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Diversity of pollinators in coriander (*Coriandrum sativum* L.)

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Abstract
Coriander (*Coriandrum sativum* L.) is an important seed spice crop dependent on diverse insect pollinators for effective pollination and seed set. The present investigation on the diversity and abundance of insect pollinators was carried out during summer 2025 at the Research Farm, Department of Entomology, College of Agriculture, Latur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra. Observations were recorded at two-hour intervals from 06:00 to 18:00 hr on the coriander variety Wai Dhanna under field conditions. A total of 28 insect species belonging to six orders (*viz.*, Hymenoptera, Diptera, Coleoptera, Lepidoptera, Hemiptera, and Odonata) were recorded visiting coriander flowers. Hymenoptera emerged as the most dominant order (85.55%) represented by eight species, including *Apis florea*, stingless bee, *Apis dorsata*, *Vespa tropica*, *Polistes* sp., *Eurytoma* sp., *Hylaeus* sp., and *Lasioglossum* sp. Among these, *A. florea* and stingless bees were the most abundant, together accounting for 81.2% of total pollinator visits. Diptera (4.73%), Coleoptera (3.92%), Lepidoptera (2.69%), Hemiptera (2.29%), and Odonata (0.82%) contributed as secondary or occasional visitors. Shannon-Wiener diversity (H), species evenness (J) and Margalef's species richness (Dmg) indices indicated that Stingless bees (H = 0.364; J = 0.109) and *A. florea* (H = 0.348; J = 0.104) were the most dominant and uniform contributors. Moderate diversity and evenness were observed in species such as *Hylaeus* sp., *Episyrphus balteatus*, *Eupeodes fumipennis*, and *Musca domestica*, while *Apis dorsata* exhibited minimal contribution (H = 0.006; J = 0.002). Margalef's richness index revealed highest species richness in Hymenoptera (7.859), followed by Coleoptera (5.859) and Lepidoptera (4.859), with Diptera and Hemiptera showing moderate richness (3.859 each) and Odonata the least (0.859). These findings confirmed the pivotal role of Hymenopteran bees, particularly *A. florea* and Stingless bees, in coriander pollination under Latur conditions. The predominance of Hymenoptera highlights their ecological significance, adaptability to coriander floral traits, and essential contribution to pollination success, yield improvement, and maintenance of agroecosystem stability.

Keywords: *Coriandrum sativum*, pollinator diversity, hymenoptera, visitation rate, diversity indices, abundance, shannon-wiener index, Margalef's richness, stingless bees, *Apis florea*

Introduction
Since ancient times, Indian spices and spicy cuisine have been renowned across the world. Traders from various regions have long visited the Indian subcontinent in search of these valuable commodities. Out of 109 spices known globally, 75 are cultivated in India, including fourteen major seed spices (*viz.*, cumin, coriander, fennel, fenugreek, ajwain, sauf, dill, nigella, pepper, cardamom, clove, cinnamon, nutmeg and tejpatta) grown commercially throughout the country. India is among the world's largest producers, consumers and exporters of seed spices owing to its diverse soils and climatic conditions, which are ideal for spice cultivation. Most of these crops thrive in semi-arid and arid zones characterized by dry or cool weather conditions (Maragoor *et al.*, 2022) [14]. In 2023, the global area under spice cultivation was 23.47 million hectares, with an average productivity of 1,205.9 kg/ha, leading to a total production of 2.83 million metric tonnes (MMT) (FAO, 2023) [7]. Coriander (*Coriandrum sativum* L.) is an important tropical spice crop belonging to the family Apiaceae (Umbelliferae). The genus *Coriandrum* comprises both the cultivated species *C. sativum* and the wild species *C. tordylium*. In ancient Sanskrit literature, it is referred to as dhanayaka or kusthumbari. It is a glabrous, aromatic, annual, erect herb cultivated for its leaves and seeds either in summer or winter. Owing to its rich content of aromatic compounds and essential oils with antibacterial, antifungal, and antioxidant properties, coriander has a long history of use as a culinary and medicinal herb (Wierdak, 2013; Mandal

and Mandal, 2015) [29, 13]. The major coriander-growing states include Madhya Pradesh, Rajasthan, Gujarat, Odisha, Assam, West Bengal, Maharashtra, Karnataka, Andhra Pradesh, Jharkhand, and Arunachal Pradesh (Anon., 2021) [1]. Coriander bears both staminate and hermaphrodite flowers, the latter being fully protandrous with anthers maturing before the stigma becomes receptive (Nemeth and Szekely, 2000) [18] and thus requiring pollinators for effective pollen transfer. Floral characteristics such as exposed nectar, abundant pollen, zygomorphic flowers, and compact umbels enhance its attractiveness to pollinators (Koul *et al.*, 1989; Diederichsen, 1996) [9, 6]. When stigmas become receptive, increased nectar secretion further stimulates pollinator activity (Free, 1993) [8]. Pollination in coriander is largely entomophilous and essential for successful seed set. Studies have shown that lack of pollinator activity can reduce yield by 50-70% (Thakur, 2022; Ranjitha *et al.*, 2023) [25, 26, 22]. Approximately 11-14 insect species are recognized as important pollinators of coriander, with *Apis* spp. being the most dominant (Thakur *et al.*, 2022) [25, 26]. Insect-mediated pollination plays a pivotal role in the crop's reproductive success, contributing not only to higher yield but also to improved seed quality characterized by uniform maturation and early harvest. Given this dependency, it is essential to generate information on the diversity and abundance of naturally occurring pollinators, as these directly influence both yield and seed quality. The present investigation was undertaken to document the diversity and abundance of insect pollinators associated with coriander (*Coriandrum sativum* L.).

Materials and Methods

The study was conducted during Summer, 2025 at the Research Farm, Department of Entomology, College of Agriculture, Latur, Maharashtra, to assess the diversity and abundance of pollinators visiting coriander flowers.

Materials

Coriander seeds of variety Wai dhana were procured from the local market of Latur. Essential equipment included a measuring tape, a stopwatch for timing pollinator visits, an insect net for capturing insect visitors and a camera for photographic documentation. Additional materials such as record books, marker pens and tags were used for field identification and data recording.

Experimental field and design

The experiment was conducted in a 10 m × 10 m plot maintained with all recommended agronomic practices for coriander cultivation. The crop was sown in January 2025, using the variety Wai dhana with a spacing of 30 cm × 10 cm. Fertilizers were applied at the rate of 100:50:50 kg NPK per hectare. The experiment was arranged in a non-replicated design under field conditions.

Observations Recorded

To study the diversity and abundance of pollinators, five random spots of 1 m × 1 m were selected within the 10 m × 10 m coriander plot. Observations on insect visitors were recorded during the flowering period at two-hour intervals throughout the day—06:00-08:00 hr, 08:00-10:00 hr, 10:00-12:00 hr, 12:00-14:00 hr, 14:00-16:00 hr, and 16:00-18:00 hr. At each interval, the number of insect visitors was recorded for five minutes per spot. The data were expressed as the mean number of pollinators per m² per five minutes.

Statistical analysis

Data on diversity and abundance of pollinators were subjected to calculate species diversity index, which was determined using the Shannon-Wiener diversity index, species evenness index and Margalef's species richness index formulae as outlined by Magurran (1988) [12].

Results and Discussion

Diversity of the pollinators

The data presented in Table. 1 revealed that coriander flowers were visited by twenty-eight species belonging to six orders *viz*., Hymenoptera, Diptera, Coleoptera, Lepidoptera, Hemiptera, and Odonata. Hymenopteran pollinators comprised eight species, *viz*., *Apis florea*, Stingless bee, *Apis dorsata* from Apidae; *Vespa tropica* and *Polistes* sp. from Vespidae; *Eurytoma* sp. from Eurytomidae; *Hylaeus* sp. from Colletidae; and *Lasioglossum* sp. from Halictidae. Dipteran visitors included four species, *viz*., *Musca domestica* (Muscidae), *Eristalinus arvorum*, *Episyrphus balteatus* and *Eupeodes fumipennis* (Syrphidae). Six coleopteran species belonging to two families were recorded, of which five species, *viz*., *Coccinella transversalis*, *Brumoides suturalis*, *Cheilomenes sexmaculata*, *Coccinella septempunctata* and *Adalia bipunctata* belonged to Coccinellidae and one species, *Aulacophora foveicollis*, belonged to Chrysomelidae. Lepidopteran foragers were represented by five families, *viz*., Crambidae, Scythrididae, Erebidae, Nymphalidae and Papilionidae, with one species each: *Spoladea recurvalis*, *Eretmocera impactella*, *Amata bicincta*, *Danaus chrysippus* and *Papilio demoleus*. Hemipteran visitors included four species: *Dolycoris baccarum* (Pentatomidae), *Gonocerus acuteangulatus* (Coreidae), *Geocoris* sp. (Geocoridae), and *Closterotomus norvegicus* (Miridae). One odonatan species, *Ischnura senegalensis* (Coenagrionidae), was also recorded. Percentage-wise, Hymenoptera (85.55%) emerged as the dominant insect order, followed by Diptera (4.73%), Coleoptera (3.92%), Lepidoptera (2.69%), Hemiptera (2.29%), and Odonata (0.82%).

The findings of the present study are consistent with earlier reports on pollinator diversity in coriander and related crops. Priyadarshni *et al.* (2025) [21] recorded 19 insect species from six orders in mustard, with Hymenoptera as the predominant group (59.38%) followed by Diptera (23.88%). Similarly, Nagulapalli and Jha (2024) [17] observed 25 insect species on coriander and black cumin, with Hymenoptera, Diptera, and Lepidoptera as major floral visitors. Uddin *et al.* (2024) [27] reported Hymenoptera dominance (50.88%) in sunflower, while Diptera was more abundant (45.71%) in marigold. Kuruva *et al.* (2024) [10] documented ten pollinator species in sunflower, of which seven belonged to Hymenoptera. Studies specifically on coriander also revealed comparable patterns. Ranjitha *et al.* (2023) [22] reported pollinators from five families of four insect orders, whereas Maragoor *et al.* (2022) [14] identified 17 species with Hymenoptera dominance. Vandhi *et al.* (2022) [28] observed Hymenoptera as the most frequent visitors (40%), followed by Diptera and Lepidoptera (16% each). Thakur (2022) [25, 26] reported Hymenoptera dominance (55.26%) in coriander and More *et al.* (2022) [16] in safflower recorded 12 species with Hymenoptera as the dominant group

(41.66%). Meena *et al.* (2021) [15] in ajwain recorded 34 species with Hymenoptera as dominant (13 species), followed by Diptera (8 species). Rasool (2020) [23] recorded 31 species in coriander, while Paikara and Painkara (2020) [19] reported 88.17% contribution by Hymenoptera. Zinzuvadiya and Ghetiya (2020) [30] confirmed Hymenoptera dominance in South Gujarat.

Table 1: Diversity of pollinators in coriander.

Sr. No	Order	Family	Common Name	Scientific Name
1.	Hymenoptera	Apidae	Little bee	*Apis florea*
2.			Stingless bee	*Trigona/Melipona* sp.
3.			Rock bee	*Apis dorsata*
4.		Vespidae	Greater Banded Hornet	*vespa tropica*
5.			Fine-backed red paper wasp	*polistes* sp.
6.		Eurytomidae	chalcid wasp	*Eurytoma* sp.
7.		Colletidae	Masked or Yellow-faced bee	*Hylaeus* sp.
8.		Halictidae	Sweat bee	*Lasioglossum* sp.
9.	Diptera	Muscidae	Housefly	*Musca domestica*
10.		Syrphidae	Hoverfly	*Eristalinus arvorum*
11.			Marmalade Hoverfly	*Episyrphus balteatus*
12.			Western aphideater	*Eupeodes fumipennis*
13.	Coleoptera	Coccinellidae	Transverse lady beetle	*Coccinella transversalis*
14.			Three-striped lady beetle	*Brumoides suturalis*
15.			Six-spotted Zigzag ladybird beetle	*Cheilomenes sexmaculata*
16.			Seven-spot ladybird beetle	*Coccinella septempunctata*
17.			Two-spotted ladybird beetle	*Adalia bipunctata*
18.		Chrysomelidae	Red pumpkin beetle	*Aulacophora foveicollis*
19.	Lepidoptera	Crambidae	Beet webworm moth	*spoladea recurvalis*
20.		Scythrididae	Eretmocera	*Eretmocera impactella*
21.		Erebidae	Handmaiden moth	*Amata bicincta*
22.		Nymphalidae	Plain tiger butterfly	*Danaus chrysippus*
23.		Papilionidae	Lemon butterfly	*Papilio demoleus*
24.	Hemiptera	Pentatomidae	Sloe bug/Hairy shield bug	*Dolycoris baccarum*
25.		Coreidae	Box bug/Dock bug	*Gonocerus acuteangulatus*
26.		Geocoridae	Big eyed bug	*Geocoris* sp.
27.		Miridae	Potato bug/mirid/capsid	*Closterotomus norvegicus*
28.	Odonata	Coenagrionidae	Common bluetail	*Ischnura senegalensis*

The recurring pattern across multiple studies underscores the importance of Hymenoptera as key pollinators, with Diptera and Coleoptera acting as secondary contributors. Lepidopteran and Hemipteran insects were occasional visitors. The present study corroborates these trends, highlighting the significant role of Hymenoptera, Diptera, and Coleoptera in coriander pollination, thereby contributing to enhanced reproductive success and yield of the crop.

Diversity indices of pollinators of coriander

The Shannon-Wiener diversity index (H), species evenness (J) and Margalef's species richness index (D_{mg}) for pollinators of coriander are presented in Tables 2 and 3. The results revealed that the highest Shannon-Wiener diversity index and Margalef's species richness index was recorded in Stingless bees (0.364 and 0.109 respectively) followed by *Apis florea* (0.348 and 0.104 respectively), indicating their dominant and stable contribution to the pollinator community. Moderate Shannon-Wiener diversity index and Margalef's species richness index values were observed in *Hylaeus sp.* (0.062 and 0.019 respectively), *Episyrphus balteatus* (0.059 and 0.018 respectively), *Eupeodes fumipennis* (0.054 and 0.016 respectively), *Musca domestica* (0.054 and 0.016 respectively), *Coccinella septempunctata* (0.045 and 0.014 respectively), *Polistes* sp. (0.042 and 0.013 respectively) and *Eristalinus arvorum* (0.042 and 0.013 respectively), *Cheilomenes sexmaculata* (0.042 and 0.013 respectively), *Ischnura senegalensis* (0.039 and 0.012 respectively), *Lasioglossum sp.* (0.039 and 0.012 respectively), *Coccinella transversalis* (0.039 and 0.012 respectively), and *Amata bicincta* (0.036 and 0.011 respectively). *Papilio demoleus* (0.033 and 0.010 respectively), *Closterotomus norvegicus* (0.033 and 0.010 respectively), *Dolycoris baccarum* (0.033 and 0.010 respectively), *Vespa tropica* (0.033 and 0.010 respectively), *Danaus chrysippus* (0.030 and 0.009 respectively), *Gonocerus acuteangulatus* (0.030 and 0.009 respectively), *Eurytoma sp.* (0.026 and 0.008 respectively), *Brumoides suturalis* (0.026 and 0.008 respectively), *Eretmocera impactella* (0.026 and 0.008 respectively), *Adalia bipunctata* (0.026 and 0.008 respectively), *Geocoris sp.* (0.022 and 0.007 respectively), *Aulacophora foveicollis* (0.015 and 0.004 respectively) and *Spoladea recurvalis* (0.015 and 0.004 respectively) exhibited low Shanon-Weiner index and Margalef's species richness index values. The lowest Shanon-Weiner index and Margalef's species richness index was recorded in *Apis dorsata* (0.006 and 0.002 respectively), showing its negligible contribution to diversity due to very few individuals. These findings indicate that Stingless bees and *A. florea* dominated both in terms of diversity and uniformity, while several other species occurred with limited and irregular presence across the flowering period. Margalef's species richness index

further supported this trend, where Hymenoptera exhibited the highest richness (7.859), followed by Coleoptera (5.859) and Lepidoptera (4.859), suggesting their stronger representation in the coriander ecosystem. Diptera and Hemiptera recorded moderate richness (3.859 each), while Odonata displayed the least (0.859), highlighting their minimal contribution to pollinator diversity. The predominance of Hymenoptera thus reflects their ecological significance and adaptability to coriander floral traits.

When compared with earlier studies, the present species-level Shannon-Wiener index values were relatively lower, which is consistent with expectations since diversity index values tend to increase with overall species abundance and sampling extent. Priyadarshni *et al.* (2025) [21] documented Shanon-Weiner index of 2.77 and evenness of 0.94 for insect pollinators of mustard, while Nagulapalli and Jha (2024) [17] reported 2.20 Shanon-Weiner index and 0.68 evenness for the New Gangetic alluvial zone in coriander, and Uddin *et al.* (2024) [27] observed Shanon-Weiner index of 2.09 and 2.42 (in sunflower and marigold respectively) and species evenness index of 0.84 and 0.92 (in sunflower and marigold respectively). Thakur *et al.* (2022) [25, 26] also recorded Shanon-Weiner index of 2.29 in pollinator communities of coriander, whereas Vandhi *et al.* (2022) [28] reported Shanon-Weiner index values ranging between 1.94 to 2.78 in coriander. Rasool (2020) [23] noted Shanon-Weiner index and species evenness values ranging from 0.054 to 0.193 and 0.016 to 0.056 respectively across diverse dipteran and hymenopteran pollinators, which are comparable to the present species-wise results in coriander. Similarly, Belamkar and Jadesh (2014) [2] found Shanon-Weiner index values near 1.0 and evenness of 0.928 for dipteran and hymenopteran flower visitors in Gulbarga. Bhowmik *et al.* (2017) [21] in coriander reported Shanon-Weiner index values of 1.195 and 1.085 for Hymenoptera and Diptera, respectively. Maragoor *et al.* (2022) [14] reported species evenness range of 0.48-0.87 in coriander and Devi *et al.* (2016) [5] recorded 0.30-0.72. Similarly, Kyerematen *et al.* (2014) [11] reported high species evenness values of 0.977. Stirling and Wilsey (2001) [24] documented species evenness ranging from 0.58 to 0.99 across pollinator communities. Margalef's richness estimates in this study correspond with previous findings of Thakur *et al.* (2022) [25, 26] (2.31 in mustard) and Paray *et al.* (2014) [20] (2.00 for Diptera in apple orchards), though higher than Rasool (2020) [23] who reported 3.41 for Hymenoptera in coriander. Deepa (2021) [4] reported Margalef's richness values ranging between 0 and 3.21 across various time interval in pumpkin. Such variations can be attributed to differences in crop phenology, habitat conditions and sampling intensity. Overall, the high richness and diversity of Hymenopteran species reaffirm their pivotal role in maintaining pollinator diversity and ecosystem stability in coriander agroecosystems.

Table 2: Shanon-Weiner diversity index (H) and Species evenness (J) of pollinators in coriander.

Pollinators	N_i	N	H	J
Apis florea	607	1225	0.348	0.104
Stingless bee	387	1225	0.364	0.109
Apis dorsata	1	1225	0.006	0.002
vespa tropica	8	1225	0.033	0.01
polistes sp.	11	1225	0.042	0.013
Eurytoma sp.	6	1225	0.026	0.008
Hylaeus sp.	18	1225	0.062	0.019
Lasioglossum sp.	10	1225	0.039	0.012
Musca domestica	15	1225	0.054	0.016
Eristalinus arvorum	11	1225	0.042	0.013
Episyrphus balteatus	17	1225	0.059	0.018
Eupeodes fumipennis	15	1225	0.054	0.016
Coccinella transversalis	10	1225	0.039	0.012
Brumoides suturalis	6	1225	0.026	0.008
Cheilomenes sexmaculata	11	1225	0.042	0.013
Coccinella septempunctata	12	1225	0.045	0.014
Adalia bipunctata	6	1225	0.026	0.008
Aulacophora foveicollis	3	1225	0.015	0.004
spoladea recurvalis	3	1225	0.015	0.004
Eretmocera impactella	6	1225	0.026	0.008
Amata bicincta	9	1225	0.036	0.011
Danaus chrysippus	7	1225	0.03	0.009
Papilio demoleus	8	1225	0.033	0.01
Dolycoris baccarum	8	1225	0.033	0.01
Gonocerus acuteangulatus	7	1225	0.03	0.009
Geocoris sp.	5	1225	0.022	0.007
Closterotomus norvegicus	8	1225	0.033	0.01
Ischnura senegalensis	10	1225	0.039	0.012

N_i = No. of individuals of a species, N = Total no. of pollinators visiting the crop, H = Shanon-Weiner diversity index and J = Species evenness.

Table 3: Margalef's Species richness Index (D_{mg}) of pollinators on coriander.

Order	No. of species	Total individuals	D_{mg}
Hymenoptera	8	1225	7.859
Diptera	4	1225	3.859
Coleoptera	6	1225	5.859
Lepidoptera	5	1225	4.859
Hemiptera	4	1225	3.859
Odonata	1	1225	0.859

Conclusions

Overall, Hymenoptera were the most dominant pollinators of coriander, with *Apis florea* and Stingless bees contributing most to diversity, evenness, and richness. Diptera and Coleoptera acted as secondary contributors due to their moderate abundance, while Lepidoptera, Hemiptera, and Odonata were poorly represented. These results indicate that coriander flowers primarily attract hymenopteran pollinators, which play a crucial role in effective pollination and maintaining ecosystem functioning.

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