggered flowering schedules, as recommended by Klein *et al.*, 2007<sup>[6]</sup>. Such practices not only stabilized forage availability but also buffered against climate-induced shifts in flowering patterns. The importance of wild flora, such as ber and guava, underutilized crops in maintaining pollinator diversity and bridging forage gaps was also evident.

Different bee species have a different biological and behavioural trait, which means they need different management approaches in agricultural or apicultural field. Nesting and migration patterns of *A. dorsata* were naturally synchronized with the major flow seasons, whereas *A. mellifera* required targeted colony development, migration, and supplemental inputs to align with floral peaks. This made regional floral calendars, like the one observed in Sikar, indispensable tools for guiding beekeeping operations, colony health management, and pollination planning (FAO, 2018)<sup>[3]</sup>.

Finally, the ongoing pressures of agricultural intensification, pesticide use, and climate variability threatened to disrupt the fine-tuned balance between floral resources and pollinator populations. To safeguard pollination services and biodiversity, integrated approaches that promote agrobiodiversity, conserved wild habitats, and adopted pollinator-friendly practices, such as reduced pesticide use during bloom periods and incorporation of flowering cover crops were considered essential (Garibaldi *et al.*, 2013; FAO, 2018)<sup>[3, 4]</sup>.

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