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Original Article

Pollinator diversity under natural and conventional farming systems

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ABSTRACT

Pollinators play an essential role in ecosystems and significantly contribute to improved crop production. Insect pollinators such as honey bees, bumble bees, stingless bees, megachilid bees and other solitary bees play an important role in pollinating a wide range of agricultural crops. Their diversity and population levels are largely influenced by farming practices. Conventional farming systems rely on monocultures and frequent pesticide applications leading to habitat loss, fragmentation and contamination of floral resources. Natural farming systems which maintain polyculture, minimal soil disturbance and reduced use of synthetic chemicals provide continuous and diverse floral resources. Neonicotinoid pesticides like imidacloprid adversely affect pollinators by increasing the time to initiate foraging, reducing flower visitation and limiting foraging range, ultimately lowering colony performance. Hence, promoting crop diversification, reducing chemical dependency and conserving habitats are essential for maintaining pollinator diversity.

Keywords: Conventional farming, genetically modified crops, Natural farming, Neonicotinoid pesticides, Pollinator diversity

INTRODUCTION

Pollinators are a fundamental part of both natural and agricultural ecosystems, as they facilitate the reproduction of many cross-pollinated plant species. Animal based pollination contributes nearly 35% of global food production, highlighting its critical role in sustaining food security (Klein et al. 2007). Insects are the dominant pollinators in agriculture, as they enhance pollen transfer efficiency, thereby improving crop yield and quality. Within this group, species of the family Apidae, especially honey bees and bumble bees, play a major role, while solitary bees and certain wasps also provide important pollination services. The value of insect pollination for worldwide agricultural production is estimated at about 153 billion, accounting for nearly 9.5% of the total agricultural output used for human consumption in 2005 (Gallai et al. 2009).

Pollinator diversity encompasses both the range of pollinating species and their abundance within a given ecosystem. It includes various taxonomic groups such as bees, butterflies, moths, flies, beetles, along with vertebrate pollinators like birds and bats, all contributing to pollination processes (Ollerton, 2017).

Hymenopterans, particularly honey bees and wasps, are among the most efficient pollinators owing to their frequent visits to flowers. Other groups such as dipterans, lepidopterans and coleopterans also play important roles through their distinct pollination mechanisms. Additionally, bats contribute significantly to the pollination of many plant species, especially those that bloom at night. Together, these diverse pollinators support agricultural productivity and help maintain ecological balance (Jarpla et al. 2024).

Different pollinators and their pollination rates are given in the table below (Jarpla et al. 2024)

Order	Pollination	% of pollination
Hymenoptera	Honey bees (Melittophily) Wasps (Sphecophily)	56.5% 5%
Lepidoptera	Butterflies and Moths (Phalaenophily)	4%
Diptera	Flies (Myophily)	19%
Coleoptera	Beetles (Cantharophily)	5%
Chiroptera	Bats (Chiropterophily)	6.5%

Types of bee pollinators

Apidae is the largest and most widely distributed bee family, encompassing honey bees, bumble bees and carpenter bees, with nearly 5,700 species documented worldwide. This family is further categorized into three primary subfamilies which are Apinae, Xylocopinae and Bombinae and comprises of around 25 genera (Pannure, 2016). Besides these, several native solitary bees are grouped under families such as Megachilidae (leaf cutter bees), Halictidae (sweat bees), Colletidae (miner bees) and Melittidae (digger bees).

Honey bees

Honey bees are one of the most important groups of insect pollinators, belonging to the genus *Apis*, family Apidae and order Hymenoptera. In Asia, different sp. of honey bees have been reported, including the European honey bee *Apis mellifera*, Indian honey bee *A. cerana*, dwarf or little honey bee *A. florea*, rock or giant honey bee *A. dorsata* and the giant mountain honey bee *A. labriosa* (Yadav et al. 2017).

Dammer bees or Stingless bees

Stingless bees, belonging to the genera *Tetragonula* and *Melipona*, are small in size and well suited for domestication. They build irregular comb nests using wax and resin, typically in crevices, wall cavities and similar sheltered locations (Kumar et al. 2012).

Bumble bees

Bumble bees, belonging to the subfamily Bombinae, are social insects exhibiting a well-defined caste system consisting of queens, workers and drones, similar to honey bees. They are well adapted to temperate climates and higher altitudes. In India, about 62 species of bumble bees have been recorded from the Himalayan region (Williams, 2022). These bees are widely used as commercial buzz pollinators to improve fruit and seed set in protected cultivation crops such as strawberry, tomato, brinjal and cucurbits.

Native solitary bees

Solitary bees include leaf cutter bees, sweat bees, carpenter bees and digger bees:

Leaf cutter bees

Leafcutter bees are solitary bees that belong to the family Megachilidae. The adult females of the genus *Megachile* use their powerful jaws to cut leaf pieces, which they carry to their nests and use to construct their nests. These nests are typically built within pre-existing cavities such as hollow stems, dead wood or similar sheltered spaces (Kunjwal et al. 2020).

Sweat bees

Halictid bees, belonging to the family Halictidae, are solitary in nature and over 250 species of these bees have been documented worldwide. They are known for their attraction to human perspiration. Some species, including *Hoplonomia westwoodi*, *Nomia* spp. and *Lasioglossum* spp., play an important role as buzz pollinators in solanaceous crops such as tomato and brinjal (Amala and Shivalingaswamy, 2018).

Carpenter bees

Carpenter bees are members of the subfamily Xylocopinae and are generally divided into two groups. The large carpenter bees (*Xylocopa* spp.) make their nests in hard woody materials such as bamboo and tree trunks, whereas the small carpenter bees (*Ceratina* spp.) nest in plants that have soft, pith-filled stems (Amala and Shivalingaswamy, 2019).

Digger bees

Digger bees are associated with the subfamily Anthophorinae and are also found within the families Colletidae, Melittidae and Andrenidae. About 50 species of Melittid bees have been recorded in India (Saini et al. 2016). Members of the genus *Amegilla* (Anthophorinae) are solitary nesters, typically making their burrows in dry riverbanks, old clay houses and in the mortar joints of brick structures.

Natural farming and conventional farming systems

Natural and conventional farming systems differ notably in crop management, input use, soil health and environmental impact. Natural farming promotes crop diversity through polyculture, enhancing ecological balance and resilience. It relies on minimal, natural inputs, supports biological processes and improves soil health by increasing organic matter, microbial activity and nutrient cycling, making it a sustainable and eco-friendly approach. In contrast, conventional farming is largely based on monoculture, which increases vulnerability to pests and diseases. It depends heavily on synthetic fertilizers and pesticides, whose prolonged use degrades soil health and contributes to environmental pollution and biodiversity loss (Bharucha et al. 2020).

Key mechanisms driving pollinator decline in conventional farming systems

Insects are essential for the reproduction of over 80% of flowering plant species, including many important food crops. However, their populations have declined raising serious concerns for biodiversity and food security. This decline is largely attributed to intensive farming practices, monoculture, excessive pesticide use, habitat destruction, genetically modified crops, pathogens and climate change (Nath et al. 2023). The different factors that leads to the decline in pollinator diversity are:

1. Monoculture affecting pollinator diversity

Monoculture causes reduction in floral diversity and limited nesting sites due to which the diverse pollinator community fails to sustain. In such system, there exists only single season flowering periods followed by long phase of resource scarcity which restrict their survival and foraging continuity (Vujanović et al. 2023).

2. Effect of habitat loss and fragmentation on bee pollinators

A meta-analysis by Winfree et al. (2009) found that habitat loss is a key driver of declining pollinator diversity. Using the Web of Science database (covering time period from 1945 to 2007) with keywords related to bees and environmental disturbances, the authors compiled 54 independent studies. Of these, 44 examined bee abundance and 38 assessed species richness. The analysis revealed that areas experiencing severe habitat loss showed significant reductions in both bee abundance and species richness, whereas areas with moderate habitat loss showed little to no significant decline in bee populations or diversity.

3. Effects of pesticides on bees

The extensive application of pesticides in agriculture is a major anthropogenic threat to pollinators, as it adversely affects their biology and ecology, including their life cycle, behaviour, reproduction, immunity and population levels. Different effects are discussed below (Singla et al. 2021):

Foraging

A study by Dhuria et al. (2022) on Chinese cabbage compared pollinator diversity and foraging under Subhash Palekar Natural Farming (SPNF) and conventional farming (CF). A total of 19 insect species were recorded, with *Apis mellifera* as the dominant visitor. Pollinator abundance and foraging rate were highest in SPNF (20.30 flowers/min) compared to CF (16.10 flowers/min), although time spent per flower was greater in CF. Whereas for efficient pollination, bee must visit more flowers per minute and spend less time on a single flower. Overall, pollinators showed a preference for SPNF, suggesting improved pollination and potential yield benefits.

Mortality

Exposure to neonicotinoid insecticides, particularly thiamethoxam, is a major factor in the decline of *Apis mellifera*. Sharma et al. (2018) reported significantly higher bee mortality on mustard treated with thiamethoxam (0.1 g/L), especially during the first two days after spraying under semi-field conditions (293 and 231.83 bees/DBT/day) compared to control (4.17 and 9.83). Mortality declined after the third day, indicating reduced foraging on treated plants. Under field conditions, mortality was also higher on the 1st (112.50 bees/DBT/day), 2nd (112 bees) and 3rd day (46.33 bees) after spray. Overall, treated plots showed substantially higher mortality than controls.

Immune system

The immune system is a system of biological mechanisms that protects organisms from disease. In honey bees, effective immunity is crucial for both individual health and colony survival and is regulated by gene expression. Positive gene regulation enhances immunity by activating antimicrobial defense genes, whereas negative gene regulation controls immune responses by increasing inhibitory gene expression. Normally, a balance between activating immune-related genes and suppressing excessive responses ensures proper defense against pathogens. However, this regulatory balance is disrupted by exposure to pesticides and other agrochemicals, weakening immune function. Di Prisco et al. (2013) investigated the sublethal effects of neonicotinoids such as clothianidin exposure to bumble bees. This exposure enhanced the transcription of gene encoding Nf-$_{K}$B inhibitor. Thereby, affecting the insect immunity by negatively modulating the Nf-$_{K}$B nuclear factor leading to the reduction in the defense mechanism of the immune system and actively promoting the replication of the virus causing various infections and finally decline in the colony.

4. Effects of GM (genetically modified) crops on pollinators

Genetically modified (GM) crops can impact pollinators both directly and indirectly, depending on the nature of the modification, farming practices and environmental conditions. Most GM crops, including Bt cotton and Bt maize, are engineered for insect resistance or herbicide tolerance. Although direct effects on pollinators are typically low since target pests are not pollinators, exposure to Bt toxins in pollen or nectar may still cause sub-lethal effects such as altered foraging behaviour, reduced learning capacity and impaired immune responses. Malone (2004) assessed the impact of GM crops on *Apis mellifera*, focusing on plants expressing insecticidal proteins from *Bacillus thuringiensis* (Bt). Bt δ-endotoxins, particularly Cry proteins (Cry1, Cry2, Cry3), function by binding to specific gut receptors in target insects, leading to gut disruption and death. As honey bees lack these receptors, these proteins exhibit low acute toxicity to them. However, other transgenic substances, such as protease inhibitors (e.g. soybean trypsin inhibitor, aprotinin) and lectins, may possess higher risks by interfering with digestion and nutrient absorption. Additionally, indirect effects like reduced floral diversity associated with GM crop management can negatively affect pollinator health.

CONCLUSION

Pollinator diversity is crucial for maintaining agricultural productivity and ecosystem stability and clear differences exist between natural and conventional farming systems in supporting pollinator communities. Evidence from various studies and case analyses shows that the cumulative impacts of pesticides, habitat fragmentation and landscape simplification pose serious threats to both managed and native pollinator species. Therefore, the adoption and expansion of natural farming practices, along with pollinator-friendly landscape management and reduced pesticide dependency offer a sustainable pathway for conserving pollinator diversity, enhancing crop yields and ensuring long-term agricultural resilience.

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