

COMMUNITY STRUCTURE AND ECOLOGICAL DOMINANCE OF HYMENOPTERAN POLLINATORS IN MULTI-CROP AGROECOSYSTEMS OF WESTERN MAHARASHTRA

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Abstract

The diversity of hymenopteran insects directly influences pollination efficiency, ecosystem resilience, and agricultural productivity. The present investigation evaluated the community composition, dominance patterns, and spatial distribution of hymenopteran pollinators associated with major cultivated crops including sunflower, niger, mustard, rice, and soybean in Western Maharashtra, India. A total of 2,788 hymenopteran individuals belonging to 19 species under seven families were documented from sixteen agricultural sites. Family Apidae emerged as the overwhelmingly dominant group contributing 72.27% of the total abundance, followed by Ichneumonidae (7.39%), Vespidae (7.35%), Mutillidae (5.81%), Sphecidae (3.05%), Colletidae (2.15%), and Chrycidae (1.97%). Species richness was highest in Apidae with six species, whereas Vespidae contained five species and Ichneumonidae three species. The remaining families showed comparatively lower species representation. Spatial assessment demonstrated considerable variation among study sites, with Site F recording maximum hymenopteran abundance (219 individuals), while Site N showed the lowest abundance (135 individuals). Social bees including the Western honey bee, giant honey bee, and Indian honey bee constituted the principal floral visitors throughout the study period, indicating their ecological dominance within the agroecosystem. Predatory and parasitoid wasps such as potter wasps, mud daubers, and ichneumon wasps also contributed significantly to floral visitation and biological regulation of insect pests. The study reveals that diversified cropping systems support a structurally complex hymenopteran community and emphasizes the importance of pollinator-friendly agricultural practices for maintaining ecosystem services in tropical agro-landscapes.

Keywords: Hymenoptera, Pollinator diversity, Agroecosystem ecology, Floral visitors, Species richness, Agricultural biodiversity

Introduction

Pollination is one of the most essential ecological processes sustaining agricultural productivity, ecosystem stability, and biodiversity conservation across natural and cultivated landscapes. Insect-mediated pollination significantly contributes to seed formation, fruit development, genetic recombination, and maintenance of plant diversity in both wild and agricultural ecosystems (Kevan and Baker, 1983). Among all insect pollinators, members of the order Hymenoptera are regarded as the most efficient and evolutionarily advanced pollinating agents due to their specialized body structures, floral fidelity, complex social behaviour, and efficient pollen-carrying mechanisms (Michener, 2007; Jadhav 2024). Bees, wasps, and related hymenopterans play a critical ecological role in maintaining the productivity of economically important crops and sustaining trophic interactions within agroecosystems. The Western Ghats region of Maharashtra, particularly the Junnar tehsil of Pune district, represents a biologically rich agroecological zone characterized by heterogeneous agricultural landscapes, semi-evergreen hill ecosystems, seasonal flowering vegetation, and diverse cropping systems. Junnar lies along the northern Western Ghats, a globally recognized biodiversity hotspot, where tropical climatic conditions and monsoon-driven vegetation dynamics provide suitable habitats for a wide range of pollinating insects (Myers et al., 2000; Jadhav 2024). Agricultural fields in this region commonly cultivate sunflower (*Helianthus annuus*), mustard (*Brassica juncea*), soybean (*Glycine max*), niger (*Guizotia abyssinica*), rice (*Oryza sativa*), pomegranate, and various horticultural crops that collectively

provide continuous nectar and pollen resources for hymenopteran pollinators throughout different seasons. The mosaic pattern of cultivated land interspersed with grasslands, scrub forests, riverine vegetation, and forest fragments creates highly favourable microhabitats for both social and solitary hymenopteran insects. Among the different pollinator groups, family Apidae forms the ecological backbone of pollination systems in tropical agricultural ecosystems. Species such as the giant honey bee (*Apis dorsata*), Indian honey bee (*Apis cerana indica*), Western honey bee (*Apis mellifera*), and dwarf honey bee (*Apis florea*) are highly efficient pollinators because of their large colony size, extensive foraging range, and remarkable communication behaviour (Free, 1993; Nikam and Jawale 2010). Similarly, solitary bees such as carpenter bees (*Xylocopa* spp.) and blue-banded bees (*Amegilla* spp.) are recognized as effective cross-pollinators in several flowering crops due to their strong flight activity and pollen collection efficiency. In addition to bees, predatory and parasitoid wasps belonging to families Vespidae, Sphecidae, Ichneumonidae, Chrysididae, and Mutillidae contribute substantially to agroecosystem functioning through biological regulation of crop pests and maintenance of ecological balance (Gadagkar, 1991). Previous studies conducted in the Western Ghats have demonstrated that pollinator diversity is strongly influenced by habitat heterogeneity, floral abundance, climatic conditions, and agricultural management practices (Waykar et al., 2014; Jawale 2020). However, rapid agricultural intensification, indiscriminate pesticide application, habitat fragmentation, climate change, and loss of natural vegetation are causing serious declines in hymenopteran diversity worldwide, ultimately affecting pollination services, crop productivity, and ecosystem resilience (Kearns et al., 1998). In regions such as Junnar, where agriculture forms the primary livelihood and pollinator-dependent crops occupy substantial cultivated area, understanding the diversity and ecological distribution of hymenopteran pollinators becomes increasingly important for sustainable agricultural management and biodiversity conservation. Despite the ecological significance of pollinating insects in the northern Western Ghats, comprehensive studies focusing on hymenopteran diversity associated with agricultural ecosystems of Junnar region remain comparatively limited. Therefore, the present investigation was undertaken to document the diversity, abundance, family composition, and ecological distribution of hymenopteran pollinators associated with major agricultural crops cultivated in the Junnar region of Western Maharashtra, India.

Materials and Methods

The present investigation was carried out in selected agricultural agroecosystems of Western Maharashtra, India, a region forming part of the northern Western Ghats landscape characterized by tropical climatic conditions, seasonal rainfall, and diverse agricultural practices. Sixteen sampling sites designated from A to P were selected based on crop diversity, floral abundance, and observed pollinator activity. The study area consisted predominantly of mixed agricultural fields cultivating economically important crops such as sunflower (*Helianthus annuus*), niger (*Guizotia abyssinica*), mustard (*Brassica juncea*), soybean (*Glycine max*), and rice (*Oryza sativa*). These crops provide abundant nectar and pollen resources that support diverse assemblages of hymenopteran pollinators during the flowering season. Field surveys and insect sampling were conducted systematically throughout the flowering period of cultivated crops during peak foraging hours, generally between 0800 h and 1600 h, when pollinator activity was maximum. Hymenopteran insects visiting flowers were collected using sweep nets, aerial hand nets, and manual hand-picking methods following standard entomological sampling techniques described by Borror et al. (2005). Special attention was given to active floral visitors involved in pollen and nectar foraging. Collected specimens were preserved and transported to the laboratory for taxonomic examination and identification. Identification of hymenopteran insects was carried out up to species level using standard taxonomic keys, diagnostic morphological characters, and available regional faunal literature (Michener, 2007; Goulet, 1993). The identified specimens were categorized into seven families namely Apidae, Vespidae, Sphecidae, Colletidae, Ichneumonidae, Chrysididae, and Mutillidae. Site-wise and family-wise abundance of hymenopteran insects was calculated to

assess diversity patterns and community structure within the agroecosystem. Relative abundance percentages were further estimated to determine dominance patterns among pollinator families. The generated data were organized into tables and graphical representations for comparative ecological interpretation. Similar methodologies have been widely adopted in pollinator diversity studies conducted across agricultural landscapes and forest-agriculture interfaces of the Western Ghats region (Kunte, 2000; Kannagi et al., 2013; Jawale 2020).

Results and Discussion

Diversity and Composition of Hymenopteran Pollinators

The present investigation documented a total of 19 hymenopteran species belonging to seven different families from the selected agricultural agroecosystems of Western Maharashtra. Among the recorded families, Apidae exhibited the highest species richness with six species, followed by Vespidae comprising five species. Family Ichneumonidae was represented by three species, while Sphecidae included two species. The remaining families, namely Colletidae, Chrysididae, and Mutillidae, were represented by a single species each. The recorded hymenopteran fauna included giant honey bees (*Apis dorsata*), Western honey bees (*Apis mellifera*), Indian honey bees (*Apis cerana indica*), blue-banded bees (*Amegilla* sp.), carpenter bees (*Xylocopa* sp.), potter wasps, paper wasps, mud daubers, ichneumon wasps, cuckoo wasps, and velvet ants. All recorded species were observed actively visiting the flowers of cultivated crops such as sunflower, mustard, soybean, niger, and rice during the flowering season. The higher diversity of hymenopteran insects observed in the present study may be associated with the heterogeneous cropping pattern and availability of floral resources throughout the agricultural landscape. Similar observations have been reported from agroecosystems and semi-natural habitats of the Western Ghats, where diverse flowering vegetation supports rich assemblages of bees and wasps (Waykar and Baviskar 2016). Studies conducted in the northern Western Ghats of Maharashtra have also reported dominance of Apidae and Vespidae in cultivated and forest-edge habitats due to favourable climatic conditions and continuous floral availability (Kunte, 2000; Jawale 2020).

Family-wise Relative Abundance

Analysis of family-wise abundance demonstrated a clear dominance of family Apidae, which contributed 72.27% of the total hymenopteran individuals recorded during the study (Table 1). Ichneumonidae contributed 7.39% of the total abundance, followed closely by Vespidae with 7.35%. Mutillidae accounted for 5.81%, while Sphecidae represented 3.05% of the total population. Comparatively lower abundance was recorded for Colletidae (2.15%) and Chrysididae (1.97%) (Fig. 1, 3). The predominance of Apidae within the agroecosystem indicates the ecological significance of social bees as major pollinating agents in tropical agricultural habitats. Honey bees possess efficient communication systems, colony organization, and extensive foraging ranges that enable them to exploit nectar and pollen resources effectively. The abundance of flowering crops such as sunflower and mustard may have particularly favoured bee visitation during the study period. Similar dominance of Apidae has been documented from agricultural ecosystems adjoining the Western Ghats, where *Apis dorsata*, *Apis cerana*, and *Apis mellifera* constitute major floral visitors of cultivated crops (Kannagi et al., 2013; Singh et al., 2024). The comparatively lower abundance of Chrysididae and Colletidae may be related to their solitary behaviour and specialized nesting ecology. Previous studies from the Western Ghats region have similarly indicated that solitary hymenopterans generally occur in lower abundance compared to eusocial bees because of their limited colony size and restricted foraging activity (Avhad et al., 2025).

Ecological Significance of Dominant Families

Members of family Apidae were observed actively foraging on all cultivated crops throughout the investigation period. Species such as *Apis mellifera* and *Apis dorsata* showed continuous floral visitation and represented the most efficient pollinating agents recorded during the study. Their repeated visitation to flowers

indicates their major contribution toward pollen transfer and crop productivity. In tropical agroecosystems, honey bees are regarded as keystone pollinators due to their ability to maintain pollination stability across diverse crop species. Family Vespidae emerged as the second most species-rich group and included potter wasps and paper wasps. These wasps contribute significantly to agroecosystem functioning not only through pollination but also through predation of harmful insect pests. Similarly, mud daubers belonging to family Sphecidae were frequently observed visiting flowers while also functioning as natural biological control agents. The dual ecological role of predatory wasps in pollination and pest suppression enhances ecological balance within agricultural landscapes. Ichneumonid wasps recorded during the study are ecologically important parasitoids capable of naturally regulating herbivorous insect populations. Their presence indicates the existence of healthy trophic interactions within the agroecosystem. Chrysididae and Mutillidae, although comparatively less abundant, contribute to ecosystem complexity by functioning as parasitoids and kleptoparasites. Similar ecological roles of hymenopteran parasitoids and predatory wasps have been reported from forest-agriculture interfaces of the Western Ghats biodiversity hotspot (Kadam et al., 2021; Gadagkar, 1991).

Spatial Distribution of Hymenopteran Pollinators

Considerable variation in hymenopteran abundance was observed among the sixteen study sites. Site F recorded the maximum abundance with 219 individuals, followed by Site D with 216 individuals and Site E with 203 individuals (Fig.2). In contrast, Site N showed the lowest abundance with 135 individuals. Such spatial variation in pollinator abundance may be associated with differences in flowering intensity, crop diversity, pesticide exposure, microclimatic conditions, and surrounding vegetation structure. Sites characterized by mixed cropping systems and abundant flowering resources supported comparatively higher hymenopteran diversity and abundance. The presence of semi-natural vegetation around agricultural fields may also have provided suitable nesting and foraging habitats for pollinators. Similar spatial heterogeneity in pollinator assemblages has been reported from agricultural landscapes adjoining the Western Ghats, where habitat complexity and floral diversity strongly influence hymenopteran distribution patterns (Waykar et al., 2014).

Dominant Pollinating Species

Among the recorded species, the Western honey bee (*Apis mellifera*) emerged as the most dominant pollinating agent throughout the study period. Giant honey bees (*Apis dorsata*) and Indian honey bees (*Apis cerana indica*) were also frequently encountered on cultivated crops. The high abundance of these social bees reflects their advanced colony organization, efficient communication behaviour, and wider foraging range, which collectively enhance their pollination efficiency in agricultural ecosystems. Although solitary bees such as carpenter bees (*Xylocopa* sp.) and blue-banded bees (*Amegilla* sp.) were comparatively less abundant, they played an important role in cross-pollination due to their larger body size and effective pollen-carrying ability (Plat 1.). Solitary bees are recognized as efficient pollinators of several agricultural crops because they can perform buzz pollination and facilitate pollen transfer in flowers less frequently visited by honey bees. Similar findings regarding the dominance of *Apis* species and ecological significance of solitary bees have been reported from various regions of the Western Ghats and peninsular India (Abrol, 2012; Waykar et al., 2014; Jawale 2020).

Conclusion

The present investigation revealed a rich diversity of hymenopteran pollinators associated with agricultural ecosystems of Western Maharashtra. A total of 19 species belonging to seven families were documented, with Apidae representing the dominant family both in terms of species richness and abundance. The study highlights the ecological importance of bees, wasps, and parasitoid hymenopterans in sustaining pollination services and maintaining agroecosystem stability. Variation in pollinator abundance across study sites

demonstrates the influence of habitat quality and crop diversity on hymenopteran communities. Conservation of pollinator diversity through reduced pesticide application, maintenance of flowering vegetation, and adoption of pollinator-friendly farming practices is essential for sustainable agricultural production.

Acknowledgement

This work was supported under a UGC Minor Research Project. (No. F.47-918/14 (General/65/WRO) XIIth Plan, DBT Grant, Secretary, Pune District Education Association and Principal, Annasaheb Waghire Arts, Science and Commerce College, Otur, Tal. Junnar, Dist. Pune, India – 412409

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Plate 1. Representative hymenopteran pollinators recorded during the study.

Family	Number of Species	Total Individuals	Relative Abundance (%)
Apidae	6	2015	72.27
Ichneumonidae	3	206	7.39
Vespidae	5	205	7.35
Mutillidae	1	162	5.81
Sphecidae	2	85	3.05

Colletidae	1	60	2.15
Chrysididae	1	55	1.97
Total	19	2788	100

Table 1. Family-wise Diversity of Hymenopteran Pollinators

Figure 1. Family-wise Relative Abundance of Hymenopteran Pollinators

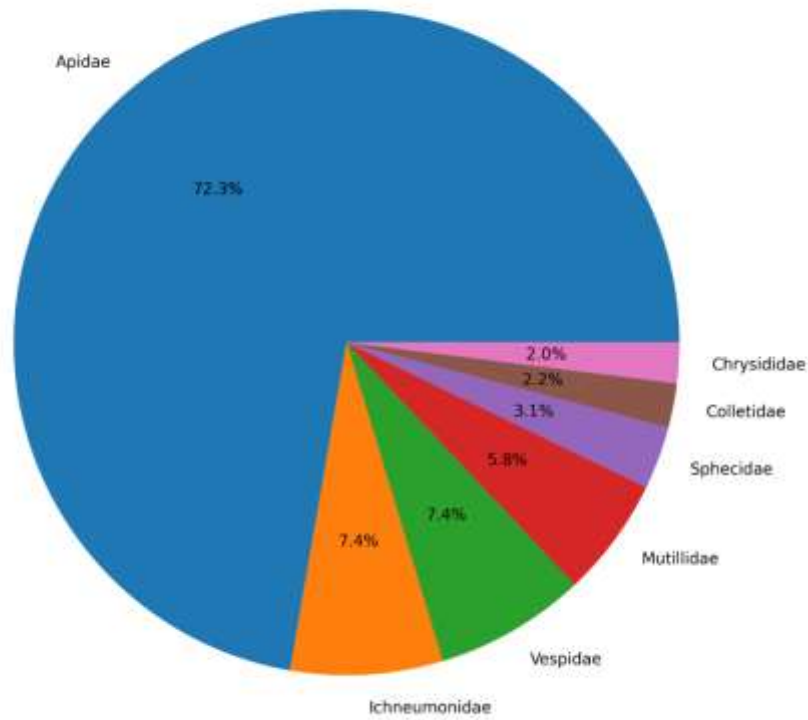


Fig. 1. Relative Abundance of Hymenopteran Pollinators

Figure 2. Site-wise Abundance of Hymenopteran Pollinators

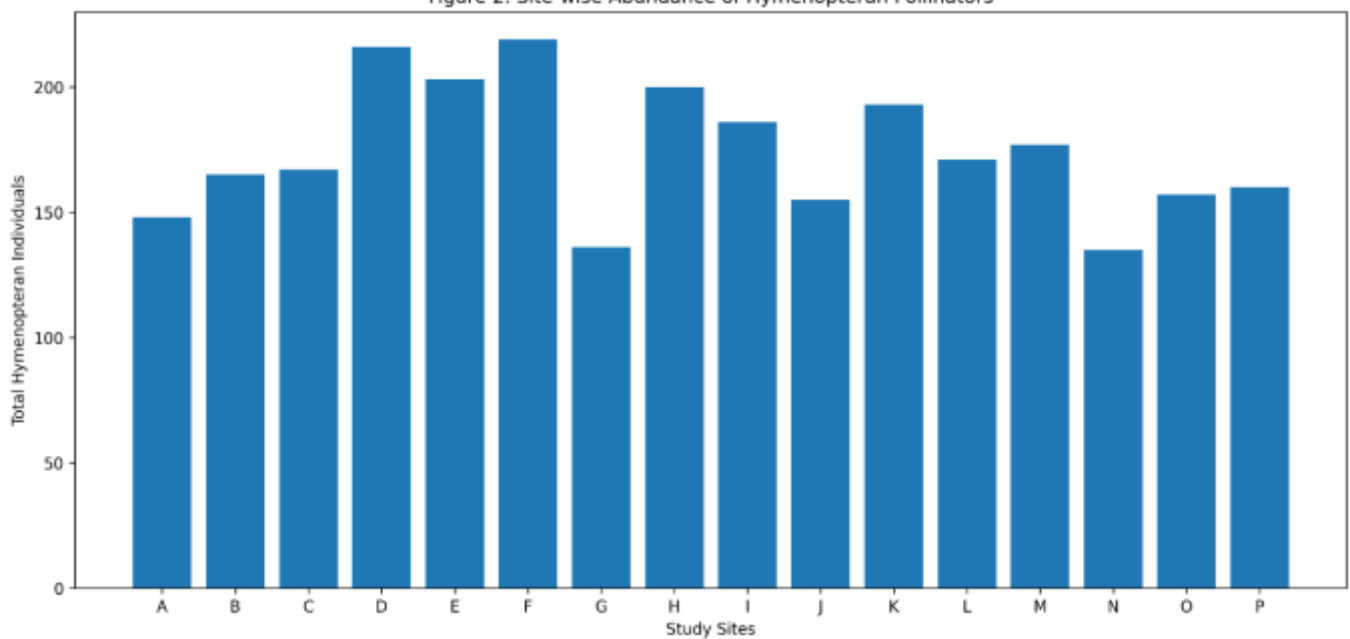
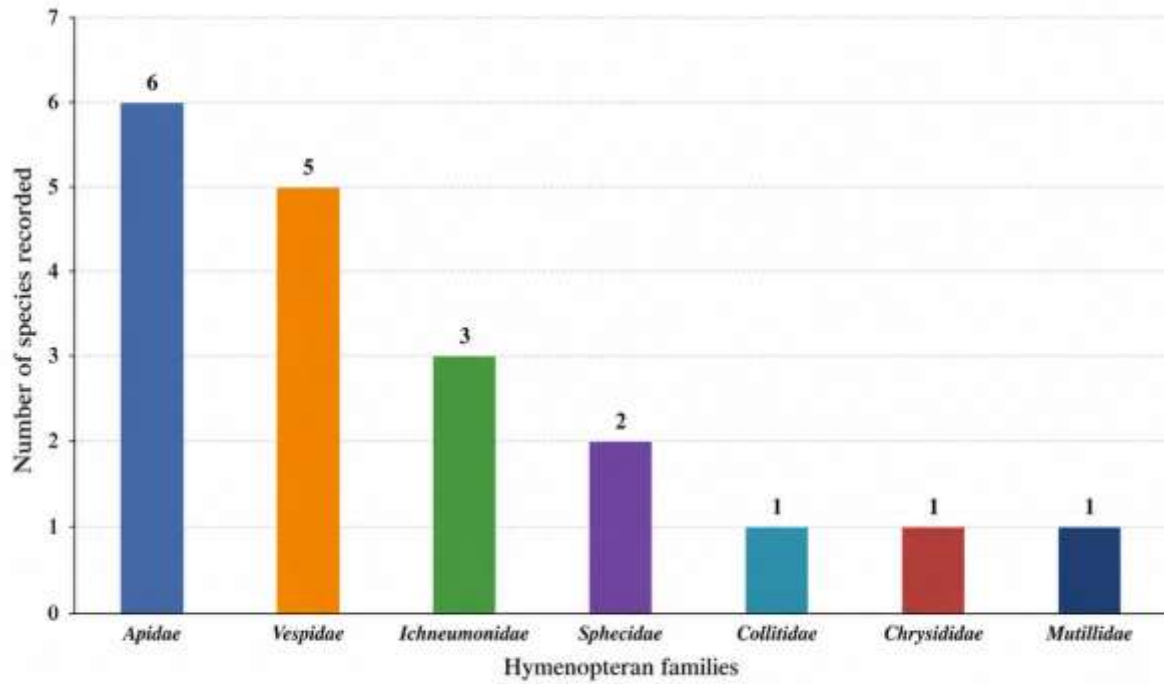


Figure 2. Site-wise abundance of hymenopteran pollinators

Figure 3. Comparative species richness among hymenopteran families.



Note: A total of 19 species belonging to 7 hymenopteran families were recorded from agricultural ecosystems during the study.

Figure 3. Comparative species richness among hymenopteran families