

Impact of Different Pollinator Species on Crop Yield, Fruit Set, and Seed Production

Kiran Dalal¹ and Dr. Bharat Bhushan²

¹Research Scholar, Department of Botany

²Assistant Professor Guide, Department of Botany

School of Natural and Applied Science

Vikrant University Gwalior (M.P) India

Abstract: *Pollination is a fundamental ecological process that supports agricultural productivity, crop quality, and the reproductive success of flowering plants. Different pollinator species, including honeybees, bumblebees, solitary bees, butterflies, moths, hoverflies, beetles, and other insects, contribute differently to fruit set, seed production, and final crop yield because of variations in their foraging behaviour, body size, pollen-carrying capacity, floral preferences, and activity patterns. This research paper examines the influence of different pollinator species on crop production, with particular emphasis on the relationships between pollinator diversity, pollination efficiency, fruit development, and seed formation. Evidence from research published between 2010 and 2022 indicates that animal pollination improves the reproductive performance of many crops, although the magnitude of the effect varies according to crop species, pollinator identity, environmental conditions, and agricultural management practices.*

Keywords: Pollinator Diversity, Crop Yield, Fruit Set, Seed Production, Honeybees, Ecosystem Services..

I. INTRODUCTION

Pollination is one of the most important biological processes influencing the reproduction of flowering plants and the productivity of agricultural ecosystems. It involves the transfer of pollen grains from the anther to the stigma of a flower, allowing fertilisation and subsequent development of seeds and fruits in compatible plants. Although some crops are self-pollinating or wind-pollinated, many economically important fruit, vegetable, oilseed, nut, and seed crops depend partly or substantially on animal-mediated pollination. Insect pollinators are particularly important because their foraging activities facilitate pollen transfer between flowers and can increase the probability of successful fertilisation.

Major pollinator groups include honeybees, bumblebees, solitary bees, butterflies, moths, hoverflies, and beetles, each of which exhibits different ecological characteristics and pollination behaviours. The contribution of these organisms is not uniform because pollination effectiveness depends on the quantity and quality of pollen deposited, the compatibility of pollen with the recipient flower, the timing of flower visitation, and the reproductive biology of the crop.

Klein et al. (2007) established the broad importance of animal pollination for global crop production, while subsequent research has strengthened the evidence that pollinator communities contribute to both agricultural productivity and crop quality. Garibaldi et al. (2013) demonstrated that wild insects improve fruit set independently of honeybee visitation across a wide range of crop systems, indicating that the conservation of wild pollinators is important even where managed honeybees are available. Similarly, Dainese et al. (2019) found that biodiversity-mediated ecosystem services, including pollination, are important contributors to agricultural production. The effects of pollinators can be evaluated through several interconnected indicators, including visitation frequency, pollen deposition, fruit-set percentage, seed number per fruit, fruit size, marketable quality, and total crop yield.

Fruit set refers to the proportion of flowers that develop into fruits, whereas seed production reflects successful fertilisation and subsequent seed development. Crop yield represents the final agricultural output and may be measured in terms of fruit or seed number, fresh or dry weight, or production per unit area. These indicators are related but are not interchangeable because increased visitation does not always produce a proportional increase in yield. The present paper therefore examines how different pollinator species influence fruit set, seed production, and crop yield, drawing on scientific literature published between 2010 and 2022 to identify the mechanisms, ecological conditions, and management practices associated with effective crop pollination.

REVIEW OF LITERATURE

The scientific literature published between 2010 and 2022 provides substantial evidence that pollinator identity, species richness, abundance, and interactions with crop plants influence agricultural productivity. Albrecht et al. (2012) examined the relationship between pollinator diversity and plant reproductive success and reported that diverse pollinator communities can improve reproductive outcomes. Their findings support the ecological principle that different pollinator species may complement one another through differences in body size, foraging behaviour, and floral preferences. Garibaldi et al. (2013) provided evidence from multiple crop systems that wild insects improve fruit set even when honeybees are present, demonstrating that managed honeybees alone may not provide all the pollination services required by crops. Garibaldi et al. (2014) further discussed the potential for increasing crop productivity through conservation and management of wild pollinator communities rather than relying exclusively on a single managed species. Garibaldi et al. (2015) analysed flower-visiting insects and fruit set across 469 fields representing 33 crop systems and found that fruit set was associated with pollinator richness, abundance, evenness, and the matching of pollinator characteristics with floral traits.

These findings indicate that pollination efficiency depends not only on the number of insects visiting flowers but also on their suitability for the crop concerned. Rollin and Garibaldi (2019) reviewed evidence concerning honeybee density and crop productivity, finding that increased colony density and visitation rates were associated with increases in measured productivity variables. However, the authors also highlighted limitations in the available experimental evidence. Tamburini et al. (2019) demonstrated that the contribution of pollination to crop yield depends on interactions with other agricultural factors, including soil resources, pest pressure, and crop characteristics. Dainese et al. (2019), through a global synthesis of 89 studies covering 1,475 locations, demonstrated the importance of biodiversity-mediated ecosystem services for agricultural production.

In a study focused on oilseed rape, Jauker et al. (2012) compared wild bees and hoverflies and found that both groups contributed to pollination, although their measured effects differed from those obtained under honeybee treatments. More recent research by Olhnuud et al. (2022) found substantial pollination deficits in apple production when comparing open pollination with artificial pollination, indicating that natural pollinator communities may not always deliver the maximum possible reproductive output. Together, these studies suggest that maintaining diverse pollinator communities and matching pollinator species to crop requirements can improve the reliability and effectiveness of agricultural pollination.

IMPACT OF DIFFERENT POLLINATOR SPECIES ON CROP YIELD

Honeybees, particularly *Apis mellifera*, are widely managed in agricultural systems because their colonies can be transported to crop fields, maintained in hives, and used to support pollination during flowering periods. Their social organisation enables large numbers of workers to forage simultaneously, making them important pollinators of crops such as apples, almonds, cucurbits, berries, and several oilseed crops. By visiting flowers to collect nectar and pollen, honeybees transfer pollen between flowers and may increase fertilisation, fruit formation, and seed development. Rollin and Garibaldi (2019) found that increased honeybee colony density and visitation rates were associated with improved crop productivity across the studies they reviewed.

Nevertheless, the relationship between honeybee abundance and yield is not necessarily linear because excessive stocking may produce diminishing benefits, while crop compatibility, weather, flower density, and the availability of other pollinators can influence outcomes. Wild bees, including bumblebees, mason bees, mining bees, and carpenter bees, also make important contributions to crop production. Bumblebees are particularly effective on some crops because of their relatively large bodies, dense hairs, and ability to forage under certain cool or cloudy conditions. Some species perform buzz pollination, in which vibrations release pollen from flowers with specialised anthers, as occurs in several crops belonging to the tomato family.

Mason bees and other solitary bees may be efficient pollinators of orchard crops because they frequently contact floral reproductive structures while collecting pollen. Garibaldi et al. (2013) showed that wild insects can increase fruit set independently of honeybee visitation, supporting the inclusion of wild pollinators in crop management strategies. A 2022 meta-analysis by the authors of Evaluation of interactions between honeybees and alternative managed pollinators found that crops receiving honeybees together with alternative managed pollinators had productivity approximately 22% higher, on average, than crops receiving honeybees alone. This finding supports complementary pollination strategies, although the magnitude of the benefit will depend on the crop and pollinator combination.

Non-bee pollinators, including hoverflies, butterflies, moths, and beetles, also contribute to crop pollination, although their importance varies among plant species and environments. Hoverflies visit flowers to obtain nectar and pollen, and some species transfer pollen effectively when their bodies contact anthers and stigmas. Jauker et al. (2012) investigated the pollination efficiency of wild bees and hoverflies in oilseed rape and showed that both groups contributed to fruit set and seed-related yield measures. Their findings demonstrate that hoverflies should not be overlooked in agricultural pollination research, even though their performance may differ from that of bees under particular experimental conditions.

Table 1: Comparative Impact of Different Pollinator Groups on Crop Production

Pollinator group	Examples	Contribution to crop yield	Effect on fruit set	Effect on seed production
Honeybees	<i>Apis mellifera</i>	Important in orchards, oilseeds, and many commercial crops	Can improve fruit formation through repeated flower visits	Supports pollen transfer and seed development
Bumblebees	<i>Bombus</i> species	Valuable in greenhouse and selected field crops	Effective in crops with flowers suited to their foraging behaviour	Can improve fertilisation in compatible crops
Solitary bees	<i>Osmia</i> , <i>Megachile</i>	Important in orchards and other specialised cropping systems	May increase fruit formation through efficient pollen transfer	Can improve seed set in pollinator-dependent crops
Butterflies	Various butterfly species	Contribute to pollination in selected crops and flowering plants	Their contribution varies with floral structure and behaviour	May contribute to seed formation where pollen transfer is effective
Hoverflies	<i>Syrphidae</i> family	Contribute to pollination in selected crops and diversified farms	Can transfer pollen while visiting flowers for nectar or pollen	May support fertilisation in suitable plant species
Other wild insects	Beetles, moths, and	Crop-specific and often complementary	Depends on visitation, pollen transfer, and	Varies with the pollinator and

	other flower visitors	contributions	flower compatibility	reproductive biology of the crop
Mixed pollinator communities	Managed bees and diverse wild insects	May improve overall pollination reliability and productivity	Different species can provide complementary pollination services	Functional diversity can support improved seed development

EFFECT OF POLLINATOR SPECIES ON FRUIT SET

Fruit set is an important indicator of pollination success because it represents the proportion of flowers that develop into fruits following pollination and fertilization. Adequate pollen transfer can increase the probability of successful fertilization, reduce flower abortion, and improve early fruit development in pollinator-dependent crops. However, fruit set is influenced by several interacting factors, including pollen compatibility, flower condition, temperature, water availability, plant nutrition, and the capacity of the plant to support developing fruits.

Different pollinator species can produce different fruit-set outcomes because of differences in the number of flowers visited, the amount of compatible pollen deposited, and their ability to reach the reproductive structures of particular flowers. Garibaldi et al. (2015) found that fruit set across 33 crop systems was better explained when pollinator abundance, species richness, evenness, and the match between pollinator traits and crop floral characteristics were considered together.

This indicates that the presence of a greater number of insect species may improve pollination when those species collectively possess characteristics suited to the crop. In apple production, Olhnuud et al. (2022) reported that fruit set was, on average, 41% lower under open pollination than under artificial pollination across the studies included in their global meta-analysis. They also found that access by insect pollinators increased fruit set by 71% compared with insect exclusion, although the magnitude of these differences varied by cultivar and geographical region. These findings demonstrate that natural pollination can provide substantial reproductive benefits while still leaving opportunities to improve pollination in some orchards. Fruit-set measurements should consequently be interpreted alongside crop variety, flowering conditions, pollinator visitation, and experimental treatment rather than attributed solely to pollinator abundance.

The relative contribution of different pollinator species to fruit set also depends on their behaviour and the floral architecture of the crop. In crops with accessible flowers, honeybees may visit a large number of blossoms during a foraging trip, thereby facilitating pollen transfer across plants. Bumblebees and solitary bees may be especially effective when flower structure, pollen-release mechanisms, or environmental conditions favour their particular foraging traits.

Hoverflies and other insects may provide supplementary pollination where their activity overlaps with crop flowering. A diverse community can also distribute pollination activity across different periods of the day or variable weather conditions, potentially reducing the risk of inadequate pollen transfer. Nevertheless, a high visitation rate does not always guarantee successful fruit formation because some visits may deposit little compatible pollen or may occur at unsuitable stages of flower development.

IMPACT OF POLLINATOR SPECIES ON SEED PRODUCTION

Seed production depends on successful pollen transfer, fertilisation, embryo development, and the availability of resources to support mature seeds. Pollinators may influence seed production by increasing the proportion of flowers fertilised and, in some crops, the number of ovules that develop into viable seeds. In fruit crops such as apples, seed number can also affect fruit development, shape, and quality because developing seeds contribute to hormonal processes associated with fruit growth. In oilseed crops, including oilseed rape, effective pollination can influence the number of pods formed, the number of seeds per pod, and the total weight of harvested seeds. Jauker et al. (2012)

investigated wild bees and hoverflies in oilseed rape and reported differences in fruit set, seeds per pod, and seed-yield measures across pollinator treatments.

Their study illustrates that different pollinator groups may contribute to seed production even when their overall effectiveness differs from that of other pollinators. The relative contribution of each group depends on the crop's reproductive biology, the structure of its flowers, and the ability of insects to transfer compatible pollen. In crops that require cross-pollination, movement between genetically compatible plants is especially important, whereas in self-compatible crops the effects of animal pollination may vary according to the degree of pollen limitation. The findings of Garibaldi et al. (2013) concerning the benefits of wild insects and those of Dainese et al. (2019) concerning biodiversity-mediated agricultural services support the broader view that diverse pollinator communities can contribute to the reproductive processes underpinning crop production.

II. CONCLUSION

Different pollinator species play important roles in determining crop yield, fruit set, and seed production, but their relative effectiveness depends on the biological characteristics of the crop and the environmental conditions in which pollination occurs. Honeybees provide valuable managed pollination services, while bumblebees, solitary bees, hoverflies, butterflies, moths, and other flower-visiting insects can provide additional or complementary benefits. Evidence published between 2010 and 2022 indicates that diverse pollinator communities can improve reproductive success, increase the reliability of pollen transfer, and support the production of fruits and seeds in many agricultural systems.

Wild insects are particularly important because their contribution may extend beyond the services provided by managed honeybees. Nevertheless, pollination is only one component of agricultural productivity, and its benefits may be constrained by inadequate soil resources, poor irrigation, pest damage, or unfavourable weather. Sustainable crop production therefore requires a combined strategy involving effective managed pollination, conservation of wild pollinators, protection of natural habitats, reduced exposure to harmful pesticides, and appropriate crop management. Further field-based studies should quantify the contributions of individual pollinator species and determine how different pollinator combinations affect fruit set, seed quality, and marketable yield. Overall, conserving pollinator diversity while selecting appropriate pollination strategies for individual crops represents an important approach to improving agricultural sustainability, protecting ecosystem services, and supporting long-term food security.

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