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# Seasonal availability of bee flora at Coronation Garden, Kirtipur, Nepal

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**Abstract**

This study explores the seasonal availability of bee flora at Coronation Garden, Tribhuvan University, Kirtipur, during 2015-2016. A field survey documented flowering plant species visited by bees, confirming their role as bee flora through visual observations. Identified species were categorized into major, medium, and minor groups based on the nectar and pollen they provided. A total of 197 plant species were identified as bee flora, including horticultural, ornamental, wild, and agricultural species. The spring season of 2016 exhibited the highest abundance of blooming plants, making it the most favourable period for bees. The study emphasizes the importance of seasonal variation in bee flora availability, providing valuable insights for beekeeping practices.

**Keywords:** Apiary, distance, major, nectar, pollen, pollination

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## Introduction

Pollination is a cornerstone of plant reproduction, ensuring the production of seeds and sustaining life across generations. Beyond its ecological significance, pollination holds immense agricultural and economic values, driving the production of fruits, vegetables, and other essential crops. The process involves diverse pollinators, including wind, water, insects, birds, and bats, each playing a vital role in the mutualistic relationship with plants. This intricate interdependence showcases a remarkable example of co-evolution between entomophilous plants and anthophilous insects (Suryanarayan, 1986).

Incomplete pollination results in malformed fruits and vegetables, reducing their market value. Crops like almonds, apples, cherries, and squash heavily rely on pollinators to achieve optimal yields (Isaccs and Tuell, 2007). Among pollinators, bees are particularly indispensable due to their efficiency and adaptability. Beekeeping, therefore, represents a crucial agricultural enterprise, supporting pollination and providing marketable products such as honey, wax, royal jelly, and pollen (Melaku *et al.*, 2008). In Nepal, beekeeping is a low-investment, high-impact practice, especially beneficial for marginalized communities, including women (Maskey, 1992).

Diverse biodiversity and varied topography make Nepal an ideal hub for beekeeping, with native bee species such as *Apis laboriosa*, *A. dorsata*, *A. florea*, and *A. cerena* thriving across different elevations (Thapa, 2003). These species exhibit unique ecological traits and foraging behaviours, demonstrating their high adaptability and efficiency towards distinct climatic zones of Nepal.

Introduction of the non-native bee species, *Apis mellifera*, in early 1990s, further expanded the commercial beekeeping opportunities in Nepal (Thapa *et al.*, 2000).

Bee flora, comprising plants that provide nectar and pollen, is central to the survival of honeybee colonies and the success of beekeeping ventures. The quality and abundance of bee flora are temperature, climate, and land-use practices (Adhikari and Ranabhat, 2011).

Documenting bee flora and understanding its seasonal variations provide insights into optimizing beekeeping productivity and ensuring sustainable apiary management.

Nepal is an agricultural country, with approximately 73% of the population dependent on farming. Agriculture contributes significantly to the nation's economy, accounting for 31.8% of the Gross Domestic Product (GDP). Given this, agriculture-related activities, such as beekeeping and colony management, hold great potential to complement traditional farming practices and enhance rural livelihoods.

The Coronation Garden located in Tribhuvan University area, Kirtipur represents a semi-natural landscape. Despite its potential, there is a limited knowledge about its ecological value and capacity to support pollinators. The area is bordered by agricultural lands, orchards, and residential zones where vegetable crops are cultivated. This unique combination of habitats makes the garden rich in ornamental plants, horticultural species, vegetable crops, and forest trees. This diversity provides honeybees with an abundant supply of nectar- and pollen-producing flora across different seasons. Notable plants in this area include different *Citrus* species, *Callistemon citrinus*, *Grevillea robusta*, *Trifolium repens*, *Oxalis corniculata*, *O. latifolia*, *Cuphea micrantha*, and *Lagerstroemia indica*.

These plants ensure the availability of bee forage throughout the year, making the region an excellent site for studying bee-flora interactions. Findings of this study would help to enhance local beekeeping practices, improve livelihoods of small farm holders, and contribute to conservation of pollinators amidst global challenges like habitat loss and pesticide usage (Riscu and Bura, 2013).

## Materials and methods

### *Study area*

The present study was conducted in the Coronation Garden, Kirtipur, located approximately about seven km southwest of Kathmandu City Centre (Fig. 1). This semi-natural landscape is a part of the Tribhuvan University Campus in Kirtipur and spans an afforested area. The study site lies between the latitudes 27°40' N–27°41' N and longitudes 85°16' E–85°18' E, with an elevation ranging from 1300 to 1400 m. asl. The study area covers 2.76 $km^2$ area and is characterized by a diverse array of planted trees, along with ornamental garden plants, horticultural species, and areas of cultivated land and open spaces. Eight apiaries were established near the garden. This region's unique composition of flora and semi-natural habitats makes it an ideal site for studying honeybee behavior and their interactions with the surrounding environment.

The Coronation Garden located at Tribhuvan University area of Kirtipur falls within the subtropical zone of Nepal. According to meteorological data of Tribhuvan International Airport Station at elevation 1350 m asl. between 2000 to 2018, located nearby this garden indicates that the area experiences a mean annual maximum temperature of 29.8°C and mean annual minimum temperature 3.0°C. The monsoon season, characterized by heavy rainfall, occurs from July to August. In contrast, the dry season spans from October to mid-December and early November to mid-March. In 2015, the average annual minimum temperature of the study area was recorded at 12.6°C, while the average maximum temperature was 29.8°C.

The study area lies at the subtropical ecological zone of Nepal. The vegetation of the area is characterised by subtropical species such as *Schima wallichii*, *Castanopsis indica*, *C. tribuloides*, *Alnus nepalensis*, and *Rhododendron arboreum*. Although natural forests are absent in the study area, there are many planted tree species including *Populus sp.*, *Jacaranda mimosifolia*, *Cinnamomum camphora*, *C. tamala*, *Callistemon citrinus*, *Grevillea robusta*, and *Eucalyptus camaldulensis* also present. Ground vegetation and herbaceous flora also providing abundant forage for honeybees.

Foraging plants were identified and observed across three different seasons. Observations of nectar and pollen sources were based on honeybee activity on flowers. Nectar sources were identified when honeybees extended their proboscis into flowers, while pollen sources were determined by observing bees carrying pollen on their hind legs.

This methodology followed the approach described by Bista and Shivakoti (2000/2001; 2001). Plant species were subsequently identified by experts and verified with published reports.

### *Sampling unit*

A single bee flora visited by a honeybee at least five times was considered as the smallest sampling unit in this study, determined through visual observation. Flora visitation or landing by honeybees were recorded three days a week, from early morning (6:00A.M.) to evening (6:00P.M.), over a continuous period of nine months covering three seasons.

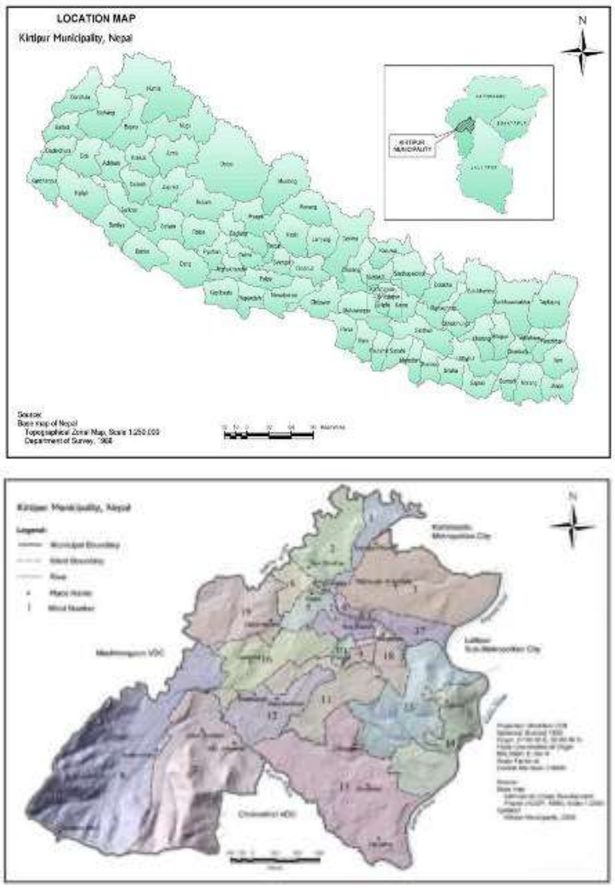


**Figure 1.** Map of study area. Source: ICIMOD, MENRIS 2003.

### *Setting of bee hives*

A total of eight hives were used in the study, comprising four *Apis cerana* and four *A. mellifera*. These hives were strategically placed at the interface of the Coronation Garden with a 5 m distance. This arrangement was aimed at mitigating issues such as colony collapse disorder (CCD) while providing a safe shelter for the honeybees, with the added benefit of human interaction. Additionally, the nearby blooming species offered an abundant source of pollen and nectar for the bees. The distance from each hive to the nearest blooming flower was measured scientifically. Each blooming plant species was closely monitored to determine if *Apis cerana* and *A. mellifera* were landing on them. A species was identified as bee flora if it was visited by honeybees at least five times. The blooming season and pollen collection of each plant species were recorded, along with their valid scientific names. Photographs of each flowering plant species were taken for documentation.

### *Distance of bee flora*

The measurement of each blooming/flowering species was conducted within a 1 km radius around the beehives located in the Coronation Garden of Tribhuvan University. The distance was categorized into three subunits: near (0-150 m), far (150-300 m), and very far (more than 300 m). The distances for near, far, and very far were recorded as D1, D2, and D3, respectively.

### *Color of bee flora*

During field visits, different flower species were observed blooming at various times. Mostly ornamental and horticultural plants were recorded. The flowers displayed a range of colors, which were classified into four categories: Red, White, Yellow, and Blue. Flower colors were identified based on photographs taken and by referencing additive color theory from Wikipedia. According to research by Grueter *et al.* (2011), Lunau *et al.* (2011), and Hempel *et al.* (2014), color plays a crucial role in honeybee foraging, with honeybees easily recognizing flower colors, especially when rewarded with nectar concentration.

### *Identification of bee flora*

Most of the bee flora species were ornamental and horticultural plants. Identification was straight forward, as most plants were already tagged with valid scientific names. Photographs taken during field visits facilitated easy identification through photo plates. Major bee foraging plants were further confirmed through direct observation, while the surrounding flora and location were regularly monitored. Unidentified plants were matched with specimens from the Tribhuvan University Central Herbarium (TUCH), the National Herbarium, Godawari (KATH), consulting literature such as *Garden Flowers* by Bajracharya *et al.* (1997), and *Annotated Checklist of Flowering Plants of Nepal* (Press *et al.*, 2000) and confirmed after consulting with experts. Scientific names were verified through https://powo.science.kew.org/. Major bee flora was those that produced surplus nectar and pollen, which were abundantly accessible. Medium bee flora supported annual flows of nectar and pollen, aiding colony development and maintenance. Minor bee flora provided sufficient nectar and pollen to help honeybees survive during dearth periods (Pratap, 1997). The distance of each flower from the bee hives was measured according to assumptions made by Crane (1990), Verma (1990), Pratap (1997), and Phillips (2001). Bee flora were categorized into major, medium, and minor groups based on Bista *et al.* (2000/2001, 2001), Sivaram (2001), and Adhikari and Ranabhat (2011).

### *Time and duration of field survey*

Field data were collected in three phases: June, July, and August 2015; September, October, and November 2015; and March, April, and May 2016. The colder months (November to February) were excluded from the study due to the dearth period, when foraging sources are scarce and colony collapse disorder (CCD) becomes a risk for honeybees (Adhikari and Ranabhat, 2011). After this period, the eight hives were reset in their original locations, and research continued. March to May 2016 represented the most productive period for honeybees (Adhikari and Ranabhat, 2011). A bee floral calendar was developed based on these data, with the foraging plants marked and observed throughout the study. The months of June, July, and August 2015 were classified as the Summer Season, September to November 2015 as the Autumn Season, and March to May 2016 as the Spring Season. During each season, bee floras were recorded, and pollen samples were collected for further analysis.

### *Analysis of bee flora*

The bee flora in the study area was identified based on bee visitation. A flower species was classified as bee flora only after visual confirmation of honeybee activity, specifically when bees collected food from the flowers (Pratap, 1997; Sivaram, 2001; Adhikari and Ranabhat, 2011). Foraging activity of *Apis mellifera* peaked around midday, while *A. cerana* foraged primarily in the early morning and late afternoon (Pudasaini and Thapa, 2014). Therefore, I observed and documented bee flora from early morning (6 A.M.) to midday (2 P.M.), conducting field observations three days a week throughout the three seasons. Following the methods of Pratap (1997), Sivaram (2001), and Adhikari and Ranabhat (2011) the blooming species visited frequently by bees and from which they collected nectar and pollen were classified as bee flora. Activities observed on flowers, such as honeybees extending their proboscis for nectar or carrying pollen on their hind legs, were used to identify pollen and nectar sources (Bista and Shivakoti, 2000/2001, 2001). Based on the abundance of nectar, pollen, and honeydew, plant species were categorized as major bee flora (N1P1), medium bee flora (N2P2), or minor bee flora (N3P3) (Adhikari and Ranabhat, 2011).

### *Species diversity*

Shannon-Weiner Index (H) = $-\Sigma$ pi ln pi, Simpson's Dominance Index (D) = $\Sigma (n/N)^2$ and Species richness as seasons were calculated following Simpson (1949), Magurran (2004), and Oksanen *et al.* (2024). Where pi = ni/N, ni is the number of individuals in species i (ni) and N is the total number of individuals in that season. The value of H ranged between 0 to infinity. The lowest H value that 0 represents no diversity and high H value represents high diversity. The value of D ranges from 0 to 1 where, high score (close to 1) indicates low diversity and low scores (close to 0) indicate high diversity. All data were analysed in MS-Excel and R (R Core Team, 2024).

## Results

### *Generic diversity of bee flora and families*

The Coronation Garden at Tribhuvan University was home to a highly diverse array of bee flora. This study identified a total of 197 bee species across 70 families. The largest family was Asteraceae, which contained 17 genera, followed by Leguminosae with 16 genera. Other notable families included Rosaceae with 9 genera, and Cucurbitaceae with **7** genera. The families Amaryllidaceae, Amaranthaceae and Apocynaceae included 4 genera each (Fig. 2).

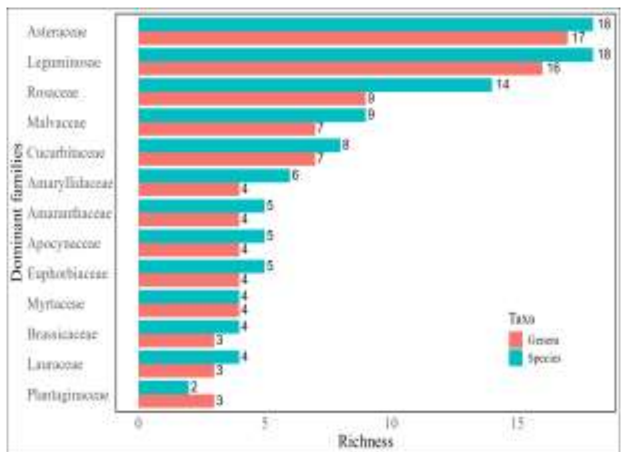


**Figure 2.** Generic and specific representations of bee flora along family.

### *Species diversity of bee flora along families*

The families with the highest number of species were Asteraceae and Leguminosae, each with 18 species. The Rosaceae contained 14 species**,** Malvaceae contained 9 species**,** while the Cucurbitaceae family had 8 species and the Amaryllidaceae family included 6 species. The Amaranthaceae**,** Apocynaceae, and Euphorbiaceae families each had 5 species. The Brassicaceae, Lauraceae, and Myrtaceae families each contained 4 species. Additionally, there were 2 species recorded from the Plantaginaceae (Fig. 2).

### *Life form diversity of bee flora*

The most dominant life form was herb, with 119 species, followed by trees with 71 species, shrubs with 21 species, and climbers with 20 species (Fig. 3). However, the distribution of species varied across seasons. In the Summer Season (2015), a total of 54 herb species, 15 tree species, 10 shrub species, and 10 climber species were recorded (Fig. 3). In Autumn Season (2015), it was found 2 tree species, 4 shrubs, 24 herbs and 7 climber species (Fig. 3). Likewise, in Spring Season (2016), it was found 54 tree species, 7 shrubs, 41 herbs and 3 climber species (Fig. 3).

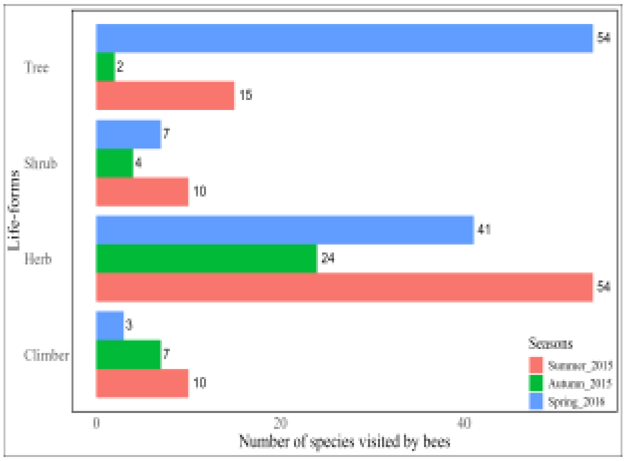


**Figure 3.** Life-form diversity by seasons.

### *Pollen and nectar status of bee flora*

A total of 197 plant species were identified as important bee flora in the study area that were primarily visited by *Apis cerena* and *A. mellifera*. Among them, **77** sps were ornamental, 27 sps crops, 50 sps wild plants, 8 sps naturalized, and 35 sps were horticultural plants. Out of 197 species, 45 were classified as major (N1P1), 41 as medium (N2P2), and 62 as minor (N3P3) sources for both nectar and pollen (Fig. 4). Additionally, 48 plants exhibited unequal status for pollen and nectar, categorized as N1P2, N1P3, N2P1, N2P3, N3P1, and N3P2.

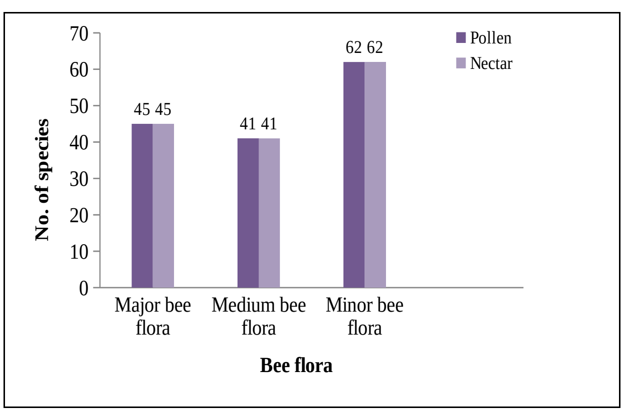


**Figure 4.** Bee flora according to sources of pollen and nectar

### *Bee flora in relation to distance along with pollen and nectar status*

The distance of bee flora was categorized into three subdivisions: near, far, and very far in meters. A total of 139 species were classified as near, followed by 28 species as far, and 30 species as very far (Fig. 5). Among the near species, 48 species were classified as major bee flora, 47 species as medium, and 44 species as minor. Similarly, for the far species, 5 species were classified as major, 8 species as medium, and 15 species as minor. For the very far distance species, 22 species were classified as major, 5 species as medium, and 3 species as minor (Fig. 5).

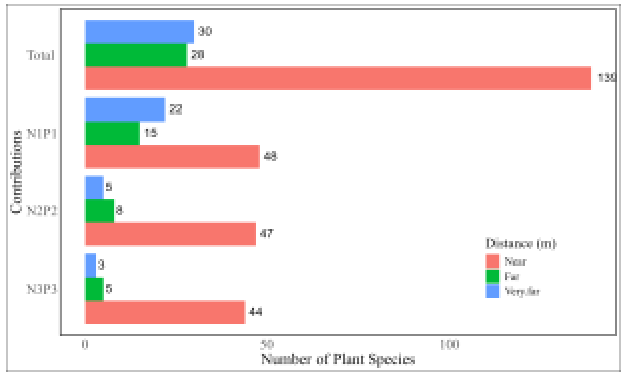


**Figure 5**. Distance of bee flora in source of pollen and nectar

### *Categorization of bee flora according to color*

A total of 197 bee floras were identified, categorized by distinct colors: 56 species were red, 15 species were blue, 46 species were yellow, and 80 species were white (Fig. 6).

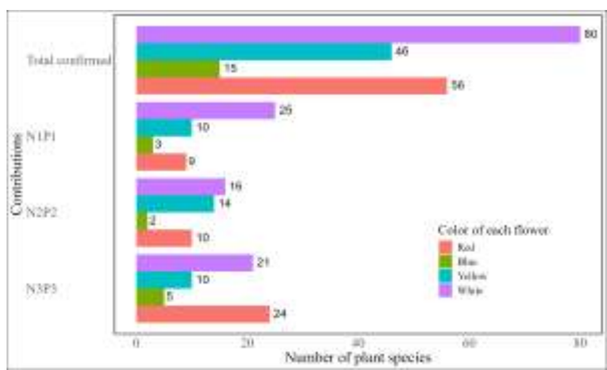


**Figure 6.** Representation of bee flora along color with pollen and nectar sources

The bee flora of each color was categorized into major, medium, and minor sources of pollen and nectar. For red flowers, 9 species were classified as major, 10 species as medium, and 24 species as minor. For blue flowers, 3 species were major, 2 species were medium, and 5 species were minor. In the case of yellow flowers, 10 species were major, 14 species were medium, and 10 species were minor. Finally, for white flowers, 25 species were major, 16 species were medium, and 21 species were minor (Fig. 6). There were 48 species unrepresented in this number.

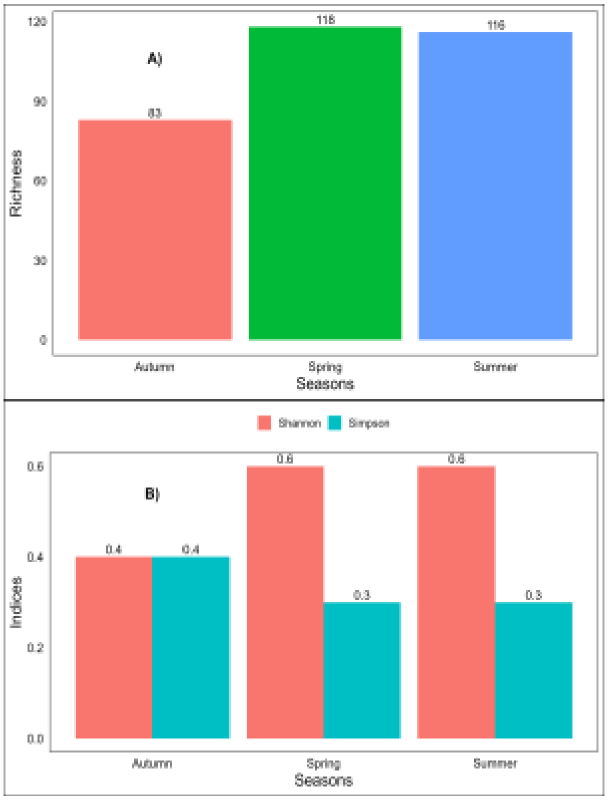


**Figure 7.** Seasonal bee flora diversity. A) Species richness B) Diversity Indices

***Species Richness, Shannon Index, Simpson Index***

Species richness was found to be 116 for summer (2015), 83 for autumn (2015) and 118 species for spring season (2016) (Fig. 7A). The value of Shannon index was found to be 0.6 for summer (2015), 0.4 for autumn (2015) and 0.6 for spring (2016) (Fig. 7B). The Simpson index was found to be 0.3 for summer (2015), 0.4 for autumn (2015) and 0.3 for spring (2016) (Fig. 7B).

## Discussion

The study documented a total of 197 plant species belonging to 70 families in the Coronation Garden of Tribhuvan University, Kirtipur, which serve as bee flora across three distinct seasons—spring (2016), summer (2015), and autumn (2015). The absence of bee flora during winter due to the dearth period as similar to Adhikari and Ranabhat (2011). This provides a comprehensive view of the plant species that contribute to the honeybee forage resources in the region. Among these families, Leguminosae and Asteraceae were found to be the most abundant, which aligns with findings by Sivaram (2001) and Mbah and Amao (2004), who also reported Fabaceae as a major bee flora family. These families' dominance may be attributed to their substantial floral resources, particularly nectar and pollen, which are crucial for honeybee populations.

***Seasonal variation in bee flora***

Our study revealed significant seasonal variation in the number of species that serve as bee forage plants. The spring season (2016) had the highest number of bee flora, with 118 species, followed by summer (2015) with 116 species, and the autumn (2015) season with 83 species.

These findings align with the work of Adhikari and Ranabhat (2011) and Kearns and Inouye (1993), who noted that the spring and summer seasons are often the most favorable for honeybee foraging, with a peak in nectar and pollen availability.

Several factors can explain these seasonal differences. The spring season is generally marked by the peak blooming of many tree species, which coincide with the needs of pollinators. The summer season sees a slight dip in species diversity, but many horticultural and ornamental plants remain in bloom. In contrast, autumn represents a dearth period, with fewer species available for pollinators, leading to potential challenges for colony development and honey production. This observation is consistent with Bista and Shivakoti (2001), who found that a lack of available forage plants during autumn could lead to the phenomenon of colony collapse disorder (CCD), which has been reported in many parts of the world.

***Pollen and nectar sources***

The study classified the plants based on their pollen and nectar status into major (N1P1), medium (N2P2), and minor (N3P3) categories, as well as those with unequal pollen and nectar statuses (e.g., N1P2, N2P1). This classification highlights that not all bee flora provides the same amount of resources, but each species plays a role in supporting honeybee populations. Even plants with lower quantities of nectar or pollen are vital, especially during periods of colony development or dearth. For example, species like *Albizia julibrissin*, *Azalea japonica*, and *Malvaviscus arboreus* have long blooming periods and are considered reliable sources during times of limited forage.

In line with Adhikari and Ranabhat (2011), our results also emphasized that horticultural species, particularly ornamental plants, are essential for beekeeping. These species provide consistent resources throughout the growing season and contribute significantly to colony health. Additionally, vegetables like *Cucumis sativus, Cucurbita maxima*, and *Sesamum indicum* serve as important sources of both nectar and pollen, reinforcing the importance of crop species for honeybee foraging.

***Distance and foraging behavior***

Distance from the apiary plays a significant role in honeybee foraging behavior. Our study categorized plants into three distance categories: near (0-150 m), far (150-300 m), and very far (above 300 m). The results showed that the majority of the bee flora was located within 150 meters of the hives, with 139 species in this category. This suggests that honeybees prefer foraging closer to their colonies, where they can access resources more easily. However, in times of food scarcity, bees can forage much further, up to 3 km from their hive, as observed by Phillips (2001) and Crane (1990). This adaptability is essential for ensuring the survival of bee populations when resources are limited.

Interestingly, the very far species (those beyond 300 m) were primarily horticultural species, indicating that these plants might be of great importance during specific periods, even if they are located further from the hives. This could be due to the higher concentration of nectar and pollen in these plants, making them valuable forage sources for bees willing to travel longer distances.

***Floral colors and bee preferences***

Our study also examined the relationship between flower color and bee foraging behavior. Bees are known to be attracted to certain colors, particularly blue, purple, and white, which are known to be highly visible to them. In our study, white flowers were the most abundant, with 79 species recorded, followed by red (56 species), yellow (46 species), and blue (15 species). These results are consistent with the findings of Lunau *et al.* (2011), who reported that bees are more attracted to flowers that offer both abundant nectar and pollen. The dominance of white flowers among horticultural plants indicates that these plants are particularly valuable for honeybees. The high concentration of nectar and pollen in white-flowered species, such as *Trifolium repens* and *Callistemon citrinus*, makes them especially attractive to foragers. Furthermore, flowers with higher concentrations of these floral cues were more likely to be categorized as major bee flora.

***Species richness and pollinator diversity***

The diversity of bee species across seasons was also analyzed using the Shannon Index and Simpson Index. The Shannon Index was highest in spring (2016), reflecting both high species abundance and evenness, suggesting that the spring season offers the most balanced and abundant forage resources. On the other hand, the Simpson Index, which reflects the dominance of particular species, was higher in autumn (2015), suggesting that fewer species dominated the bee flora during this period.

The high species richness observed in spring and summer seasons underscores the importance of understanding floral phenology for effective beekeeping management. Beekeepers can utilize this information to maximize honey production by aligning colony management with the flowering periods of major bee flora species. The varying blooming periods of different species emphasize the need for a floral calendar, as recommended by previous studies such as those by Bista and Shivakoti (2000/2001), and Adhikari and Ranabhat (2011), which would help optimize the timing of migration and hive management.

## Conclusion

In conclusion, the study highlights the diverse array of plants in the Coronation Garden of Kirtipur that serve as valuable forage resources for honeybees. The findings reinforce the importance of horticultural species, ornamentals, and agricultural crops in sustaining healthy bee populations. Seasonal variations in species availability, as well as the role of distance and floral characteristics, should be carefully considered for efficient beekeeping practices. The results underscore the need for comprehensive floral calendars and the strategic planting of bee-friendly species to ensure year-round support for honeybees. Furthermore, this study contributes to the growing body of knowledge on pollinator ecology in Nepal, providing a baseline for future research on the interaction between bees and plant species in diverse environments.

## Recommendations

***Promotion of bee flora conservation and planting initiatives***

The study reveals a high diversity of bee flora in the region, highlighting the potential for further enriching this diversity. It is recommended to expand the plantation of multipurpose plants and prioritize the conservation of honeybee flora.

***Encouragement of horticultural planting for bee forage***

While horticultural species dominate the region's bee flora, these species are essential not only for beekeeping but also for fruit production and the socio-economic development of farmers. It is recommended to actively encourage farmers to cultivate more horticultural species, particularly those known to be important for bee forage. This would not only help sustain honeybee populations but also lead to increased agricultural productivity and improved economic conditions for local farmers.

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