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# Differential Visitation of Non-*Apis* Bee Pollinators for Invasive over Non-Invasive Plants: A Case Study from the Kole Ramsar site, Kerala, India

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## ABSTRACT

The present work investigated the pollination preferences of non-*Apis* bees in the Kole wetlands of Thrissur, Kerala. The twelve-month study (May 2024 to April 2025) was conducted across six different sites within the Thrissur Kole wetlands. The association between non-*Apis* bees and flowering plants of the Asteraceae family was specifically examined. A total of 13 non-*Apis* bee species belonging to eight genera and two families were recorded from seven flowering plants. Among the seven plants, three were non-invasive, and four were invasive. The bee family Halictidae was predominant, accounting for seven species under five genera, followed by Apidae, with six species under three genera. The genus *Ceratina* dominated the collection and was associated with a larger number of Asteraceae plants. High species abundance was recorded on *Mikania micrantha* between December 2024 and February 2025. Overall, significantly higher bee species richness and abundance were recorded from the invasive plants compared to the non-invasive plants. This differential visitation is due to phenology, flower colour, abundance of flowers in the invasive plants, and their rich rewards, such as abundant nectar, pollen, and long-lasting flowers that attract adapted pollinators. Increased pollinator attraction to invasive species can intensify their ecological impacts, thereby altering native plant communities, pollinator behaviors, and overall ecosystem balance of the Kole wetlands.

*Keywords:* solitary bees, bee rewards, floral traits, conservation, native flora, pollination ecology, Kole wetlands.

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## INTRODUCTION

Bees are the most effective pollinators worldwide, which belong to the superfamily Apoidea of the order Hymenoptera. Apoidea includes seven families (Michener et al., 2000). India has 796 bee species (Pannure & Belavadi, 2019), out of over 26,164 species documented globally (Dorey et al., 2026). Eighty-six species of bees under 19 genera are reported from Kerala (Anju, Jobiraj, & Bijoy, 2020). Recently, nine species of non-*Apis* bees from the subfamily Nomiinae were recorded from different parts of Thrissur district, Kerala (Athul, Vishnu, Prakash, Bijoy, & Shaji, 2025).

Flowering plants represent up to 95% of all vascular plants on the earth, out of which 4681 species, 57 subspecies, and 287 varieties occur in Kerala (Nayar, Rasiya Beegam, Mohanan, Rajkumar, & Sibi, 2006). The state constitutes only 1.18% of India's geographical area, yet it hosts 27.57% of the country's flowering plants (Nayar, Sibi, Rasiya Beegam, Mohanan, & Rajkumar, 2008). The family Asteraceae constitutes the largest vascular plant family with approximately 30,000 species and over 1,100 genera. The family is well-represented in temperate or subtropical regions, and they possess flat clusters of small flowers at the top of the stem and, owing to their diverse flower colours, and they are widely distributed and abundant across a variety of habitats, contributing significantly to local floral diversity (Achika, Arthur, Gerald, & Adedayo, 2014; Hajra, 1995), it comprises about 10% of the total diversity (Mandel et al., 2019). In India, the family is represented by ca. 900 species under 167 genera (Hajra, 1995). In Kerala, a total of 180 species from 64 genera have been recorded (Nayar et al., 2008). A total of 82 invasive plant species, representing 30 families, have been recorded in Kerala, among which 13 species belong to the family Asteraceae (Sankaran, Suresh, & Sajeev, 2012).

Wetlands are extremely important for wildlife protection, recreation, pollution and sediment control, flood prevention, and food production (Jayson, 2002). The Kole wetland, one of Kerala's rice granaries, is a unique wetland ecosystem in South India. It is part of the Vembanad-Kole wetland system, covering 15,1250 ha and designated as a Ramsar site in 2002. A significant portion of the Kole wetland remains submerged under water for about six months of the year, lending it both terrestrial and aquatic properties. The interactions between agriculture and wetlands are of considerable importance, as the demand for food production places pressure on wetlands (Srinivasan, 2011).

The present study aims to understand the association between non-*Apis* bees and Asteraceae plants in this area, which not only provides insights into pollination ecology but also informs strategies for conserving pollinators and their habitats amid increasing anthropogenic activities. Documentation of biodiversity is an urgent requirement, as knowledge about the ecosystem's structure, composition, and species diversity helps to improve the protection of species.

## MATERIALS AND METHODS

### Study area

The Kole region is situated in the Thrissur and Malappuram Districts of Kerala State, and the land is linked to the sea through drainage channels and backwaters. The total extent under paddy is 18602 ha, which is 2.35 per cent of the State's gross rice cultivation area (Jayson, 2002). The study was conducted from a total of six sites- three from Thrissur North Kole; Manakody Kole (Lat. 10.471136$^0$ Long 76.167233$^0$), Alappad Kole (Lat. 10.446739$^0$ Long. 76.165403$^0$), and Pullazhi Kole (Lat. 10.529572$^0$ Long. 76.166053$^0$), and three from Thrissur South Kole; Kattoor Kole (Lat. 10.366523$^0$ Long. 76.163552$^0$), Muriyad-Anandapuram Kole (Lat. 10.366399$^0$ Long. 76.248462$^0$), and Chemmanda Kole (Lat. 10.395886$^0$ Long. 76.19761$^0$) (Fig. 1).

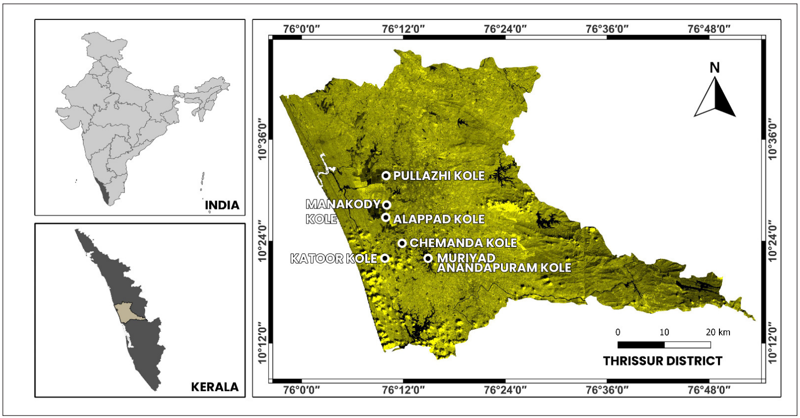


Figure 1. Map showing the location of the six sampling sites in the Thrissur district.

### Collection, Preservation, and Identification

An observational strategy was used to document the diversity of non-*Apis* bees associated with flowering plants in the family Asteraceae. Bee sampling was conducted once per month at each of the six study sites over one year (May 2024 to April 2025), resulting in 12 sampling events per site. The transect was 150 m long and 1 m wide on both sides of the wetland bund. Observations and collections were conducted at three-time intervals: 09:00–10:00 am, 12:00–1:00 pm, and 3:00–4:00 pm. Associated bees were directly collected from the plants using a sweep net during each observation period. Habitat associations and correlations between flowering plants of the family Asteraceae and bees were specifically examined and documented. In addition, plant traits including flower colour, inflorescence, flowering season, and blooming period were observed and recorded during data collection, although flowering stages were not classified separately. Collected specimens were killed by using ethyl acetate, and the killed specimens were then pinned and preserved. Detailed morphological examinations were carried out using high-resolution stereo zoom microscopes, including Labomed® iVu 5100 and Luxeo® 6Z, to facilitate taxonomic identification.

Genera and species-level identifications were performed following the taxonomic keys and descriptions provided by Pauly (2009, 2014). Asteraceae plant species were identified by a botanical expert using field photographs collected during the surveys. The invasive status of plant species was determined following the handbook on invasive plants of Kerala published by the Kerala State Biodiversity Board (Sankaran, Suresh, & Sajeev, 2012). Bees exhibiting resource interactions with flowers for either nectar, pollen, or both are recorded through direct observations during repeated surveys and are considered florally associated plant species for this study. All collected specimens were deposited at the Shadpada Entomology Research Lab (SERL) at Christ College (Autonomous), Irinjalakuda, Thrissur, Kerala, India.

### Data analyses

Relative bee abundance was calculated as the total number of individual bees, and relative species richness was calculated based on the total number of species collected. Student's t-test was calculated using R software.

## RESULTS AND DISCUSSION

A total of 13 species under eight genera and two families of non-*Apis* bees were recorded (Table 1), from seven flowering species of the Family Asteraceae. The study represents 15% of the species and 42% of the genera reported from Kerala.

| Family | Genus | Sl. No. | Non-Apis bee species |
|---|---|---|---|
| Apidae | *Amegilla* | 1 | *Amegilla zonata* (Linnaeus, 1758) |
| | *Ceratina* | 2 | *Ceratina binghami* Cockerell, 1908 |
| | | 3 | *Ceratina smaragdula* (Fabricius, 1787) |
| | | 4 | *Ceratina unimaculata* Smith,1879 |
| | | 5 | *Ceratina dentipes* Friese, 1914 |
| | *Tetragonula* | 6 | *Tetragonula travancorica* Shanas and Faseeh, 2019 |
| Halictidae | *Nomia* | 7 | *Nomia crassipes* (Fabricius, 1798) |
| | *Austronomia* | 8 | *Astronomía capitata* (Smith, 1875) |
| | | 9 | *Austronomia ustula* (Cockerell, 1911) |
| | *Hoplonomia* | 10 | *Hoplonomia westwoodi* Gribodo, 1894 |
| | | 11 | *Hoplonomia elliotii* Smith, 1875 |
| | *Pseudapis* | 12 | *Pseudapis oxybeloides* (Smith, 1875) |
| | *Halictus* | 13 | *Halictus lucidipennis* Smith, 1853 |

Table 1. Checklist of non-*Apis* bees from the study area.

Out of seven plants, three were non-invasive, and four were invasive (Table 2). A total of 340 specimens were collected from our study site during the study period. Species richness of non-*Apis* bees is higher during the post-monsoon period, followed by the pre-monsoon period, while the abundance shows an opposite trend during these periods. Bees associated with invasive plants comprised the majority of the collected individuals (72.94%) and exhibited higher relative species richness (92.31%) than those associated with non-invasive plants (27.06% abundance and 69.23% species richness).

| Family | Sl. No. | Plant species | Plant category |
|---|---|---|---|
| **Asteraceae** | 1 | *Mikania micrantha* Kunth | Invasive |
| | 2 | *Synedrella nodiflora* (L.) Gaerts | Invasive |
| | 3 | *Sphagneticola trilobata* (L). Pruski | Invasive |
| | 4 | *Tridax procumbens* L. | Invasive |
| | 5 | *Eclipta prostate* (L.) L. | Non-invasive |
| | 6 | *Cyanthillium cinereum* (L.) H. Rob. | Non-invasive |
| | 7 | *Grangea maderaspatana* (L.) L.Poir | Non-invasive |

Table 2. Checklist of associated Asteraceae plants from the study area.

Bees under the family Halictidae were predominant, with seven species under five genera, followed by Apidae, with six species belonging to three genera (Table 1). The genus *Ceratina* dominated the collection and was associated with the highest number of Asteraceae plants over the study period. The highest species abundance was recorded from *Mikania micrantha* (51) in March 2025, and the lowest abundance was recorded from *Cyanthillium cinereum* (1) in January 2025.

The maximum number of non-*Apis* species (12) was recorded in *Mikania micrantha,* a seasonally flowering (December 2024 to March 2025) invasive plant, followed by *Sphagneticola trilobata*, with six species. In contrast, *Cyanthillium cinereum*, a perennial non-invasive bloomer, hosted nine species. (Table 3). *Tetragonula travancorica, Austronomia capitata,* and *Hoplonomia elliotii* were observed exclusively following the flowering of invasive plant species, and a single bee species (*Austronomia ustula*) was recorded specifically from the non-invasive plants.

| | Plants | Associated non-Apis bee species |
|---|---|---|
| Invasive | *Mikania micrantha* | *A. zonata, C. binghami, C. smaragdula, C. unimaculata, C. dentipes, N. crassipes, H. westwoodi, P. oxybeloides, A. capitata, H. lucidipennis, T. travancorica, H. elliotii* |
| | *Sphagneticola trilobata* | *C. binghami, C. smaragdula, N. crassipes, H. westwoodi, C. unimaculata, H. lucidipennis* |
| | *Tridax procumbens* | *C. binghami* |
| Non-invasive | *Eclipta prostate* | *H. lucidipennis* |
| | *Cyanthillium cinereum* | *C. binghami, C. smaragdula, C. unimaculata, C. dentipes, N. crassipes, H. westwoodi, P. oxybeloides, H. lucidipennis, A. ustula* |
| | *Grangea maderaspatana* | *P. oxybeloides, H. lucidipennis* |

Table 3. Non-*Apis* bee species collected from invasive and non-invasive plants.

A similar study conducted by Vishnu, Bijoy, & Soumya (2024) on the association between invasive plants and bees in the Manakody Kole wetland revealed the presence of 10 non-*Apis* bee species from three invasive plants, of which four were associated with *Sphagneticola trilobata*. In this study, the family Apidae was dominant, with seven species, followed by Halictidae. Athul et al. (2025) reported nine non-*Apis* bees associated with 15 flowering plants from the Kole wetlands of Thrissur, out of which nine are Asteraceae plants. They also observed that the highest bee species richness was recorded in invasive plants compared with non-invasive plants, and that the bee–plant association was similar to that recorded in the present study.

Although plant and flower density were not quantified in the present study, it likely played a role in attracting more non-*Apis* bees to invasive species, as dense floral patches are known to improve pollinator detectability and foraging efficiency.

Species richness (t = 3.23, p = 0.008) and species abundance (t = 2.33, p = 0.02) during the monsoon season (June to September) differed significantly, indicating reduced and uneven pollinator activity under high rainfall conditions. In the post-monsoon period (October to January), a significant difference in species abundance was observed (t = −3.04, p = 0.011). In contrast, species richness did not vary significantly (p = 0.091), suggesting that post-monsoon (February to May) conditions predominantly affect population size rather than species diversity. During the pre-monsoon season, neither species richness nor abundance showed statistically significant differences, although abundance was marginally significant (p = 0.05). This pattern reflects a relatively stable community structure with pronounced numerical dominance of certain species, particularly of invasive plant species (Fig. 2 & Table 4).

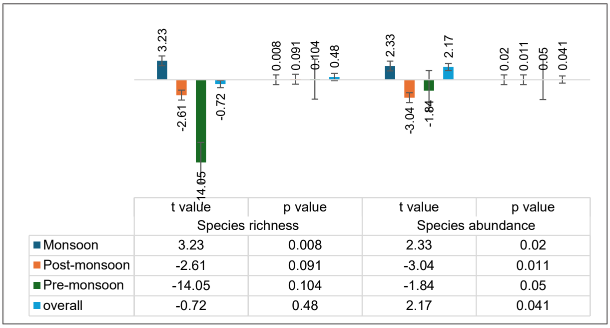


Figure 2. Season-wise student t-test analysis.

| Season | Species richness | | Species abundance | |
|---|---|---|---|---|
| | **t value** | **p value** | **t value** | **p value** |
| Monsoon | 3.23 | 0.008 | 2.33 | 0.02 |
| Post-monsoon | -2.61 | 0.091 | -3.04 | 0.011 |
| Pre-monsoon | -14.05 | 0.104 | -1.84 | 0.05 |
| overall | -0.72 | 0.48 | 2.17 | 0.041 |

Table 4. Season-wise *t*-test analysis.

Bee richness on *Cyanthillium cinereum* was recorded throughout the year, with species diversity peaking before the flowering of invasive plants. However, during the invasive flowering period (December 2024–April 2025), bee abundance declined, even though overall bee richness was highest on the invasive species *Mikania micrantha* and *Sphagneticola trilobata* (Fig. 3). Why? Most studies have focused on general floral characteristics, such as floral traits, fragrance, colour, pollen and nectar resources, inflorescence type, and other floral rewards, which contribute significantly to the remarkable diversity of angiosperms by attracting and sustaining pollinator interactions (Zariman, Omar, & Huda, 2022). The attractiveness of flowers to pollinating insects is positively related to the size of individual flowers, inflorescences, or floral patches, with large and visually conspicuous inflorescences being more readily perceived and often offering greater floral rewards (Jones & Reithel, 2001; Petanidou & Lamborn, 2005; Lázaro, Lundgren, & Totland, 2015). Invasive plant species that become dominant and offer abundant nectar and pollen, or have large, long-lasting floral displays, can attract and utilise pollinators adapted to such floral rewards, and these species can adopt diverse strategies for their spread. (Pyšek et al., 2011; Morales & Traveset, 2009; Chrobock et al., 2013; Master & Emery, 2015; Vishnu et al., 2024).

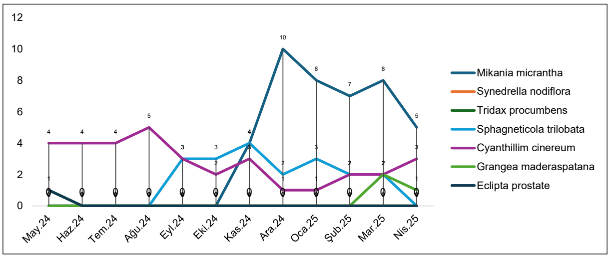


Figure 3. Month-wise species richness from associated Asteraceae plants.

Similarly, during the study period, in addition to documenting bee diversity and plant associations, we also made qualitative field observations of floral characteristics, including flower colour, inflorescence type, blooming, and flowering season. Although these traits were not measured quantitatively, our observations indicated that several invasive plant species possessed attractive white or yellow flowers arranged in dense, large blooming inflorescences (Table 5). Such floral displays may provide readily available, reliable nectar and pollen within a limited area, allowing non-*Apis* bees to forage more efficiently while reducing the time and energy required to search for alternative floral resources. These factors may partly explain the higher visitation of non-*Apis* bees to invasive plants observed in the present study.

| Plant | Flower colour | Floral characters | Possible reason for bee attraction (based on available literature) |
|---|---|---|---|
| *Mikania micrantha* | White | Small, fluffy, clustered in heads; many delicate disc florets. Scented, produces nectar. | Nectar production is high, characterized by a white colour, a pleasant scent, and continuous mass flowering. |
| *Sphagneticola trilobata* | Bright yellow | Daisy-like bright yellow ray florets | Pollen and nectar-rich, yellow colour, ground-cover growth |
| *Cyanthillium cinereum* | Pink/violet | Small cluster head | Pollen and nectar-rich, violet colour |

Table 5. Comparison of floral features of plants with more bee species records.

Why do invasive plants provide such rewards to bees and make themselves attractive to pollinators? These invasive species produce nearly seven times more seeds per individual each year, for a given seed mass, than native species, with seed development typically occurring within two months after flowering and pollination facilitated by insects; thus, attracting pollinators enhances pollination success, increases seed production, and promotes the establishment and spread of these species in new environments (Mason, Cooke, Moles, & Leishman, 2008). Example: *Mikania micrantha* primarily reproduces through stem propagation, although seed-based reproduction also occurs (Poudel, Adhikari, & Thapa, 2019).

Invasive species are recognised as one of the major drivers of global climate and land-use change. Accelerated human activities are expected to promote the introduction of alien species beyond their native biogeographical regions (Jaureguiberry et al., 2022; Wang, Wan, & Qu, 2017). Studies on invasive species abundance and richness indicate that maximum air temperature and warm climatic conditions have the strongest influence, followed by other factors such as soil temperature, proximity to urban areas, slope, soil pH, and human population density (Gulzar, Ahmad, Hassan, Rashid, & Khuroo, 2024). Higher air temperatures enhance species richness by promoting plant growth, earlier flowering, and greater seed production (Walther, Roques, & Hulme, 2009). Warm temperatures also favour invasive plants by improving their competitive ability, enabling faster germination from the soil seed bank, rapid growth, and quicker spread compared to native species (Zerebecki & Sorte, 2011). Supporting these observations, our study revealed that invasive plants exhibited higher abundance and species richness during periods of elevated temperature (Post and Pre-monsoon). Additionally, increased wind speed was found to significantly facilitate seed dispersal, further contributing to the spread of invasive plant species.

In our study, the dynamics of bee diversity and their associations with invasive and non-invasive plants were strongly influenced by seasonal climatic conditions and other environmental factors. Moderate temperatures and calm wind conditions during the Post-Monsoon and Pre-Monsoon seasons created favourable microclimatic conditions for bee activity, resulting in higher abundance and moderate species richness (Fig. 4). Conversely, reductions in bee diversity observed across invasive and non-invasive plant communities may be attributed to a combination of abiotic and anthropogenic factors, including fluctuations in temperature, wind speed, and rainfall, as well as the application of herbicides and insecticides, vegetation removal before agricultural activities, and other land-use disturbances. Collectively, these findings highlight the importance of both seasonal environmental conditions and human-induced habitat modifications in shaping bee diversity and plant–pollinator interactions within the study area.

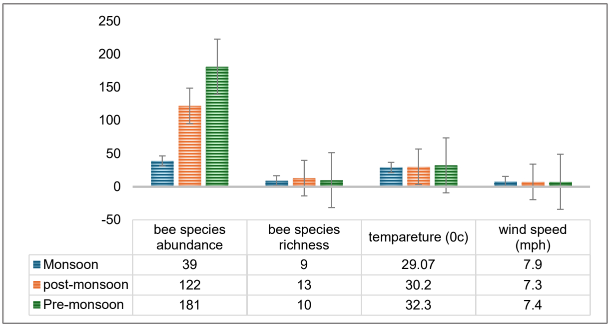


Figure 4. Seasonal variation in species abundance and richness in relation to temperature and wind speed.

## CONCLUSION

This study characterizes the diversity of non-*Apis* bee species and analyzes their interactions with Asteraceae plants within the Thrissur Kole wetland ecosystem of Kerala, emphasizing the importance of bees and Asteraceae plants for conservation. A total of 13 non-Apis bee species representing eight genera and two families were recorded visiting seven flowering Asteraceae species. Among these, four invasive plant species accounted for 72.94% of total bee abundance and 92.31% of recorded bee species richness. In contrast, three non-invasive plant species accounted for 27.06% of bee abundance and 69.23% of bee species richness. Bee diversity is exceptionally high in the invasive plant (*Mikania micrantha)* compared to non-invasive plants. The genus *Ceratina* dominated the collection and was associated with the highest number of Asteraceae plants over the study period. Three bee species (*Tetragonula travancorica, Austronomia capitata,* and *Hoplonomia elliotii*) were recorded only after the flowering of invasive plants, and a single bee species (*Austronomia ustula*) was exclusively recorded from non-invasive plants.

This study documents the association of non-*Apis* bees with invasive and non-invasive Asteraceae species in the Kole wetlands and suggests that floral characteristics may influence pollinator visitation patterns. The findings provide baseline information on plant–pollinator interactions in this wetland ecosystem and highlight the need for further studies to evaluate the ecological implications of pollinator use of invasive plant species.

Unfortunately, not all factors influencing bee pollination efficiency have been thoroughly examined by pollination researchers. Based on our observations and the available literature, the visitation of non-*Apis* bees to Asteraceae plants appears to be associated with specific floral traits and rewards. *Mikania micrantha* and *Sphagneticola trilobata* produce abundant, continuously blooming head inflorescences within a limited area during particular seasons. They are characterized by bee-attractive floral colours and a monoculture effect, in contrast to *Cyanthillium cinereum*. Consequently, non-*Apis* bees may be attracted to these invasive species because they provide continuous access to nectar and pollen over extended periods, thereby reducing the energy and time required to search for floral resources elsewhere. These characteristics may represent important advantages for non-*Apis* bees when selecting invasive plant species in the presence of native plants. However, increased visitation to invasive plants may alter plant–pollinator interactions by reducing pollination services available to native flora, potentially leading to lower seed production and reduced reproductive success of native plant species. At the same time, enhanced pollination may facilitate the spread and establishment of invasive plants, increasing their dominance within the habitat. Such shifts in pollinator foraging patterns may have broader ecological consequences, affecting not only plant community composition but also the insects and other organisms that depend on native vegetation. Over time, these changes could influence ecosystem functions, including nutrient cycling and soil health, particularly in ecologically sensitive landscapes such as the Kole wetlands.

The observed variation in bee diversity across invasive and non-invasive plants suggests that plant–pollinator interactions in the Kole wetlands are influenced by seasonal environmental conditions and anthropogenic habitat disturbances. These findings emphasize the need to consider both ecological and land-use factors when assessing pollinator diversity and conservation in wetland ecosystems.

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