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Research Article

Seasonal Abundance of Common Honey Bees and Floral Resources in Mixed Agriculture and Grassland Habitats

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ABSTRACT

Beekeeping is a traditional practice that has played a significant role in the sustainable development of rural and tribal communities. The diversity and abundance of honey bees depend on the floral resources available and can be influenced by seasonal environmental changes. In the present study, the seasonal abundance of colonies of three common honey bees *Apis cerana*, *Apis florea* and *Apis dorsata* in a draught-prone tropical area in Karjat, Maharashtra, India was monitored for three consecutive years. Also, the floral resources of flowering plants and their seasonal composition were studied. The study was conducted in mixed agriculture and grassland habitats at 11 locations. A total of 4408 colonies of three honey bee species were observed. The study revealed that *A. florea* (57.42%) is the most abundant species followed by *A. cerana* (25.88%) and *A. dorsata* (16.70%), and their proportion remains similar in different seasons. A total of 72 plant species were recorded with nectar and pollen as floral resources. It is found that the proportion of agricultural crop plants is high in the monsoon season whereas the composition of flowering plants varies in different seasons. The results of the present study suggest that mixed agriculture and grassland ecosystems support the abundance of *A. florea* species, i.e., the change in the seasonal floral resources influences bee species abundance and non-crop plants are important in maintaining the honey bee populations. The results of the present study will be helpful as baseline information for the sustainable development of apiculture in mixed agriculture and grassland habitats and to understand the role of tropical grassland flora in maintaining the diversity of bees.

Keywords: *Apis florea*; abundance; floral resources; seasonal variation; correspondence analysis.

INTRODUCTION

Honey bees are ecologically and economically important insects as they are involved in plant pollination and the production of nutritional and medicinal products (Narang et al., 2022; Requier et al., 2019; Sharma et al., 2016). Their diversity and abundance are dependent on the availability of floral resources (Blaauw & Isaacs, 2014; Jha & Kremen, 2013; Kaluza et al., 2017). The availability of floral resources can be influenced by seasonal environmental changes (Coffey & Breen, 1997). As honey bees are dependent on floral resources, their diversity and abundance can also be the function of seasonal variations in environmental factors (Bänsch et al., 2020; Danner et al., 2016; Guezen & Forrest, 2021; Mensah et al., 2017). Also, temperature is a crucial factor responsible for the foraging of bees (Kamaraj & Rasappan, 2024). Therefore, seasonal dynamics in honey bee abundance and vegetation resources need to be investigated to understand the influence of fluctuating environmental conditions in the era of global warming.

Grassland habitats are more prone to seasonal changes as the life cycle of grass is short and can be influenced by environmental factors such as rain and temperature. Moreover, grasslands play a significant role in the ecosystem as they can support pollinator bees. Therefore, fluctuations in honey bee abundance in grassland ecosystems need to be investigated.

Further, agricultural habitats may have a significant role in determining bee diversity and abundance (Decourtye et al., 2010; Fisher et al., 2017). Several studies have shown that the increase in flowering plant diversity in agricultural ecosystem providing nutritional resources promote bee diversity and crop pollination (Kaluza et al., 2017; Sutter et al., 2017; Williams et al., 2015). Honey bee diversity studies in mixed agriculture and natural habitats could provide insight into the role of agricultural land in maintaining natural bee population and their role in crop pollination and production (Rogers et al., 2014). India is one of the leading agricultural countries covering a major portion of its land for crop production. The Indian agriculture system comprises seasonal and perennial crops as well. Since honey bees are important pollinators, studies on sustaining honey bee population in agro-ecosystems help in improving livelihoods of rural farmers and tribal communities (Dalwai, 2012).

Honey harvesting along with agriculture has long been practiced in human cultures and has been a supportive source for human livelihood (Abrol, 2023; Basu & Purkait, 2023). Although traditional beekeeping has been practiced in rural India, commercial honey production is also getting popular among farmers cultivating horticultural and agricultural crops (Abrol, 2023; Jamwal et al., 2021). Information on the bee diversity and abundance in agro-ecosystems can be helpful for the sustainable development of apiculture (Jamwal et al., 2021). Moreover, the concurrent studies of diversity of agricultural crops could help in evaluating their significance for the development of bee keeping practices (Al-Ghamdi & Al-Sagheer, 2023; Coffey & Breen, 1997; Waykar & Baviskar, 2015). Considering the need of bee diversity studies in mixed natural and agro-ecosystems, the abundance of three common honey bee species, Indian honey bee (*Apis cerana*), Dwarf honey bee (*Apis florea*) and Giant honey bee (*Apis dorsata*) was investigated in the present study. *Apis cerana* is domesticated in India and considered as ideal for beekeeping. *Apis florea* is an important pollinator and *A. dorsata* is known for production of enormous honey and wax. It builds its nest in dense foliage hanging to small branches nearly 0.2 to 8.2 m above the ground level. *Apis cerana* is a medium sized honey bee built in multiple combs in dark places parallel to each other keeping uniform distance while *A. dorsata* build single or aggregately multiple nests on the high tree branches or overhanging rocks about 30-50 m (Mishra, 2013). These species of honey bees play significant role in the pollination of several agricultural crops and natural plants. Additionally, combs of these

common honey bee species are harvested for honey and made into several other products supporting the local community (Mishra, 2013).

The abundance of active bee colonies of these three species was studied at eleven locations in Ahmednagar district of central Maharashtra, India. Additionally, the diversity of agricultural and surrounding non-agricultural plants providing floral resources in mixed agriculture and dry grassland habitats, was studied. All the locations in the present study are situated in the Karjat block of Ahmednagar district, which is a drought prone area mainly comprising grassland habitats and agricultural land that are mostly used for seasonal crop cultivation (Malaviya et al., 2018). The present study was undertaken to investigate the role of mixed grassland and agriculture habitats in a tropical region on the seasonal abundance of common honey bees. This study aims to (1) assess seasonal variations in the abundance of three honey bee species (*A. cerana, A. florea,* and *A. dorsata*) in a drought-prone region, and (2) investigate the role of agricultural and non-crop floral resources in honey bee populations across different seasons.

MATERIAL AND METHODS

A total of 11 locations in Karjat block, Ahmednagar district, Maharashtra, India were selected (Fig. 1). The study locations consist of agriculture, grasslands and deciduous forest patches near rural settlements. All the sites were surveyed in different seasons for three consecutive years (2021–2023). The selected sites were visited each month to record plants with floral resources. Two consecutive visits were made in each season (summer, monsoon, and winter) to record the number of colonies per species. During field visits, *Apis* bee colonies were actively searched with the help of field assistants. Colonies inhabited by bees were considered active and these were included in the study. The number of bee hives observed were recorded and to confirm the species, 4–5 bees were collected by the net sweeping method. Collected honey bee specimens were preserved in 70% ethanol and brought to the laboratory. Species identification was done following the standard references (Mishra, 2013). Foraging activity of bees around flowering plants was recorded on field. The data of flowering plants was recorded along with the floral value (nectar and/or pollen) for honey bees. Plant species recorded in the present study are agricultural crops and common plants in the study area. In ambiguous situations, plant identity was determined after referring to the Flora of Ahmednagar district (Singh & Pradhan,1999) or by consulting with experts. Floral calendars were prepared for each flowering plant. Collected data of the plant species with floral resources was grouped into the seasons and data of seasonal distribution of plants with floral resources was analysed using Chi-square χ^2 tests of contingency analysis and to show the relationship between seasons and the presence of the plant species. Correspondence analysis was performed in PAST Version 4.10 (Hammer & Harper, 2001).

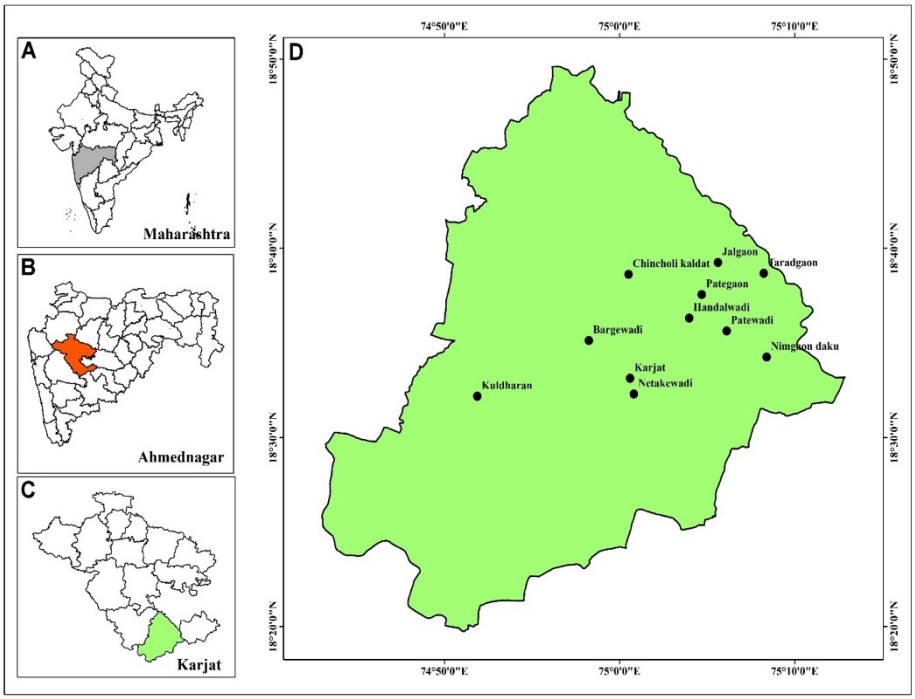

Figure 1: Study sites of common honey bee colonies investigated in Karjat, Ahmednagar, Maharashtra, India in 2021–2023. **A.** Map of India, with Maharashtra state shaded in gray. **B.** Map of Maharashtra state, with Ahmednagar district shaded in red. **C.** Ahmednagar district, with Karjat block shaded in green. **D.** Study sites.

RESULTS

During different seasons, 4408 colonies of three species were recorded throughout the study. Colonies of *A. florea* were the most common (57.42%) in the study area, followed by *A. cerana* and *A. dorsata* (Fig. 2). The highest number of bee colonies were observed at Kuldharan site and the lowest bee colonies were recorded at Karjat site (Table 1). The highest number of *A. cerana*, *A. florea,* and *A. dorsata* colonies were observed at Taradgaon, Nimgaon daku and Netakewadi, respectively. The lowest number of *A. cerana*, *A. florea* and *A. dorsata* colonies were observed at Chincholi kaldat, Netakewadi and Bargewadi respectively (Table 1).

Colonies of *A. florea* were the most common in all seasons followed by *A. cerana* and *A. dorsata* (Fig. 3). In the summer season, the highest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Handalwadi, Kuldharan, and Kuldharan, respectively while the lowest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Karjat town, Netakewadi, and Bargewadi, respectively. In the monsoon season, the highest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Taradgaon, Nimgaon Daku, and Chincholi Kaldat, respectively while the lowest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Karjat town and Bargewadi, respectively. In the winter season, the highest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Bargewadi, Bargewadi, and Chincholi Kaldat, respectively while the lowest number of *A. cerana*, *A. florea*, and *A. dorsata* colonies were recorded at Chincholi kaldat, Netakewadi, and Pategaon, respectively. Details of the seasonal abundance of colonies of different species are described in Table 2.

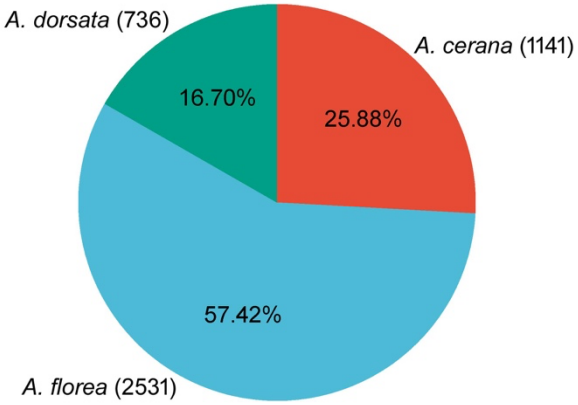

Figure 2: Proportion of all *Apis* honey bee colonies recorded across different seasons in Karjat, Ahmednagar, Maharashtra, in 2021–2023. Numbers in parenthesis are the number of colonies recorded for respective species.

Table 1: Percentage of *Apis cerana*, *A. florea*, and *A. dorsata* colonies recorded across sites in Karjat, Ahmednagar, Maharashtra, India in 2021–2023. Values in parentheses represent number of colonies recorded.

Study sites	***A. cerana***	***A. florea***	***A. dorsata***
Karjat town	20.20 (59)	62.67 (183)	17.12 (50)
Netakewadi	22.74 (78)	51.02 (175)	26.23 (90)
Chincholi Kaldat	19.78 (75)	55.14 (209)	25.06 (95)
Jalgaon	29.33 (115)	52.29 (205)	18.36 (72)
Patewadi	28.41 (106)	54.42 (203)	17.15 (64)
Handalwadi	29.09 (112)	58.44 (225)	12.46 (48)
Pategaon	30.06 (135)	57.68 (259)	12.24 (55)
Taradgaon	31.65 (138)	53.44 (233)	14.90 (65)
Nimgaon Daku	22.63 (98)	65.12 (282)	12.24 (53)
Bargewadi	25.57 (112)	63.01 (276)	11.41 (50)
Kuldharan	23.15 (113)	57.58 (281)	19.26 (94)

A total of 72 species of plants belonging to 30 families were recorded (Table 3 and 4). Plants belonging to the family Fabaceae (15.2%) were predominant followed by Cucurbitaceae (11.1%) and Asteraceae (8.3%; Table 4). A total of 39 (54.16%) agricultural crop plants and 33 (45.83%) wild plants were recorded in the study area (Table 4). More than 50% of the plant species were found to be sources of nectar and pollen (Table 3). 26.38% plants were providing nectar source while 11.11% plants were providing pollen source. Five species of plants (*Coriandrum sativum*, *Moringa oeifera*, *Tridax procumbeans*, *Ocimum forskoelei*, and *Adhatoda vasica*) serve as a floral source for the entire year as these floweri throughout the year. Flowering plants along with the floral calendar are described in detail in Table 4.

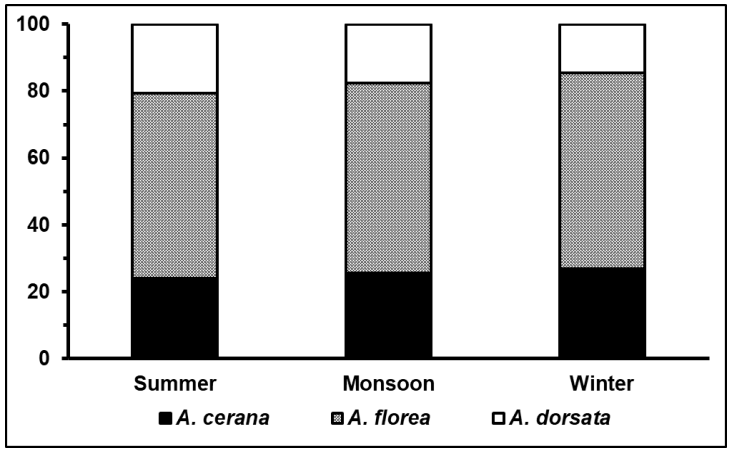

Figure 3: Season-wise proportion of colonies of *Apis cerana*, *A. florea*, and *A.dorsata* recorded in Karjat, Ahmednagar, Maharashtra, India in 2021–2023.

Table 2: Number of *A. cerana*, *A. florea*, and *A. dorsata* colonies at selected locations in Karjat, Ahmednagar, Maharashtra, India across seasons in 2021–2023.

Study sites	Summer			Monsoon			Winter		
	A. cerana	***A. florea***	***A. dorsata***	***A. cerana***	***A. florea***	***A. dorsata***	***A. cerana***	***A. florea***	***A. dorsata***
Karjat Town	11	58	12	7	23	9	41	102	29
Netakewadi	14	43	36	11	34	17	53	98	37
Chincholi Kaldat	17	57	29	19	39	19	39	113	47
Jalgaon	31	47	24	23	37	16	61	121	32
Patewadi	29	49	21	21	38	16	56	116	27
Handalwadi	38	53	14	31	43	9	43	129	25
Pategaon	34	63	18	29	53	13	72	143	24
Taradgaon	37	59	21	33	50	18	68	124	26
Nimgaon Daku	19	71	13	17	64	11	62	147	29
Bargewadi	23	67	12	15	57	8	74	152	30
Kuldharan	24	72	37	20	61	18	69	148	39

Table 3: Number of plants and representing families recorded with floral value for honey bees in Karjat, Ahmednagar, Maharashtra, India. Numbers in parentheses are percentages.

	Total	Nectar	Pollen	Nectar + Pollen
Number of plants	72	18 (25.00)	10 (13.88)	44 (61.11)
Number of families	30	11 (36.66)	6 (20.00)	13 (43.33)

Table 4: List of the plants recorded in in Karjat, Ahmednagar, Maharashtra, India with flowering season and floral value for honey bees. Source: N = Nectar; P = Pollen; NP = Nectar + pollen.

Family	Botanical name	Common name	Source (Nectar/ Pollen)	Flowering season
Agricultural flora				
Anacardiaceae	*Mangifera indica*	Mango	NP	March–April
Annonaceae	*Annona squamosa*	Custard apple	NP	Sept–Oct
Apiaceae	*Coriandrum sativum*	Coriander	NP	Jan– Dec
Brassicaceae	*Brassica rapa*	Mustard	N	Jan– April
Brassicaceae	*Raphanus sativus*	Radish	NP	Dec–March
Caricaceae	*Carica papaya*	Papaya	NP	Feb–March
Compositae	*Helianthus annuus*	Sunflower	NP	March–May
Cucurbitaceae	*Cucumis sativus*	Cucumber	NP	Aug–Nov
Cucurbitaceae	*Cucurbita pepo*	Pumpkin	NP	Aug–Oct
Cucurbitaceae	*Citrullus lanatus*	Watermelon	P	July–Sept
Cucurbitaceae	*Cucumis melo*	Muskmelon	P	Feb–May
Cucurbitaceae	*Luffa acutangula*	Silk gourd	NP	July–Oct
Cucurbitaceae	*Momordica charanta*	Bitter gourd	NP	June–Sept
Cucurbitaceae	*Lagenaria siceraria*	Bottle gourd	NP	Aug–Sept
Fabaceae	*Trigonella foenum*	Fenugreek	NP	Jan–April
Fabaceae	*Cicer arietinum*	Chickpea	P	Dec–April
Fabaceae	*Vigna radiata*	Green gram	N	Aug–Nov
Fabaceae	*Vigna mungo*	Black gram	N	Aug–Oct
Fabaceae	*Cajanus cajan*	Pigeon pea	N	July–Sept
Fabaceae	*Tamariandus indica*	Tamarind	N	July–Oct
Leguminosae	*Cyamopsis tetragonolobus*	Cluster bean	N	June–Aug
Liliaceae	*Allium sepa*	Onion	NP	June–Aug
Liliaceae	*Allium sativum*	Garlic	NP	Aug–Sept
Malvaceae	*Abelmoschus esculentus*	Ladyfinger	P	March–April,June–Aug
Moringaceae	*Moringa oeifera*	Drumstick	NP	Jan–Dec
Myrtaceae	*Psidium guajava*	Guava	NP	May–June
Myrtaceae	*Syzygium cumini*	Jambhul	NP	Feb–April
Myrtaceae	*Callistemon* spp.	Bottlebrush	N	March–Sept
Poaceae	*Zea mays*	Maize	P	Aug–Sept, Feb–March
Poaceae	*Triticum aestivum*	Wheat	N	Feb–April
Poaceae	*Sorghum vulgare*	Jawar	N	Sept–Nov
Poaceae	*Pennisetum typhoides*	Bajara	N	July–Sept
Punicaceae	*Punica grantum*	Pomegranate	NP	March–June
Rhamnaceae	*Ziziphus jujuba*	Zizipus	NP	July–Nov
Rhamnaceae	*Ziziphus mauritiana*	Ziziphus	NP	May–June
Rutaceae	*Murraya koenigii*	Curry leaves	N	March–May
Rutaceae	*Aegle marmelos*	Bel	NP	May–June
Rutaceae	*Citrus limon*	Lemon	NP	Oct–Jan, July–Sept
Solanaceae	*Solanum melongena*	Brinjal	P	Jan–March, June–July
Wild flora				
Acanthaceae	*Justicia betonica*	Squirrel tail	NP	Jan–April, Oct–Dec
Acanthaceae	*Adhatoda vasica*	Adhulsa	N	Jan–Dec
Amaranthaceae	*Achyranthes aspera*	Devil horsewhip	P	March–May
Amaranthaceae	*Amaranthus viridis*	Slender amaranth	P	Sept–Nov
Amaranthaceae	*Alternanthera sessils*	Dwarf copperleaf	NP	Dec– April
Amaranthaceae	*Digera muricata*	False Amaranthus	N	Jan–March
Apocynaceae	*Calatropis procera*	Calatropis (Rui)	NP	Feb, March, Nov
Apocynaceae	*Thevetia peruviana*	Yellow Oleander	N	May–Aug
Asteraceae	*Bidens pilosa*	Beggar tick	NP	July–Dec
Asteraceae	*Calendula arvensis*	Field marigold	NP	Jan–April
Asteraceae	*Centaurea sinaica*	Blooming plant	NP	Jan–May and Dec

Asteraceae	*Flaveria trinervia*	Clustered yellowtop	NP	April–July, Jan, Dec
Asteraceae	*Parthenium hysterophorus*	Congress	N	Aug–Dec
Asteraceae	*Launaea nudicaulis*	Bold leaf launaeae	NP	Aug–Dec
Cactaceae	*Opuntia ficus indica*	Opuntia	NP	May, June
Compositae	*Tridax procumbeans*	Tridax daisy	NP	Jan–Dec
Convolvulaceae	*Convolvulus arvensis*	Shankhapushpi	NP	Oct–Dec
Cucurbitaceae	*Citrullus colocynthis*	Indrayan	P	Jan, Feb, June, Oct
Euphorbiaceae	*Phyllanthus emblica*	Amla	NP	March–May
Euphorbiaceae	*Ricinus communis*	Castor	NP	Nov–Feb
Fabaceace	*Delonix regia*	Gul mohar	NP	March–May
Fabaceae	*Acacia arabica*	Acacia	N	July–Dec
Fabaceae	*Tephrosia purpurea*	Unhali	N	Nov, Dec
Fabaceae	*Trifolium arevense*	Rabbit foot clover	NP	March, April, May
Fabaceae	*Senna alexandrina*	Tarvad	P	April, May, Nov
Lamiaceae	*Ocimum forskoelei*	Tulsi	NP	Jan–Dec
Malvaceae	*Abutilon theophrasti*	Velvet leaf plant	NP	July–Sept
Malvaceae	*Gossypium* spp.	Cotton	NP	Sept–Dec
Meliaceae	*Azadiracta indica*	Neem	NP	April–May
Mimosaceae	*Acacia catechu*	Khair	NP	Sept–Dec
Myrtaceae	*Eucalyptus* spp.	Nilgiri	NP	Nov–March
Papaveraceae	*Argemone mexicana*	Styanashi	NP	Feb–April
Verbenaceae	*Lantana camara*	Tantani	N	Jan–May, July–Sept

The highest number of plants were available during the monsoon season (Fig. 4). The proportion of crop plants was high during the monsoon season and low in summer and winter. Conversely, non-crop plant proportion was higher during summer and winter compared to the monsoon season (Fig. 4).

Correspondence analysis revealed similarities in the presence of flowering plants in different seasons. First two axes highlighted 54.25% similarity in flowering plants in different seasons (Table 5). Scatter plot clearly shows seasonal groups based on plants with floral resources (Fig. 5).

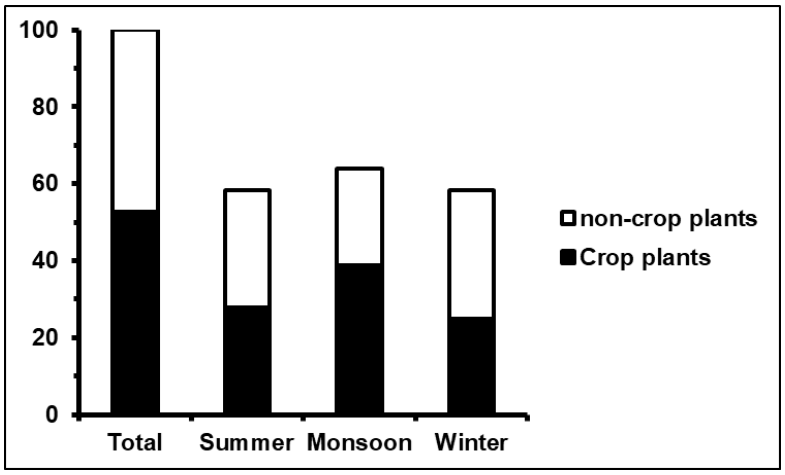

Figure 4: Seasonal distribution of all crop and non-crop plant sources available for honey bees from eleven study sites in Karjat, Ahmednagar, Maharashtra, India in 2021–2023.

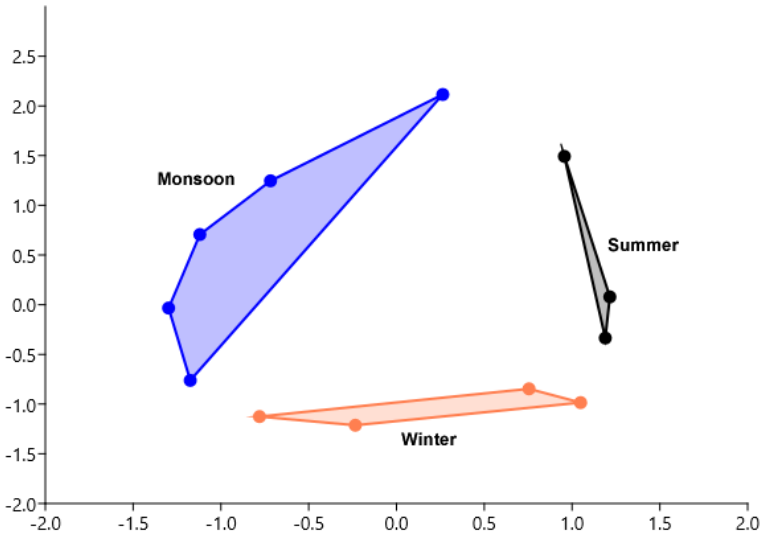

Figure 5: Correspondence analysis ordination biplot showing relationship of composition of plants with floral resources for honey bees across different seasons in Karjat, Ahmednagar, Maharashtra, India in 2021–2023. (Note- Biplot represents the plotting of Chi-squared distances between months and plant species for axis 1 (X axis) and axis 2 (Y axis). Dots represent the month of the particular season).

Table 5: Eigenvalues and percentage of variance explained on different axes after Correspondence analysis of floral resources available for honey bees across different seasons.

Axis	Eigenvalue	% of variance
1	0.56	32.20
2	0.38	22.05
3	0.24	14.01
4	0.20	11.66
5	0.11	6.13
6	0.07	3.94
7	0.06	3.25
8	0.04	2.53
9	0.03	1.66
10	0.02	1.39
11	0.02	1.17

DISCUSSION

Beekeeping, a traditional practice, has played a significant role in sustainable development of tribal and rural communities (Abrol, 2023; Basu & Purkait, 2023). Understanding the honey bee species community of a particular area along with the data on floral resources is a preliminary step toward sustainable apiculture practices (Al-Ghamdi & Al-Sagheer, 2023; Waykar & Baviskar, 2015). In the present study, we evaluated the abundance of colonies of three important honey bee species over three years along with the plants providing floral resources from mixed dry grassland and agricultural area from rural Maharashtra. The results revealed that *A. florea* is the most predominant honey bee species in the study area (Fig. 2). Previously, *A. florea* was reported as a dominant honey bee in some Indian habitats including the agro-ecosystem, coastal regions, and mountain grasslands (Goyal, 1974; Indhu et al., 2022; Kamaraj & Rasappan, 2024). Contrastingly, other honey bees including *A. dorsata* and *A.*

mellifera were also reported to be predominantly present in different parts of the country (Abrol, 2020; Balachandran et al., 2014; Goyal, 1974; Rathee et al., 2023). These observations highlight differences in the abundance of honey bees belonging to various species in different geographical locations (Parveen et al., 2022; Potts et al., 2003; Sen et al., 2023). Moreover, several biotic and abiotic factors influence the diversity of honey bees in a particular habitat (Horn et al., 2021; Neov et al., 2019; Smart et al., 2016). The abundance of different species of honey bees is mainly dependent on the floral resources available in the particular habitat (Fisher et al., 2017; Rollin et al., 2013; Smart et al., 2016).

The present study revealed that the proportion of colonies of different species was similar throughout the year. However, the composition of the plants providing floral resources varied in different seasons. These observations suggest that irrespective of the changes in the vegetation in selected sites, the colony proportions remains similar. The stability of colonies proportions across seasons may indicate that honey bees are capable of utilizing a diverse range of floral resources (Abrol, 2020; Chauhan et al., 2017; Lazar et al., 2024). Moreover, other biological factors including predation, competition, etc. can also be responsible for the maintenance of their proportion (Monceau et al., 2013; Roubik & Wolda, 2001). Flowering plant communities vary in different seasons mainly due to the increase in agricultural crops during the monsoon season. However, the proportion of non-agricultural plants remained similar in different seasons. As the proportion of different species of honey bees is similar in different seasons, it seems that non-agricultural plants are playing a crucial role in supporting the populations of the bees included in the present study. Previous studies also have shown the role of non-crop plants in maintaining bee diversity in agricultural fields (Nicholls & Altieri, 2013; Sutter et al., 2017; Williams et al., 2015).

The selected study region is a drought prone dry grassland which flourishes during the monsoon season only. Also, the area included in the present study mainly consistsof agricultural land along with semi-urban patches, grasslands with small bushy forests, and some dense forest patches. Therefore, diverse flora in the habitat provide rich floral resources throughout the year. More than 50% agricultural crop plants were recorded in the study area. These observations suggested that consistent availability of agricultural crops throughout the year support *A. cerana*, *A. florea* and *A. dorsata* bee population. Previous studies also demonstrated that the plant diversity in agricultural land enhances and supports bee diversity (Nicholls & Altieri, 2013; Rivers-Moore et al., 2020; Sutter et al., 2017). The present study revealed the abundance of *A. florea* in mixed agricultural and natural grassland habitats suggesting this species is suitable for bee keeping practices (Kishan et al., 2017).

In the present study, we recorded the interaction of honey bees with fruit crops, suggesting that honey bees species monitored in the present study are important for sustainable agriculture in the study area. Furthermore, bee pollination of many wild plants is extremely important for their survival and ecosystem function (Kumar et al., 2024; Lazar et al., 2024), implying that the natural flora supporting bee diversity is crucial for the conservation of the grassland ecosystem, sustainable agriculture and apiculture practices. Importantly, the presence of natural flora around the agriculture land is also important for maintaining honey bee populations in different seasons of the year (Nicholls & Altieri, 2013). The data on the floral resource that provide plants could serve as a baseline for sustainable apiculture practices in tropical mixed habitats (agriculture and grassland). Future comparative studies of the abundance of the honey bee colonies in agriculture land, grassland, and mixed agriculture-grassland habitats need to be undertaken to find out the requirements for the sustainable apiculture and agriculture practices in the grassland ecosystem.

In the present study, seasonal honey bee comb abundance in mixed grassland and agriculture habitats was observed. Environmental parameters including rainfall and temperature were not monitored during the present study. Investigation of the influence of these environmental parameters on honey bee abundance is one of the major limitations of the present study. Moreover, the present study in an observational study of mixed grassland and agriculture habitat. Further studies can be conducted by considering environmental parameters and comparative approach to understand the role of grasslands and agriculture in maintaining honey bee diversity.

CONCLUSION

It is concluded that the proportion and abundance of *A. cerana*, *A. florea* and *A. dorsata* is stable throughout the year in mixed agriculture and dry grassland habitats of central Maharashtra. Although plant community providing floral resources vary in different seasons, it does not influence hive diversity and abundance. It is found that *Apis florea* was predominantly found in the study area and therefore can be used for apiculture practice in the studied area. Further comparative studies on the influence of grassland and agriculture habitats considering environmental factors could help in understanding their role in maintaining honey bee diversity and abundance.

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DECLARATIONS

Research permit(s). Not applicable.
Ethical approval/statement. The permission to conduct the study and collect required bee samples was obtained from Maharashtra State Biodiversity Board (MSBB/Desk-5/Research/898/2022-23).
Generative AI use. We declare that generative AI was not used in this study nor in the writing of this article.

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