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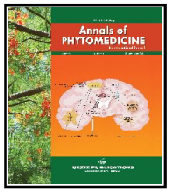

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Assessment of bee flora and development of a floral calendar in relation to pharmaceutical potential of honey and bee pollen in Eastern Uttar Pradesh, India

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Abstract

Beekeeping is a common practice throughout India and it is an invaluable source of revenue for families in the countryside. The ecological distribution and availability of honey bee floral resources varies depending on when they flower. Therefore, it is crucial to distinguish honey bee plants from all other plants, map their spatial and temporal distributions, and assess their proportional benefits to bee populations and honey production throughout this region. Moreover, the medicinal properties and quality of honey greatly depends on the variety of flowers visited by honeybees. The species that bees visit imparts certain characteristics to the honey, including pleasant flavour, distinctive colour, and pharmaceutical advantageous attributes. The present investigation was carried out to learn more about various kinds of bee flora and to create a floral calendar for the Varanasi and Mirzapur districts of Eastern Uttar Pradesh. The flowering plants were visited, their flowering duration was noted and checked for an appearance of honeybees and their foraging behavior was observed. The results revealed that flowering plants in this area were of different types such as vegetables, cereals, oilseeds, fruit crops, ornamental, plantation and weeds. The identified bee flora was further categorized into pollen and/or nectar-producing plants. Mid-October to March; August to September were identified as honey flow periods and mid-April to July was identified as the critical dearth periods in the year. A floral calendar was developed for the study area based on the availability of bee flora, utility status and flowering time. This study documents for the first time bee floral resources and prepared the floral calendar for Varanasi and Mirzapur districts of Eastern Uttar Pradesh. The study area is well-suited for bee foraging; care must be taken to preserve the current bee flora and encourage the growth of species of plants that serve a variety of purposes to make it resilient for beekeeping.

1. Introduction

Honeybees render a valuable ecosystem service by pollinating several plant species. However, honeybee performance is greatly impacted by the colony's overall health, which in turn is directly influenced by the presence of bee flora in a particular area. Bee pollination is an indispensable ecological process to ensure sustainable crop production. Honeybees are the most important and superior pollinators of the natural ecosystem, as they store pollen and nectar for future purposes (Stubbs *et al*., 1997). To fulfil their requirement, honeybees pollinate wide variety of flowers in mutualistic form right from cultivated to wild species and ornamental crops (Divekar *et al*., 2021; Divekar *et al*., 2022a).

Beekeeping depends on a constant supply of forage plants for bees. Plant species serve as an essential source of nectar and pollen in beekeeping. Due to variations in geography, climate, and other societal and agricultural practices, different plants flower for varying lengths of time in different locations. The knowledge of bee flora in the region is of paramount importance in terms of their utilization by honeybee for colony build-up and harvesting a good yield of honey including other bee products in addition to effective pollination (Divekar *et al*., 2018). Beekeeping is embraced by farmers as an agro-based rural industry since it may be included in farming systems as a component for greater benefit and to enhance the means of subsistence. Beekeeping's success is dependent on the colony's health, which in turn relies on a supply of nectar and pollen. Weak colonies are more susceptible to insect pests and disease attack (Pots *et al*., 2003).

Local flora provides food for honeybees in the area. They gather nectar from the floral and extra-floral nectaries found in flowers, which is a delicious liquid and a carbohydrate-rich source of energy. Nectar is also the starting point for making honey and pollen is a source of protein. Beekeepers should therefore be aware of the natural food sources that are accessible to bees nearby. Bee flora, often known as bee pastures, is the collective term for the plants that produce nectar and pollen. For the initiation or promotion of beekeeping in any area, it is mandatory to study the bee flora of a particular region (Upadhyay *et al*., 2014).

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Bees commonly explore forests, grasslands, agrophytocenoses (such as orchards, vineyards, and flower fields), medicinal plantations, and fragrant herbs in quest of melliferous plants (Macukanovic and Jari, 2016). Most beekeepers, according to Bakour *et al*. (2021), encourage plants that have many and varied health benefits for mankind, such as antioxidant, anti-inflammatory, antifungal, antidiabetic, diuretic, and have an impact on the treatment of various cancers as well as neurodegenerative, cardiovascular, and gastrointestinal tract diseases. As previously stated, bee products therapeutic qualities are also influenced by the botanical sources from which they are derived (Kocot *et al*., 2018). These diverse botanical sources offer bee products a variety of therapeutic qualities.

Uttar Pradesh is the most populous state that produces the highest food grains in the Country. A tropical monsoon climate can be found in Uttar Pradesh (Directorate of Economics and Statistics, Uttar Pradesh, 2016). Beekeeping can be considered an eco-friendly, rewarding, small-scale, full- or part-time career because the state comprises mainly rural areas, agricultural crop fields, and trees. Although, few attempts were made to study the bee flora from the Eastern Uttar Pradesh region by Datta *et al*. (2008); Jaiswal *et al*. (2018) and Chauhan *et al*. (2017), the thorough information about the flowering duration, the utility of bee flora as a source of pollen and/or nectar and the bee floral calendar is still lacking for the region.

Therefore, the present investigation was conducted to document the available nectar and pollen-producing bee forage plants; identify the major and minor pollen and nectar-yielding plants and develop a floral calendar for Varanasi and Mirzapur districts of Eastern Uttar Pradesh (India).

2. Materials and Methods

2.1 Study area

The study locations are selected from two districts of Eastern Uttar Pradesh; namely, Varanasi (IIVR, Jakhini and Laskariya) and Mirzapur (Adalpura and Basaratpur).

2.2 Assessment of bee flora

Direct observation of flowering plants was done at weekly interval from January to December month during 2017 and 2018. Observations in winter and autumn season were noted between 9:00 and 17:00, whereas summer observations were recorded between 8:00 and 18:00. Honeybee foraging plants were determined with the visit of honeybee workers (*Apis* spp.) on its flowers for 10 min (Silveira, 2004). The observation on nectar and pollen source was based on activities performed by honeybees on different flowers, *i.e*., honeybees with their activity of extending their proboscis into the flowers were considered as nectar source and bees carrying pollen on their hind legs were determined as pollen source plants (Bista and Shivakoti, 2001).

Throughout the survey, a comprehensive chronological record of the plant species flowering season was made. The number and frequency of honeybee visits determine the significance of flowering plants, whether they are major or minor sources of pollen and/or nectar. The number of bee flora determines their relative dominance and abundance. Finally, the plants visited by honeybees were later collected and identified with the help of a botanist and then compared with the published reports (Partap, 1997; Polunin and Stainton, 1997) for their uses by honeybees.

2.3 Sampling plot and estimation design

Twenty quadrats, each size 10 × 10 and 5 × 5 meters, were placed on each site to assess the trees and shrubs, whereas 30 quadrats measuring 1 by 1 meters were placed in search of the herbaceous plants during weekly observation (Pande *et al*., 1988). Different topographical variables, such as habitat types, altitude, aspects, slope, and various vegetation types, were taken into consideration while choosing the study plots. The habitats were identified based on the physical characters and dominance of the vegetation (Sharma *et al*., 2014).

2.4 Richness and diversity of bee forage plants

The diversity, richness and evenness of species (abundance) within plant communities are subject to variation. Employing the Shannon-Wiener diversity index, species richness, and Shannon's evenness, the species diversity of plants was assessed in different study locations. Standard ecological procedures (Pielou, 1975; Simpson, 1949) were used for data collection and analysis.

3. Results

3.1 Bee forage composition and diversity

The different plant species that were present in the study locations were periodically assessed for flowering, duration of flowering, and honeybee (*Apis* spp.) visits for pollen and/or nectar collection. Our investigation revealed that 59 plant species from 27 families were identified as pollen and/or nectar resources in Varanasi and Mirzapur districts during 2017 and 2018 (Table 1). Thirty-seven plant species were recorded as nectar as well as pollen sources, six species were observed as only nectar sources and sixteen species were found as the only source of pollen during the observation period.

Among the vegetables, bottle gourd (*Lagenaria siceraria*), bitter gourd (*Momordica charantia)*, sponge gourd (*Luffa cylindrica*), ash gourd (*Benincasa hispida)* and ridge gourd (*Lufa acutangula*) serve as major source of both the pollen and nectar whereas watermelon (*Citrullus lanatus*) serve as major source of only pollen. The rest of the vegetable crops are minor source of pollen and nectar. Cereals are good source of pollen in which maize *(Zea mays)* serve as major source of pollen. Among the oilseed crops, mustard (*Brassica nigra)* and sunflower *(Helianthus annuus*) were identified as major source of both the nectar and pollen in the region. Among the fruit crops, ber *(Ziziphus mauritiana)* serve as major source of both the pollen and nectar whereas guava *(Psidium guajava)* serve as major source of only pollen. Ornamentals and weeds serve as minor source of pollen and or nectar (Table 1, Figure 1). In July and August, sesame flowers bloomed. During this time, it was a reliable source of pollen and nectar.

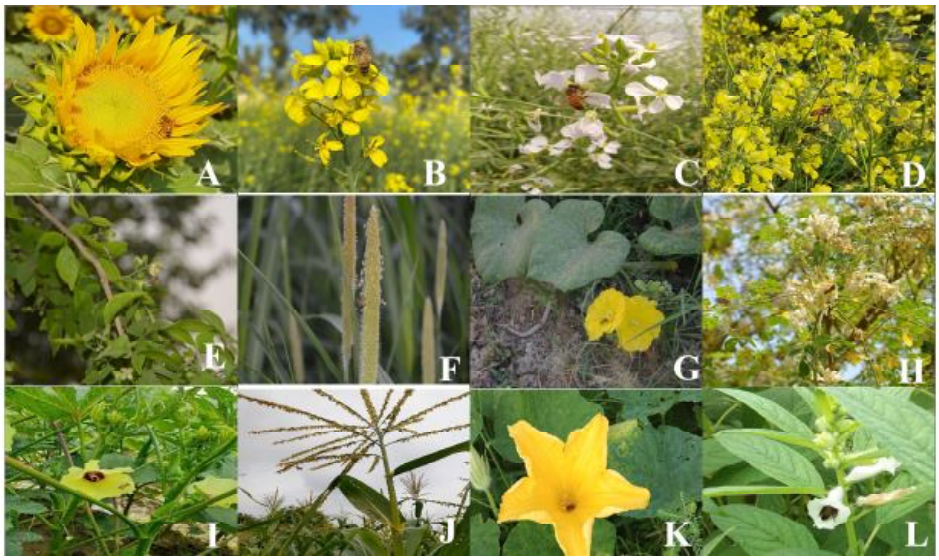

Figure 1: The photographed images of some bee forage plants identified in the Varanasi and Mirzapur districts. Honeybee visiting A. Sunflower, B. Mustard C. Radish D. Cauliflower, E. Bael, F. Bajra, G. Sponge gourd, H. Moringa, I. Okra, J. Maize, K. Pumpkin and L. Sesame.

Table 1: Checklist of plant species identified from the study area during 2017 and 2018

Common name	Scientific name	Family	Habit	Availability of flora				Flowering period	Food source	
				1	2	3	4		nectar	pollen
Vegetable										
Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	Climber	✓	✓	✓	✓	Aug-Sept	++	++
Bitter gourd	*Momordica charantia*	Cucurbitaceae	Climber	✓	✓	✓	✓	Jul-Sept	++	++
Okra	*Abelmoschus esculentus*	Malvaceae	Herb	✓	✓	✓	✓	Jul -Sept; Mar to Apr	-	+
Sponge gourd	*Luffa cylindrica*	Cucurbitaceae	Climbing vine	✓	✓	✓	✓	Sept-Nov	++	++
Chilli	*Capsicum* spp.	Solanaceae	Herb	✓	✓	✓	✓	Sept-Feb	+	+
Pumpkin	*Cucurbita pepo* L.	Cucurbitaceae	Climbers	✓	✓	✓	✓	Apr-May, Aug-Oct	++	++
Ash Gourd	*Benincasa hispida*	Cucurbitaceae	Climbing Herb	✓	×	×	×	Aug-Oct	++	++
Cucumber	*Cucumis sativus*	Cucurbitaceae	Climber	✓	✓	✓	✓	Aug-Sept	+	+
Amaranthus	*Amaranthus* spp.	Amaranthaceae	Herb	✓	✓	×	×	April, Sept-Oct	-	+
Ridge gourd	*Lufa acutangula*	Cucurbitaceae	Climbing Herb	✓	✓	✓	✓	Aug-Sept.	++	++
Brinjal	*Solanum melongena* L	Solanaceae	Herb	✓	✓	✓	✓	Mar - Jun, Sept -Dec	-	+
Sem (Field bean)	*Lablab purpureus*	Fabaceae	Vine	✓	✓	✓	✓	Oct-March	-	+
Cow pea	*Vigna unguiculata*	Fabaceae	Climbing vine	✓	✓	✓	✓	Aug-Sep, Apr-May	+	+
Soybean	*Glycine max*	Fabaceae	Herb	✓	×	×	×	Aug.-Sept.	+	-
French bean	*Phaseolus vulgaris*	Fabaceae	Climbers	✓	×	×	×	Nov-Mar	+	-
Pointed gourd	*Trichosanthes dioica*	Cucurbitaceae	Climbing Herb	✓	×	×	×	Sept-Dec	+	+

Pea	*Pisum sativum*	Fabaceae	Herb	✓	✓	✓	✓	Dec-Feb	+	+
Tomato	*Solanum lycopersicum*	Solanaceae	Herb	✓	✓	✓	✓	Dec-Mar	+	+
Winged Bean	*Psophocarpus tetragonolobus*	Fabaceae	Herb	✓	×	×	×	Sept.-Feb.	-	+
Cauliflower	*Brassica oleracea*	Brassicaceae	Herb	✓	×	×	×	Jan-Mar	+	+
Radish	*Raphanus sativus*	Brassicaceae	Herb	✓	✓	✓	×	Jan-Mar	+	+
Curry Leaf	*Murraya koenigii*	Rutaceae	Tree	✓	✓	✓	✓	Mar - May	+	-
Water melon	*Citrullus lanatus*	Cucurbitaceae	Vine	✓	✓	✓	✓	Feb - Mar	++	-
Chappan kaddu	*Cucurbita pepo*	Cucurbitaceae	Climbers	✓	×	×	×	Dec- Mar	+	+
Cereal crop										
Bajra	*Pennisetum glaucum*	Poaceae	Herb	✓	✓	✓	✓	Sep-Oct	-	+
Paddy	*Oryza sativa*	Poaceae	Herb	✓	✓	✓	✓	Sep-Oct	-	+
Maize	*Zea mays*	Poaceae	Herb	✓	✓	✓	✓	Sep-Oct	-	++
Oilseed crop										
Mustard	*Brassica nigra*	Brassicaceae	Herb	✓	✓	✓	✓	Dec-Feb	++	++
Sunflower	*Helianthus annuus*	Compositae	Herb	✓	×	×	×	Mar-May	++	++
Sesame/Til	*Sesamum indicum*	Pedaliaceae	Shrub	✓	✓	✓	×	Aug-Sept	+	+
Castor (Arandi)	*Ricinus communis*	Euphorbiaceae	Shrub	×	✓	×	✓	Oct-Mar	+	+
Fruit										
Ber	*Ziziphus mauritiana*	Rhamnaceae	Shrub	×	✓	✓	✓	Oct-Dec	++	+
Banana	*Musa acuminata*	Musaceae	Herb	✓	✓	✓	✓	Jan- Dec	++	+
Guava	*Psidium guajava*	Myrtaceae	Shrub	✓	✓	✓	✓	Feb, Jun	-	++
Papaya	*Carica papaya*	Caricaceae	Tree	✓	✓	✓	✓	Year Round	+	+
Wood apple (Bel)	*Aegle marmelos*	Rutaceae	Shrub	✓	✓	✓	✓	Aug	+	+
Jackfruit	*Artocarpus heterophyllus*	Moraceae	Tree	✓	✓	✓	✓	Feb-Mar	+	-
Indian gooseberry	*Phyllanthus emblica*	Phyllanthaceae	Tree	✓	×	×	×	Feb-Mar	+	+
Mango	*Mangifera indica*	Anacardiaceae	Tree	✓	✓	✓	✓	Feb-Mar	-	+
Ornamental										
Hibiscus	*Hibiscus rosa-sinensis*	Malvaceae	Shrub	✓	✓	✓	✓	Year Round	+	+
Rose	*Rosa rubiginosa*	Rosaceae	Shrub	✓	✓	✓	✓	May-Oct	-	+
Trumpet flower	*Tecoma stans*	Bignoniaceae	Shrub	✓	×	×	×	Nov-Mar	+	+
Hamelia	*Hamelia patens*	Rubiaceae	Shrub	✓	×	×	×	Sept-May	+	+
Ixora	*Ixora coccinea*	Rubiaceae	Shrub	✓	×	×	×	Sept-May	+	+
Marigold	*Tagetes* spp.	Asteraceae	Herb	✓	✓	✓	✓	Oct-Mar	+	-
Calendula	*Calendula officinalis*	Asteraceae	Herb	✓	×	×	×	Dec-Mar	+	+

Plantation tree										
Drumstick	*Moringa oleifera*	Moringaceae	Tree	✓	×	✓	✓	Oct.-Dec.; Mar-May	+	+
Teak	*Tectona grandis*	Lamiaceae	Tree	✓	✓	×	×	Sept-Dec	+	+
Babul	*Acacia nilotica*	Fabaceae	Tree	✓	✓	✓	✓	Oct-Dec	+	+
Kadam	*Neolamarckia cadamba*	Rubiaceae	Tree	×	✓	✓	✓	Oct-Dec	+	+
Neem	*Azadirachta indica*	Meliaceae	Tree	✓	✓	✓	✓	Apr	+	+
Royal Poinciana	*Delonix regia*	Fabaceae	Tree	✓	✓	✓	✓	Mar- May	+	+
Peepal	*Ficus religiosa*	Moraceae	Tree	✓	✓	✓	✓	Oct-Dec	+	+
Casuarina	*Casuarina equisetifolia*	Casuarinaceae	Tree	✓	×	×	×	Feb–Apr	-	+
Weeds										
Giant milkweed	*Calotropis gigantea*	Apocynaceae	Shrub	✓	✓	✓	✓	Nov-Dec	+	+
Goat Weed	*Ageratum conyzoides*	Asteraceae	Herb	✓	✓	✓	✓	Dec-May	-	+
Siam weed	*Chromolaena odorata*	Asteraceae	Shrub	✓	✓	✓	✓	Jul-Sept	-	+
Jimson weed	*Datura stramonium*	Solanaceae	Herb	✓	✓	✓	✓	Jul-Dec	-	+
Purslane	*Portulaca oleracea*	Portulacaceae	Herb	✓	✓	✓	✓	Apr–Oct	-	+

1: IIVR, 2: Laskariya, 3: Adalpura; 4: Basaratpur. —' Denotes presence and × denotes absence of bee flora, N:Nectar, P:Pollen, ++:Major Source, +:minor source, -:Not source.

Honeybees use a variety of plant types for their food sources, including 39.0% herbs, 18.0% shrubs, 21.0% trees, 19% climbers, and 3.0% vines (Figure 2A) at IIVR, Jakhini location whereas bee flora at Laskariya comprises 38% herbs, 20.0% shrubs, 22% trees, 16.0% climbers and 4% vines (Figure 2B). In the Mirzapur district, bee flora at Adalpura (Figure 2C) comprises 37% herbs, 19% shrubs, 23% trees, 16% climbers and 5% vines however at Basaratpur (Figure 2D) the bee flora includes 36% herbs, 19% shrubs, 24% trees, 16% climbers and 5% vines.

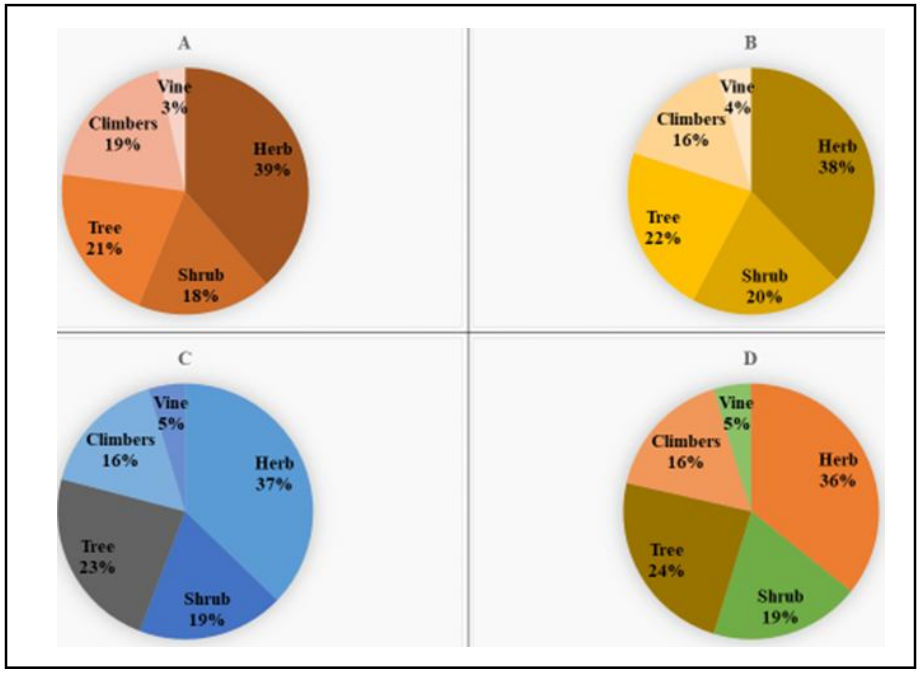

Figure 2: The growth habit of bee forage plants in different locations. A. IIVR, Jakhini, B. Laskariya, C. Adalpura and D. Basaratpur.

3.2 Bee flora distribution

The bee flora plants used by bees as food were comprised of 27 plant families, but the majority (65.00%) of the species in the region were found in six plant families: Cucurbitaceae (10 species), Fabaceae (9 species), Rutaceae (5 species), Asteraceae (4 species), Solanaceae (3 species), and Poaceae (3 species).

3.3 Species diversity

The results of the assessment of bee flora diversity using the Shannon-Weiner diversity index for identified plant species found in various study locations were summarized in Table 2. Accordingly, plant community one, has the highest bee plant diversity 1.57 followed by community two (1.49) and three (1.47). The least diversity was observed in the community four (1.46).

The Margalef species richness index was high in community one (7.98), followed by community four (6.66) and community three (5.74). The least richness index was observed in community two (5.56). A high Margalef index value indicates that the diversity of the sample being measured is high. This can be interpreted as a sign of robustness and resilience in the sampled ecosystem. A high Margalef index may also indicate that the sampled ecosystem can support a variety of species and is resilient to changes in external conditions. Pielou's evenness index was nearby 1 and higher in all the communities (>0.80).

Table 2: Diversity of bee flora in Varanasi and Mirzapur districts in different plant communities

Communities	Location of community	Margalef's richness index	Shannon-Weiner diversity index	Pielou's evenness index
Community one	IIVR Jakhini	7.98	1.57	0.90
Community two	Laskariya	5.56	1.49	0.94
Community three	Adalpura	5.74	1.47	0.92
Community four	Basaratpur	6.66	1.46	0.88

3.4 Bee floral calendar, honey flow and dearth period

Flowering time of all the plant species was meticulously tracked over the time. The standardization of routine management processes in apiaries will be greatly facilitated by the floral calendar. Since there are more perennial plants in the area, it is very important to know how they are distributed and when they bloom in order to accurately predict the pollen and nectar flow for effective beekeeping. Understanding the blooming season is crucial for the sustainable maintenance of bee colonies and for appealing honey production. The period of flowering in a particular region's bee forage is beneficial to migratory beekeeping practices. The temporal distribution of the bee flora species of the study regions are depicted in Table 3. With the help of this information, beekeepers can produce more honey from the same species in the same season. As a result, each season's availability of bee flora directly affects the performance of the colony, whether weak or strong, as well as its honey flow time.

Honey flow and dearth periods for Varanasi and Mirzapur study region have been computed and results are summarised in (Tables 1 and 3). The most intense times of honeybee foraging activity (honey flow period) were seen in the winter months of October to March and the monsoon months of August to September. Few bee forage plants, *viz*., *Hibiscus* and papaya were observed blooming throughout the seasons. During the first honey flow period mid-October–March, several vegetables, oilseeds, fruit crops, ornamentals and weeds are available in a bloom period to provide the good source of pollen and/or nectar. Vegetables like cole crops, cauliflower, radish, solanaceous vegetables, *viz*., brinjal, chilli, tomato; few cucurbits like pumpkin, pointed gourd, chappan kaddu are available as bee flora. Among the oilseeds, mustard and castor serves as a source of pollen and nectar. Various fruit crops like banana, papaya, guava, jackfruit, Indian gooseberry, mango and ber were available as bee flora. Several ornamentals like *Hibiscus*, trumphet flower, *Hemelia*, *Ixora*, marigold, calendula and weeds like goat weed, giant milkweed, jimson weed, and purslane were available during the period as bee flora. Several bee forage species found nearby indicate that the study locations are unquestionably appropriate for commercial beekeeping.

The second honey flow period was recorded from August to September in the monsoon season. Several vegetables like cucurbits, cowpea, soybean, brinjal, winged bean, okra, and chilli were available as a sources of nectar and/or pollen, oilseeds like sesame acts as minor source of pollen and nectar, fruits like papaya and bel, ornamentals like hibiscus and rose, and weeds like Siam weed, Jimson weed and purslane were available as minor source of pollen and/or nectar in the study region. Three cereals; namely, bajra, paddy and maize were available as a source of pollen during this duration. Bee colonies must be maintained by the flowering plants in an area that is valuable as a bee pasture. For honey production and colony growth, honeybees should make frequent visits to these plants. The second honey flow period, which lasted from August to September, was a time of heavy rain and overcast skies. Although, plenty of plants were in bloom during this time, bee foraging activity was quite low due to unfavourable conditions, hence this was the gap between honey flow periods.

The dearth period for bee flora was observed from mid-April to July in Varanasi and Mirzapur districts. High temperatures (above 35^0c), a shortage of water and a lack of blossoming plants made the summer a key time for food shortage to bees. Few plants like pumpkin, brinjal, cowpea, curry leaf, sunflower, papaya, ornamentals like hibiscus, rose, *Hemelia*, *Ixora*, *Moringa*, royal poinciana, and weeds like goat weed and purslane blossomed during the season. However, the amount of pollen or nectar they produced was also less per unit of area or they had fewer of them. When there is a lack of major bee flora plants, bees use these smaller sources. This time of the year was found to be adverse for honeybee foraging because of the high temperature and lack of water for blossoming plants.

Table 3: Bee flora calendar of Varanasi and Mirzapur districts of Eastern Uttar Pradesh

Bee Flora	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Vegetables	Chilli, Sem, French bean, Pea, Tomato, Winged bean, Cauliflower, Radish, Chappan Kaddu	Chilli, Sem, French bean, Pea, Tomato, Winged bean, Cauliflower, Radish, Water Melon, Chappan Kaddu	Okra, Brinjal, Sem, French bean, Tomato, Cauliflower, Radish, Curry Leaf, Water Melon, Chappan Kaddu	Okra, Pumpkin, Amaranth, Brinjal, Cowpea, Curry Leaf	Pumpkin, Brinjal, Cowpea, Curry Leaf	Brinjal	Bitter gourd, Okra	Bottle gourd, Okra, Bitter gourd, Pumpkin,Ash gourd, Cucumber, Ridge gourd, Cowpea, Soybean	Sponge gourd, Bottle gourd,Okra,Bitter gourd, Chilli, Pumpkin, Ash gourd, Cucumber, Amaranth, Ridge gourd,Brinja, Cowpea, Soybean, Pointed gourd, Winged bean	Sponge gourd, chilli, Pumpkin, Ash gourd,Amaranth,Brinjal, Sem, Pointed gourd, Winged bean	Sponge gourd, chilli, Brinjal, Sem, French bean, Pointed gourd, Winged bean	Chilli, Brinjal, Sem, French bean, Pointed Gourd, Pea, Tomato, Winged bean, Chappan Kaddu
Cereals	-	-	-	-	-	-	-	-	Bajra, Paddy, Maize	Bajra, Paddy, Maize	-	-
Oilseeds	Mustard, Castor	Mustard, Castor	Sunflower, Castor	Sunflower	Sunflower	-	-	Sesame	Sesame	Castor	Castor	Mustard, Castor
Fruit Crops	Banana, Papaya	Guava, Papaya, Jackfruit, Indian gooseberry, Mango	Papaya, Jackfruit, Indian gooseberry, Mango	Papaya	Papaya	Guava, Papaya	Papaya	Papaya, Bel	Papaya	Ber, Papaya	Ber, Papaya	Ber, Banana, Papaya
Ornamentals	Hibiscus, Trumphet flower, Hemelia, Ixora Marigold, Calendula	Hibiscus, Trumphet flower, Hemelia, Ixora, Marigold, Calendula	Hibiscus, Trumphet flower, Hemelia, Ixora, Marigold, Calendula	Hibiscus, Hemelia, Ixora	Hibiscus, Rose, Hemelia, Ixora	Hibiscus, Rose	Hibiscus, Rose	Hibiscus, Rose	Hibiscus, Rose, Hemelia Ixora	Hibiscus, Rose, Trumphet flower, Hemelia Ixora Marigold	Hibiscus, Trumphet flower, Hemelia Ixora Marigold	Hibiscus, Trumphet flower, Hemelia, Ixora Marigold, Calendula
Plantations	-	Casuariana	Moringa, Royal Poinciana, Casuariana	Moringa, Neem, Royal Poinciana. Casuariana	Moringa, Royal poinciana	-	-	-	Teak	Moringa, Teak, Babul, Kadam, Peepal	Moringa, Teak, Babul, Kadam, Peepal	Moringa, Teak, Babul, Kadam, Peepal
Weeds	Goat Weed	Goat Weed	Goat Weed	Goat Weed Purslane	Goat Weed Purslane	Purslane	Siam weed, Jimson weed,Purslane	Siam weed, Jimson weed, Purslane	Siam weed, Jimson weed, Purslane	Jimson weed, Purslane	Giant Milkweed, Jimson weed	Giant Milkweed, Goat Weed, Jimson weed

3.5 Health and nutraceutical values of honey

Natural honey (NH) is a sweet, delicious liquid food that has substantial health advantages and a high level of nutrition (Bogdanov *et al*., 2008). Bees that collect nectar from flowers secrete NH, which emerges as blossom honey. Sugars and water make up the majority of honey's constituents (Table 4). It also includes plenty of vitamins and minerals, such as B vitamins, as shown in Table 5. Inhibine, which is high in antibiotics, proteins, phenol antioxidants, and micronutrients are some of the other components of honey (White and Doner, 1980). The most prevalent sugar in honey is fructose (Table 3), which is sweeter and provides more energy than artificial sweeteners (Bogdanov *et al*., 2008). These ingredients are crucial for both nutrition and well-being.

Table 4: Nutritional composition of honey

Nutritional ingredients	Blossom honey	
	Range	Mean
Water	15-20	17.2
Total sugars		79.7
Monosaccharides		
Fructose	30-45	38.2
Glucose	24-40	31.3
Disaccharides		
Sucrose	0.1-4.8	0.7
Others	2.0-8.0	5.0
Trisaccharides		
Oligosaccharides		3.1
Erlose	0.5-6.0	
Melezitose		< 0.1
Others	0.5-1.0	0.5
Minerals	0.1-0.5	0.2
Amino acids, proteins	0.2-0.4	0.3
Acids	0.2-0.8	0.5
pH value	3.2-4.5	3.9

Data in g/100 g of honey, Adapted from Bogdanov *et al*. (2008).

Table 5: Chemical elements available in honey

Minerals	Amount (mg /100 g)	Vitamins	Amount (mg/100 g)
Sodium (Na)	1.6-17	Thiamine (B1)	0.00-0.01
Calcium (Ca)	3-31	Riboflavin (B2)	0.01-0.02
Potassium (K)	40-3500	Niacin (B3)	0.10-0.20
Magnesium (Mg)	0.7-13	Pantothenic acid (B5)	0.02-0.11
Phosphorus (P)	2-15	Pyridoxine (B6)	0.01-0.32
Selenium (Se)	0.002-0.01	Folic acid (B9)	0.002-0.01
Copper (Cu)	0.02-0.6	Ascorbic acid (Vit. C)	2.2-2.5
Iron (Fe)	0.03-4	Phyllochinon (K)	0.025
Manganese (Mn)	0.02-2		
Chromium (Cr)	0.01-0.3		
Zinc (Zn)	0.05-2		

Adapted from Bogdanov *et al*. (2008)

Ascorbic acid, pantothenic acid, niacin, and riboflavin are few of the vitamins in honey, along with minerals such as calcium, copper, iron, magnesium, manganese, phosphorus, potassium, and zinc. Table 4 provides a comprehensive list of the vitamins, minerals, other micronutrients, and trace elements that can be found in honey. Honey has a strong nutritional profile and contains a variety of elements, albeit in little amounts, which promotes its usage as food. It is recommended for adults to consume significant amounts of NH (70–95 g daily) to receive all of its beneficial nutritional and health effects because several of its key elements are present in low concentrations (Yaghoobi *et al*., 2008).

Table 6: Pollen composition and nutritional requirements as required daily intake (RDI)

Main components	Amount (%)	Average RDI	% RDI for 100 g of pollen
Protein	10-40	50[a]	36-146.67
Lipids	1-13	80[a]	0.67
Carbohydrates (fructose, glucose, sucrose, fiber)	13-55	320[a]	6.67-306.67
Crude fiber	0.3-20	30[a]	2-120
Minerals	-	-	-
Potassium	400-2000[b]	2000[c]	33.33-180
Phosphorus	80-600[b]	1000[c]	13.33-106.67
Calcium	20-300[b]	1100[c]	3.33-46.67
Magnesium	20-300[b]	350[c]	13.33-153.33
Zinc	3-25[b]	8.5[c]	66.67-526.67
Manganese	2-11[b]	3.5[c]	100-566.67
Iron	1.1-17[b]	12.5[c]	13.33-246.67
Copper	0.2-1.6[b]	1.2[c]	26.67-240
Vitamins	-	-	-
Ascorbic acid (Vitamin C)	7-56[b]	100[c]	13.33-100
Â-Carotene (Provitamin A)	1-20[b]	0.9[c]	100-4000
Tocopherol (Vitamin E)	4-32[b]	13[c]	53.33-440
Niacin (Vitamin B3)	4-11[b]	15[c]	46.67-133.33
Pyridoxin (Vitamin B6)	0.2-0.7[b]	1.4[c]	26.67-86.67
Thiamine (Vitamin B1)	0.6-1.3[b]	1.1[c]	100-213.33
Riboflavin (Vitamin B2)	0.6-2[b]	1.3[c]	80-280
Pantothenic acid	0.5-2[b]	6[c]	13.33-60
Folic acid	0.3-1[b]	0.4[c]	133.33-446.67
Biotin (Vitamin B7)	0.05-0.07[b]	0.045[c]	200-280

Adapted from: Zakaria *et al*. (2022) [a]- RDI is given in g/day, [b]- Amount is given in mg/100 g; [c]- RDI is given in mg/day.

3.6 Bee pollen as a nutritional and health-promoting agent

Foraging honeybees collect pollen grains from flowering plants and bring them to bee hive in the form of pollen loads (moistened with some nectar or honey to bind the grains and form lumps). There are several flowers from which the pollen grains are produced. The colours, morphologies, and surface textures of pollen are used to determine its floral source using a scanning electron microscope (Thakur and Nanda, 2020). Although, the botanical origin is the main factor in determining the chemical composition of the pollen, other elements such as geographical origin, weather, climate, the type of soil where the pollen is harvested, the time of harvesting, and even the species of bees can also have an impact (Feas *et al*., 2012).

The nutritional elements of each pollen differ significantly, and they all have a variety of beneficial medicinal effects (Kieliszek *et al*., 2018). Since a very long time ago, it has been used as a dietary supplement and even as medication (Linskens and Jorde, 1997). It has been shown that pollen contains an array of nutrients, including proteins, lipids, carbohydrates, vitamins, and minerals, which contribute to its medicinal and nutritional characteristics (Table 6). Since pollen contains such a wide variety of compounds, it has excellent antioxidant properties (Kostic *et al*., 2019), as well as several other potential health benefits for consumers, including anti-inflammatory and anticarcinogenic activities (Margaoan *et al*., 2019).

4. Discussion

The present investigation revealed that vegetables, cereals, oilseeds, plantation crops and fruit trees were available as bee flora in the study region. During the dearth period i.e. in July and August, sesame flowers were available as a reliable source of pollen and nectar. These results are in line with the findings of Taha (2005) in Kafrelshiekh, Ismail *et al*. (2013) in Fayoum, Esmael *et al*. (2016) in Alexandria and El-Beheira provinces.

In all the study locations, herbs are the dominant bee forage, followed by trees, shrubs, climbers and vines. Even though, herbs were the major component of the bee flora in all of the study areas, trees coupled with shrubs were the region's largest source of honey bee flora. This may be because they are deeply rooted and have evolved to thrive in areas with little rainfall. This is attributable to the nectar and pollen produce of the plants, honeybees' floral preferences, and local climate conditions. Our results are in agreement with the results of Ara *et al*. (2019) who reported that annual herbaceous plants were found as abundant sources of pollen and nectar for bees followed by perennial herbs, shrubs, trees and finally by biennial herbs in Kashmir Himalaya.

Cucurbitaceae, Fabaceae, Rutaceae, Asteraceae, Solanaceae, and Poaceae are the major contributing bee forage families in the study region. A similar study conducted by Addi and Bareke (2019) reported that Asteraceae is the most frequent family represented by the highest number of bee forage species. The dominance of the Asteraceae family could be attributed to the potential of its species for honey production in Ethiopia (Bareke and Addi, 2018). However, many authors have mentioned that Fabaceae is the dominant family (Gurmessa *et al*., 2013; Kuma and Shibru, 2015). There are plenty of Fabaceae plants that are not bee pasture, therefore this is not from the perspective of beekeeping but rather the overall floristic makeup. The dominant family, however, varies from location to location. Our results are in agreement with those obtained by Esmael *et al*. (2016) in Egypt; Taha (2015) and Adgaba *et al*., (2017) in Saudi Arabia, where they reported that the dominant bee flora families were Asteraceae, Brassicaceae, Cucurbitaceae, Fabaceae and Rosaceae.

The higher values of diversity indices indicate that the bee flora is more evenly distributed in the study locations. Similar findings were reported by Bareke & Addi (2018) in the Guji zone indicates that a high diversity of bee flora resource was found in communities one to three. Diverse floral environments can promote higher reproductive fitness, which leads to stronger colonies and more prolific foragers (Alaux *et al*., 2017). To preserve honeybee colony fitness, the risk of pesticide contamination of bee flora must be avoided (Reyes-Carrillo *et al*., 2009). Biopesticides, biocontrol agents and plant secondary metabolites that are relatively safer should be preferred for crop protection of bee flora to avoid any adverse effects on pollinator bees (Dukare *et al*., 2021; Divekar *et al*., 2022b, Kumar *et al*., 2022; Sharma *et al*., 2022).

At the study locations, four species of honeybees, *viz., Apis dorsata*, *Apis cerana indica*, *Apis florea* and *Apis mellifera* were reported. However, *A. mellifera* was newly introduced in the region (Divekar *et al*., 2018). The giant bee *A. dorsata* was well distributed in both the study regions. These wild bees are considered as effective pollinators of various agro-horticulture crops (Divekar *et al*., 2022a).

Our results revealed that the duration from Mid-April to July was observed as dearth period whereas the period from mid-October to March was recorded as honey flow season in the study area. Akratanakul (1990), also illustrated that in order to survive, prosper and be productive, honeybee colonies must have a supply of both nectar and pollen in adequate quantities. Harugade *et al*. (2016) reported that the period between June and August (during the rainy season) was recognized as the dearth period. Continuous rain and subsequent temperature fluctuations at this time were also found to be unfavorable for honeybee foraging. According to Waykar *et al*. (2014), honey flow times were found to be from mid-December to mid-February and mid-July to mid-September, whereas key dearth periods were found to be from mid-April to mid-June. Similar findings on bee flora of different regions of India were reported by researchers and confirmed that the period from April-May (Pandey and Ramakrushna, 2018); July-August (Behera *et al*., 2014) was a dearth period.

According to Zamarlicki (1984), knowing the bee forage species is the most crucial element in beekeeping and the survival of honey bees is correlated with the availability of bee flora. The floral and beekeeping potential in a particular region can be determined by the performance of bee forage plants, taking into account both botanical and paleontological factors (Sharma *et al*., 2014).

5. Conclusion

Enhancing the effectiveness of the beekeeping sector and successful beekeeping depend on having a thorough understanding of the type, density and quality of the bee flora in a given area. The results of this investigation showed that 59 plant species from 27 families were identified, serving as forage plants for various bee species.

The most plentiful source of pollen and nectar for bees was shown to be herbaceous plants, followed by shrubs and trees. In the Eastern Uttar Pradesh districts of Varanasi and Mirzapur, it became apparent that the Cucurbitaceae family was predominant among plants that produced pollen and nectar. Weeds were observed to serve as a source of both pollen and nectar. The majority of pollen and nectar-producing plants (37 plant species) were discovered to be bi-dimensional, contributing as a sources of both pollen and nectar as opposed to pollen (16 plant species) or nectar (6 plant species) exclusively (uni-dimensional).

There are short and long-term phases of honey flow and dearth in every region. In Varanasi and Mirzapur districts of Eastern Uttar Pradesh, mid-October to March, and August-September were observed as honey flow periods whereas, mid-April to July was observed as the dearth period. The successful management of bee colonies during these times will be made possible by this understanding of bee flora. Therefore, the present investigation serves as a ready reckoner, an inventory of existing nectariferous/ polleniferous bee flora and the floral calendar for Varanasi and Mirzapur districts of Eastern Uttar Pradesh (India) helps in practicing migratory beekeeping. Along with the honeybee's contribution as a living organism, plants can contribute to the antioxidant activity of bee products like honey and pollen; the antioxidant characteristics can be perceived as a possible signal for melliferous plants. Further investigation should be done on bee products made from a wide variety of medicinal plants in this context, as well as on the discovery of any connections that may exist between the bioactive components found in plant parts, their nectars, and bee products.

Author contributions

Conceptualization: PAD and ABR; formal analysis: PAD, SGK, KS, SY; investigation: PAD and CKV; data curation: PAD and SGK, KS and SY; writing-original draft preparation: PAD and KS; writing review and editing: ABR, SY and BS; supervision and project administration: ABR and BS. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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