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DIVERSITY, FORAGING BEHAVIOR AND TEMPORAL ACTIVITY OF POLLINATORS AND FLORAL VISITORS ON DRAGON FRUIT (*HYLOCEREUS UNDATUS* AND *H. POLYRHIZUS*)

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ABSTRACT

During the flowering period of 2023–24, the diversity and foraging behavior of pollinators and floral visitors associated with dragon fruit (*Hylocereus undatus* and *H. polyrhizus*) were investigated. A total of 15 insect taxa belonging to three orders *viz.*, Hymenoptera, Lepidoptera, and Coleoptera were recorded. Hymenoptera was the dominant order with seven taxa, comprising four honey bee species, *Apis dorsata* F., *A. cerana* F., *A. mellifera* L., and *A. florea* F. (Apidae), which were regular diurnal visitors collecting both pollen and nectar. *Ropalidia marginata* P. (Vespidae) was an occasional diurnal visitor, while *Camponotus compressus* F. and *Tapinoma melanocephalum* F. (Formicidae) were regular nectar-foraging visitors. Lepidoptera was represented by *Tirumala sp*. (Nymphalidae), an occasional diurnal visitor, and *Agrius sp*. (Sphingidae), a nocturnal visitor coinciding with the night-blooming habit of dragon fruit. Six coleopteran species were recorded, of which *Colasposoma sp*. (Chrysomelidae), *Coccinella transversalis* F. and *C. sexmaculata* (Coccinellidae), *Mylabris pustulata* Thun. (Meloidae), *Popillia schizonycha* A. (Scarabidae), and *Myllocerus viridanus* F. (Curculionidae) were occasional early-morning visitors, whereas *Carpophilus sp*. (Nitidulidae) was a regular visitor with extended activity from pre-dawn to midday. Order-wise Shannon diversity index values were highest for Coleoptera (H′ = 0.367), followed by Hymenoptera (H′ = 0.356) and Lepidoptera (H′ = 0.269). The study highlights the functional dominance of honey bees as primary pollinators and the complementary role of non-*Apis* insects in ensuring continuous pollination in dragon fruit ecosystems. In this study, we focus on pollination as a critical factor influencing fruit set and yield. The approach involves understanding the diversity of floral visitors and promoting the conservation of pollinators to enhance fruit set, improve fruit quality, and increase the productivity of dragon fruit in Maharashtra, India.
***Keywords* :** Dragon fruit, *Hylocereus*, floral visitors, pollinators, foraging behavior, diversity.

Introduction

Dragon fruit (*Hylocereus* spp.), belonging to the family Cactaceae, is an emerging high-value horticultural crop valued for its nutritional, medicinal, and economic importance. Commonly known as Pitaya, Pitahaya, Kamlam, Strawberry Pear, Queen of the Night, or Night-blooming Cereus, the species has trailing, succulent stems with modified areoles that produce oval-shaped fruits in diverse colors. Although its precise origin is uncertain, dragon fruit is believed to have originated in the rainforests of Mexico and Central America, particularly along the Pacific coasts of Guatemala, Costa Rica, and El Salvador, with Southeast Asia as a secondary center of diversification (Wu *et al*., 2006; Ibrahim *et al*., 2018; Britton & Rose, 1963). Among its numerous species, *H. undatus*, *H. polyrhizus*, *H. costaricensis*, and *Selenicereus* *megalanthus* are most widely cultivated globally (Ortiz-Hernández & Salazar, 2012; Cálix de Dios *et al*., 2014).

The fruit is highly prized for its attractive appearance, pleasant flavor, and rich nutritional profile, including antioxidants (betalains), prebiotics, vitamins, and minerals, which provide health benefits such as reducing risks of diabetes, colon cancer, cardiovascular disorders, and regulating blood pressure and cholesterol (Le Bellec *et al*., 2006; Lima *et al*., 2020; Rahimi *et al*., 2019). Commercial propagation is primarily through stem cuttings, which root within 15–25 days and produce shoots in 30–45 days, followed by rapid vegetative growth during the first year. Flowering occurs 8–18 months post-planting, with large, hermaphroditic, nocturnal flowers that reach anthesis at night. Fruit set occurs within 3–5 days, and fruits reach maturity in 30–40 days. With proper training, pruning, and nutrient management, plants remain productive for 20–25 years (Mizrahi *et al*., 1997; Le Bellec *et al*., 2006).

Dragon fruit demonstrates excellent tolerance to high light intensity, elevated temperatures, and drought due to adaptations such as succulent stems, reduced leaves, waxy epidermis, Crassulacean Acid Metabolism (CAM), and aerial roots, enabling cultivation even on degraded or saline soils. However, it is sensitive to prolonged waterlogging and high salinity (Nobel, 1994; Nerd *et al*., 2002; Yadav *et al*., 2024). Global cultivation has expanded rapidly, led by China, Vietnam, Indonesia, Taiwan, Malaysia, and Nicaragua, while India's cultivation area has increased from 4 ha in 2005 to over 3,000 ha by 2020, primarily in Gujarat, Karnataka, and Maharashtra (Arivalgan *et al*., 2019; Singh & Singh, 2017; Wakchaure *et al*., 2020). In India, Andhra Pradesh ranked first in dragon fruit production in India with 27.89 kilotonnes cultivated over 79.7 km², followed by Telangana (7.29 kilotonnes; 6.2 km²) and Maharashtra (6.20 kilotonnes; 8.0 km²). Karnataka ranked fourth with 4.40 kilotonnes from 6.0 km², while Tripura occupied the fifth position producing 2.98 kilotonnes over 1.7 km². West Bengal ranked sixth (2.35 kilotonnes; 3.2 km²), followed by Tamil Nadu (0.80 kilotonnes; 1.5 km²), Nagaland (0.77 kilotonnes; 0.8 km²), and Mizoram (0.74 kilotonnes; 35.4 km²). Kerala ranked tenth with a production of 0.56 kilotonnes cultivated over 0.5 km² (Desikheti, 2025). In Maharashtra, Solapur (183 ha), Sangli (127 ha), Osmanabad 95 ha), Pune 989 ha), Ahilyanagar (49 ha), Nanded (38 ha), Beed (36 ha), Nashik (17 ha), Dhule (15 ha) and Wardha (13 ha) (Horticulture Department, Maharashtra, 2023). The expansion of dragon fruit cultivation in terms of area and production necessitates identifying the inputs, constraints, and sustainable management practices that contribute to improved fruit quality and higher productivity.

Among all cultivation, maintenance, and management practices, pollination is a key factor influencing fruit set and yield. As a night-blooming species, dragon fruit is primarily pollinated by nocturnal agents such as bats, hawk moths, and nitidulid beetles, whereas honey bees (*Apis cerana*, *A. florea*, and *A. dorsata*) contribute to early-morning pollination (Pushpakumara *et al*., 2005; Gunasena *et al*., 2007; Kirejtshuk *et al*., 2007). Some species, including *H. undatus* and *H. polyrhizus*, exhibit total or partial self-incompatibility, requiring hand pollination for commercial yields (Ortiz-Hernández & Salazar, 2012; Weiss *et al*., 1994). While bees may assist in fruit development, the absence of consistent information on floral biology, pollination requirements, and pollinator behavior outside the plant's native range limits optimal cultivation. Identifying floral visitors and conserving pollinators are vital for enhancing fruit set, quality and improving productivity of dragon fruit in India and other regions.

Materials and Methods

Study site: Observations on the composition and diversity of floral visitor species were recorded to identify the most efficient pollinators during the dragon fruit flowering period of 2023–24 at a farmer's field in Dahegaon, Tal. Kopergaon, Dist. Ahilyanagar, Maharashtra, India.

Materials: Sweeping net and microscope

Observation of Floral Visitors

Visual Counting of Floral Visitors

Floral visitor observations were conducted using ad-libitum sampling, counting all visitors, including nocturnal species, during five-minute sampling periods at hourly intervals. Observations were carried out from 06:00 to 18:00 h, with each hourly interval comprising a standardized five-minute visual scan. This approach allowed assessment of temporal variations in species composition and abundance throughout the day. Crepuscular and nocturnal visitors were documented using a time-lapse camera in combination with direct visual observations. Sampling was repeated across different flowering phases of dragon fruit. For insect visitors, the most frequently occurring species and their foraging preferences (nectar or pollen collection) were recorded to facilitate subsequent analysis of foraging behavior, following the methodology of Belavadi and Ganeshaiah (2013).

Nectar and Pollen Foraging by Floral Visitors

Nectar- and pollen-foraging floral visitors were observed during different flowering phases. Four flowers, each from a different direction of the plant, were randomly selected, tagged, and labeled for systematic observation. Bees visiting these flowers were monitored for five minutes at hourly intervals between 06:00 and 19:00 h. During each observation period, honey bee species alighting on flowers were recorded. Bees carrying visible pollen loads on their hind legs were classified as pollen foragers, while those collecting nectar without pollen loads were designated as nectar foragers. Foraging activity was quantified as the number of nectar- or pollen-gathering bees per five-minute interval across the four sampled flowers.

Identification of specimens

Specimens were identified using standard taxonomic keys and descriptions: *Apis* species following Ruttner (1988), Gupta *et al*. (2014), Baldock (2008), Else (1999), Rowson and Pavett (2008), Pesenko *et al*. (2000), Perkins (1976), Morgan (1984), Juho *et al*. (2015), Day (1988), Wiśniowski (2009), Richards (1980), Archer (2003, 2014), Yeo and Corbet (1995), Bitsch *et al*. (1993, 1997, 2001), and Olmi (1994); wasps following Guichard (2002); ants following Bolton and Collingwood (1975), Collingwood (1979), Czechowski *et al*. (2002), Seifert (2018), and Plowes and Patrock (2000); hawk moths (Sphingidae) following Pathania *et al*. (2014); the blue tiger butterfly following Kunte (2025); coleopteran insects following Klimaszewski and Watt (1997); ladybird beetles following Jouveau (2018); blister beetles following Pinto and Bologna (1999); ash weevil following Ramamurthy and Ghai (1988); and nitidulid beetles (*Carpophilus* spp.) following Leschen and Marris (2005).

Diversity of Floral Visitors

The visitation frequency of each floral visitor species was recorded to identify the most abundant and potentially effective pollinators of dragon fruit. Pollinator count data were subsequently used to calculate the Shannon–Wiener diversity index (H) Shannon, C. E., & Weaver, W. 1949 using the formula:

$$H = Pi \times \ln Pi$$

Wherein,

'H' is the Shannon-Wiener index of diversity.

'Pi' is the proportion of the i^{th} species of visitor.

This index provided a measure of species diversity and evenness among floral visitors.

Result and Discussion

Table 1 represents the diversity, foraging behavior, and temporal activity of floral visitors recorded on two dragon fruit types, *Hylocereus undatus* and *H. polyrhizus*, during the 2023–24 flowering period. The table includes information on insect order, family, common and scientific names, visitation frequency, type of forage collected (pollen, nectar, or both), foraging period, number of taxa per order, and Shannon diversity index (H') for each insect group.

A total of 14 floral visitor species were recorded on *H. undatus* and *H. polyrhizus* during the 2023–24 flowering period, with Hymenoptera representing seven taxa, Coleoptera six taxa, and Lepidoptera two taxa. The Shannon diversity index (H') was 0.356 for Hymenoptera, 0.269 for Lepidoptera, and 0.367 for Coleoptera, indicating moderate diversity among visitor groups. Among Hymenoptera, four honey bee species *Apis dorsata, A. cerana, A. mellifera,* and *A. florea* were regular visitors, collecting both pollen and nectar. Foraging activity started earliest in *A. dorsata* at 05:40 hrs and continued until 11:00 hrs, while *A. cerana* and *A. mellifera* were active from 06:00–11:30 hrs. The smallest species, *A. florea*, foraged from 08:00–12:00 hrs. The paper wasp (*Ropalidia marginata*) was an occasional visitor (08:00–18:00 hrs), whereas ants (*Camponotus compressus* and *Tapinoma melanocephalum*) were regular nectar visitors throughout the day (06:00–18:00 hrs), although their role in effective pollination is limited due to minimal contact with reproductive structures.

Table 1: Floral visitors of dragon fruit types, *Hylocereus undatus* and *Hylocereus polyrhizus* during flowering period of 2023-24

Order	Family	Common name	Scientific name	Dragon fruit types		Forage collected	Foraging period	No. of Taxa	Shannon diversity index (H')
				H. undatus	*H. polyrhizus*				
Hymenoptera	Apidae	Rock bee	*Apis dorsata* Fab.	Regular	Regular	P+N	05:40-11:00 hrs	07	0.356
		Indian bee	*Apis cerana* Fab.(yellow & black strain)	Regular	Regular	P+N	06:00- 11:30 hrs		

		Little bee	*Apis florea* Fab.	Regular	Regular	P+N	08:00- 12:00 hrs		
		Italian bee	*Apis mellifera* L.	Regular	Regular	P+N	06:00-11:30 hrs		
	Vespidae	Paper wasp	*Ropalidia marginata* P.	Occasional	Occasional	N	08:00-18:00 hrs		
	Formicidae	Indian black ant	*Camponotus compressus* F.	Regular	Regular	N	06:00-18:00 hrs		
		Ghost ant	*Tapinoma melanocephalum* F.	Regular	Regular	N	06:00-18:00 hrs		
Lepidoptera	Nymphalidae	Blue tiger butterfly	*Tirumala* sp.	Occasional	Occasional	N	07:00-08:00 hrs	02	0.269
	Sphingidae	Sphinx moth	*Agrius* sp.	Occasional	Occasional	N	18:00-21:00		
Coleoptera	Chrysomelidae	Leaf beetle	*Colasposoma* sp.	Occasional	Occasional	P	7:30-09:00 hrs	06	0.367
	Coccinellidae	Ladybird beetle	*Coccinella transversalis F. and C. sexmaculata*	Occasional	Occasional	P	08:00-10:00 hrs		
	Meloidae	Blister beetle	*Mylabris pustulataThun.*	Occasional	Occasional	P	07:00-09:00 hrs		
	Scarabidae	Scarab beetle	*Popillia schizonycha* A.	Occasional	Occasional	P	07:00-09:00 hrs		
	Curculionidae	Ash weevil	*Myllocerus viridanus* F.	Occasional	Occasional	P	07:30-10:00 hrs		
	Nitidulidae	Nitulid beetle	*Carpophilus* sp.	Regular	Regular	P	02:00-12:00 hrs		

P = Pollen, N = Nectar, P+N = Pollen and Nectar

Lepidopteran visitors were occasional, with the blue tiger butterfly (*Tirumala sp.*) active from 07:00–08:00 hrs and the nocturnal sphinx moth (*Agrius sp.*) active from 18:00–21:00 hrs. Their contribution as supplementary pollinators may support cross-pollination during periods of low bee activity. Coleopteran species exhibited early-morning foraging behavior. *Colasposoma sp.* (07:30–09:00 hrs), ladybird beetles (*Coccinella transversalis* F. and *C. sexmaculata*, 08:00–10:00 hrs), blister beetle (*Mylabris pustulata*, 07:00–09:00 hrs), scarab beetle (*Popillia schizonycha*, 07:00–09:00 hrs), and ash weevil (*Myllocerus viridanus*, 07:30–10:00 hrs) were occasional visitors, primarily collecting pollen. *Carpophilus sp.* (Nitidulidae) was a unique regular visitor from 02:00–12:00 hrs, likely exploiting flowers before peak bee activity. The early-morning activity of beetles suggests an adaptive strategy to reduce competition and predation risk.

Overall, *Apis* species dominated flower visitation, with A. cerana visiting the highest mean number of flowers, followed by *A. florea, A. mellifera,* and *A. dorsata*. Temporal niche partitioning among bees and supplementary visitation by beetles and moths likely enhance cross-pollination and fruit set in both dragon fruit types. These findings indicate a complex pollination network in dragon fruit, emphasizing the importance of conserving both *Apis* and non-*Apis* insect populations for maintaining pollination services.

These findings are consistent with Reddy *et al.* (2025) who reported fourteen floral visitor species on *Hylocereus undatus* and *H. polyrhizus*, dominated by Hymenoptera with four honey bees (*Apis dorsata*, *A. cerana*, *A. mellifera*, and *A. florea*) as regular diurnal visitors. *Ropalidia marginata* was an occasional visitor, while *Camponotus compressus* and *Tapinoma melanocephala* were regular ant visitors. *Tirumala* sp. was an occasional lepidopteran visitor, and among Coleoptera, five species were occasional visitors, whereas *Carpophilus* sp. was the only nocturnal visitor. Overall, *A. mellifera* was the most abundant species, followed by *A. cerana*, *A. florea*, and *A. dorsata*.

Contrasting with the present study, earlier research conducted in the native habitats of these cacti (Muniz *et al.*, 2019; Locatelli *et al.*, 1997; Rocha *et al.*, 2019) reported that species of *Pilosocereus* are pollinated by bats and moths. However, no such non-insect pollinators were observed in the current investigation, supporting the findings of Sajjanar and Eswarappa (2015), Moulya *et al.* (2023) and Reddy *et al.* (2025). Although bats are recognized as natural pollinators of pitaya, Valiente-Banuet *et al.* (2007) reported that they were not observed visiting the flowers of either of the two pitaya species studied. Pitaya flowers exhibit traits typical of chiropterophily, including large, widely open nocturnal flowers with white or pale coloration, strong night-time fragrance, abundant pollen and/or nectar, and a short lifespan, opening at night and closing early the following morning (Rech *et al.*, 2014). In the absence of nectar production in the studied species, bat visitation is unlikely, unless bats were deceived by the floral cues or visited to feed on pollen. Valiente-Banuet *et al.* (2007) suggested that bats observed visiting pitaya flowers in Mexico were likely pollenivorous, feeding primarily on pollen rather than nectar.

Conclusion

The flowering period of *H. undatus* and *H. polyrhizus* supports a diverse assemblage of floral visitors. Regular visitation by *Apis* species, particularly *A. cerana*, ensures efficient pollen and nectar transfer, making them the principal pollinators. Occasional visitors from Lepidoptera and Coleoptera provide supplementary pollination, with temporal niche partitioning minimizing competition. Conservation of floral visitor diversity, especially *Apis* species, is crucial for maximizing fruit set and yield. Management practices promoting habitat diversity and minimal pesticide use are recommended to sustain effective pollinator populations in dragon fruit orchards.

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Author contributions

S.G. Biradar – Experimentation and data collection. Writing original draft preparation. S.B. Kharbade – Conceptualisation; Experimentation, Supervision, Data curation; Formal analysis and Review the manuscript; S.T. Aghav–Conceptualisation; Experimentation, Supervision; J.K. Dhemre – Conceptualisation; Experimentation, Supervision; B.M. Bhalerao – Conceptualisation; Experimentation, Supervision; M. R. Patil – Conceptualisation; Experimentation, Supervision and Statistical Analysis.

All authors read and approved the manuscript.

Conflict of Interest

There is no potential conflict of interest was reported by the author(s).

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