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Significance of pollinators for sustainable agriculture and biodiversity conservation

From the familiar potted plant to growing a wide range of seed producing botanical species relies primarily on pollination to sustain their existence. Pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fiber crops which reciprocate by offering food and shelter. Crop pollination is the key to food production and security which has been little understood, however it has a great significance for biodiversity conservation at essentially no cost. As farm fields have become larger, production systems have intensified, and the use of agricultural chemicals that impact beneficial insects such as pollinators has increased. As a result pollination services are showing declining trends in a number of instances. A major barrier to enhance pollinator conservation and management is the existing knowledge base which is scattered and often inaccessible to people who need it for introducing appropriate pollinator-friendly practices into agricultural management.

POLLINATION is a keystone process in both human managed and natural terrestrial ecosystems. It is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems. The vast majority of flowering plant species only produce seeds if animal pollinators move pollen from the anthers to the stigmas of their flowers. Without this service, many interconnected species and processes functioning within an ecosystem would collapse.

Pollination

In the higher plants, sexual reproduction and perpetuation of species are brought about through pollination. These plants may be either self-fertile, capable of setting fruit or seed with their own pollen, or self-infertile requiring pollen from other plants of the same species for cross pollination. In this way, pollination is part of the reproduction of flowering plants and involves the transfer of pollen from the anther of a flower to the stigma of the same or another flower. In the self-pollinated plants pollen from the anthers automatically falls on to their stigmas. However, even these plants may produce more and better fruits or seeds by cross pollination than by self-pollination. In the case of cross pollinated plants, the chief agents who carry the pollen from plant to plant for pollination are wind, insects, water, various mammals etc. Each plant species has evolved its own technique for this important transference of pollen. Many plant species depend upon insects to transfer pollen from one flower to another as the insects forage for nectar and/or pollen.

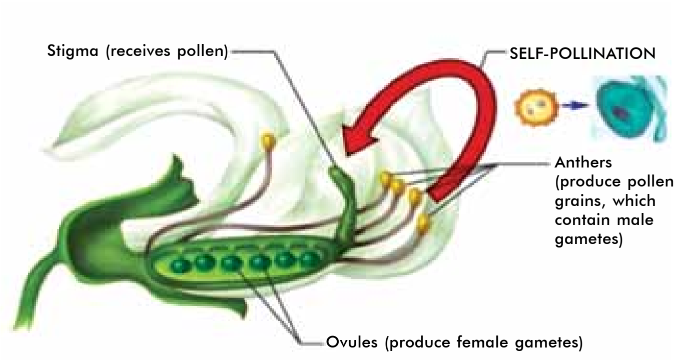
Diversity of pollinators

The diversity of pollinators and pollination systems is striking. Most of the 20,000-25,000 species of bees (Hymenoptera: Apidae) are effective pollinators, and together with moths, flies, wasps, beetles and butterflies, make up the majority of pollinating species. Besides bees (*Apis* species), syrphids and non-*Apis* bees also play very important role in pollination. Syrphids are one of the most important groups of pollinators. The most abundant syrphids are *Episyrphus balteatus* De Geer, *Melanostoma orientale* We., *Syrphus corollae* Fab. and *Eristalis tenax* L. Among non-*Apis* bees *Trigona* spp. (Melliponinae) and *Xylocopa aestuans* L. (Xylocopinae) are also found very efficient insect pollinators. Entomophily refers to cross pollination aided by insects. The value of the increased crop production, due to insect pollinators, is worth $203 billion. In India, crop yields per hectare of all crops are just 40-50% of the world productivity per acre. Bee pollination can play a major role in bridging the gap.

Cross pollination mediated by different types of insects

Pollination class	Type of insect
Melitophily	Bees
Cantharophily	Beetles
Myophily	Syrphid and Bombylid flies
Sphingophily	Hawk moths
Psychophily	Butterflies
Phalaeophily	Small moths

Pollinators such as bees, birds and bats affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide. Vertebrate pollinators include bats, non-flying mammals (several



Process of self pollination

species of monkey, rodents, lemur, tree squirrels, olingo and kinkajou) and birds (humming birds, sun birds, honey creepers and some parrot species).

Bees (Apidae) in general and social bees in particular, are the most important pollinators of cultivated plants; they depend almost entirely on the pollen and nectar of flowers. Honeybees, and in particular *Apis mellifera* L., are the most economically valuable pollinators of crop monocultures worldwide; they are available throughout the growing season, they pollinate a wide variety of crops, and they can be concentrated in large numbers whenever and wherever needed. Thus, among all pollinators bees are recognized as the most generally efficient pollinators because:

1. Bees have hairy bodies which easily pick up grains of pollen as they move about in flowers
2. Each bee usually visits flowers of a single species during each foraging trip
3. Each foraging bee has not only to collect sufficient food for her own requirements, but must forage continuously for nectar and pollen to supply the daily food needs of the colony.

During a single day, one honey bee may visit several thousand flowers of one plant species, collecting nectar and/or pollen and transferring pollen grains from one flower to another as she goes. Other insects, and in particular flies, can carry much pollen on their bodies, but they are not such consistent foragers as bees. Current understanding of the pollination process shows that, while interesting specialized relationships exist between plants and their pollinators, healthy pollination services are best ensured by an abundance and diversity of pollinators.

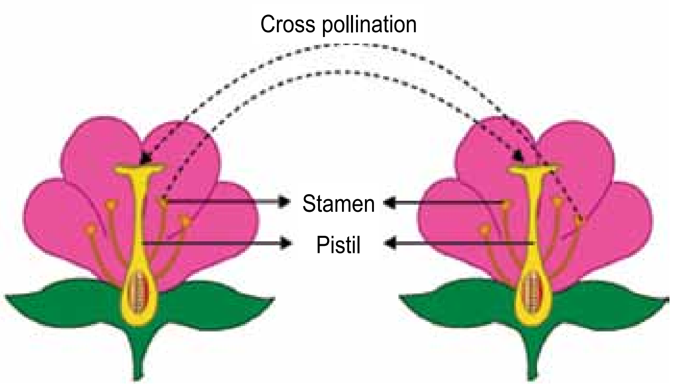
Importance of pollination

Pollination of crop plants is, in many cases, a major requirement for achieving sufficient crop set. Pollination is required for seed production, to enhance seed quality and numbers, to maximize fruit yield and quality, to create hybrid seed, and to improve uniformity in crop ripening. Pollination is necessary for all seed and fruit production. In some crops, it is the seed that is harvested for food, for example: oilseed crops, nuts, legumes such as beans and peas, and cereals like rice and maize. In other crops, we eat the fruit that develops with the seed, for example citrus fruit and tomatoes. Seed is needed for the production of the next generation of crops, and the process of seed production allows natural selection to take place.

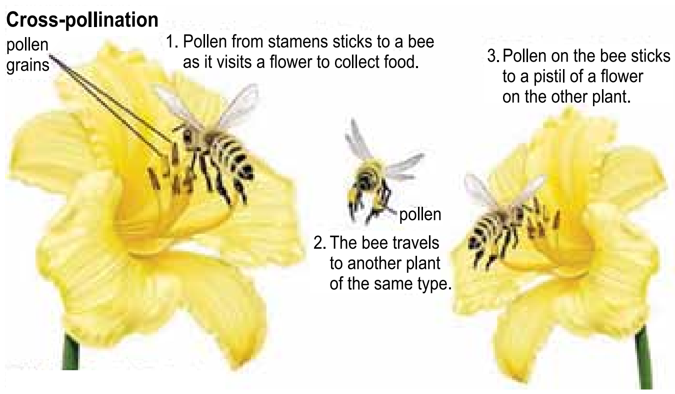
It has been estimated that at least 20 genera of animals other than honeybees provide pollination services to the world's most important crops. For human nutrition the benefits of pollination include not just abundance of fruits, nuts and seeds, but also their variety and quality; the contribution of animal-pollinated foodstuffs to human nutritional diversity, vitamin sufficiency and food quality is substantial. In this way, humans depend on animal pollination directly or indirectly for about one third of the food they eat.

Potential problems with pollination of cultivated crops "Pollination Crisis"

Over the past 50 years, insufficient pollination has been found to be one of the important causes of low yield in many field and orchard crop species. Kearns described what they called a global "pollination crisis" in which disruption of pollination systems and declining populations of certain types of pollinators have been reported on every continent except Antarctica. They suggested that pollination systems were under increasing threat from anthropogenic sources, including fragmentation of habitat, changes in land use, modern agricultural practices, and use of chemicals such as pesticides and herbicides, and invasions by non-native plants and animals. Today, it seems that pollination systems in many areas of agriculture are threatened by inadequacy of pollinators, or lack of sustainably managed pollinators indigenous or imported. Therefore, management of pollinating agents is used on some crop species, whereas others require supplementary pollination.



Process of self pollination



Process of cross pollination through honey bee

Table 1. Percent increase in yield due to bee pellination

Crop	% increase	Crop	% increase
Oilseed crops		**Legume/Pulses**	
Mustard	128.1-159.8	Alfalfa	23.4-19733.3
Rai	18.4	Barseem and other clovers	23.4-33150
Toria	66-120	Vetches	39-20000
Sarson	222	Broad beans	6.8-90.1
Rapeseed	12.8 to 139.3	Dwarf beans	2.8-20.7
Safflower	4.5-114.3	Kidney beans	500-600
Linseed	1.7-40	Runner beans	20.6-1100
Niger	260.7	Arhar	21-30
Sunflower	20-3400	Other pulses	27-30
Orchard crops		**Vegetable for seed/fruits**	
Apple varieties	180-6950	Radish	22-100
Pear	240-6014	Cabbage	100-300
Plum	6.7-2739	Turnip	100-125
Cherry	56.1-1000	Carrot	9.1-135.4
Strawberry	17.4-91.9	Onion	353.5-9878
Raspberry	291.3-462.5	Brinjal	35-67
Persimmon	20.8	Cucumber	21.1-411
Litchi	4538-10246	**Miscellaneous crops**	
Citrus varieties	7-233.3	American cotton	5-20
Grape	756-6700	Egyptain cotton	16-24
Squash	771.4-800	Buckwheat	62.5
Guava	70-140	Coffee	16.7-39.8
Papaya	22.4-88.9	This increase in yield is in addition to the value of honey and other hive products. Bee pollination also improves the quality of seed/fruit.	
Mosambi	36-750		
Orange	471-900		

(*Source:* Souvenir of National Beekeepers Meet, 2019).

Reduced native pollinators

Agricultural intensification might reduce the diversity and abundance of native pollinators and therefore reduce yields in some crops that are entirely dependent on pollinators. Populations of wild pollinators can enhance yields of some crops and, therefore, form an important natural resource. Distance from natural or semi-natural habitats resulting agriculture intensification has been found to have negative effects on abundance of crop pollinators. Ricketts found that bee diversity, visitation rates, pollen deposition rates, and fruit set were all significantly greater in coffee fields near tropical forest than in those further away. The greatest relative declines occurred among stingless and solitary bees and other native flower visitors, which were rarely seen more than a few hundred meters inside the plantations.

Effect of climate change on pollination services

Changing climate may cause changes in the time of growth, flowering and maturation of crops, with consequent impacts on crop-associated biodiversity, particularly pollinators. Key biological events such as insect emergence and date of onset of flowering need to occur in synchrony for successful pollination interactions. Effective crop pollination is heavily dependent on biological timing, of both the crop and its pollinators. Present species extinction rates are 100 to 1000 times higher than normal due to human impacts. The greater risk is not that pollinators fail to adapt the present climatic condition, but that too many of them fail to survive. The extreme weather events that will accompany global warming may have severe impacts on pollinators already stressed from climatic change. Less mobile pollinators (small bees and beetles, for example) may be most severely impacted.

Farming communities may best adapt to climate change impacts on pollinators by: giving consideration to the season long resources needed by pollinators, both before and after crop flowering (often provided by wild or semi-wild areas of habitat in agricultural landscapes). Ensuring connectivity of natural habitats in farming areas, so that pollinators can more easily disperse and make needed range shifts in response to changing climate.

Poor pollination

Desired pollination

Factors associated with degradation of pollinator's biodiversity

A number of factors linked to industrial modes of agriculture affect bee colonies and other pollinators around the world, ranging from habitat degradation due to monocultures with consequent declines in flowering plants and the use of damaging insecticides.

Impact of pesticides on pollinators

Broad-spectrum insecticides (e.g. Carbamates, Organophosphates and Pyrethroids) can cause population decline of beneficial insects such as pollinators. Bees perform essential pollination. Honey bees population remains under pressure due to attack of parasitic mites, viral diseases, habitat loss and pesticides. Intensified agricultural practices, habitat loss, and agrochemicals are considered to be among the chief environmental threats to honeybees and wild bees. Agricultural policy must reduce these pressures to ensure adequate pollinator populations. In UK, 95 incidents of bee poisoning during 1995-2001 caused by organophosphates (42%), carbamates (29%) and pyrethroids (14%). Synergistic effects between pyrethroids and EBI fungicides (imidazole or triazole fungicides) can increase the risk to honeybees. Field margins without use of pesticides (herbicides in particular) had a positive effect on the number of Lepidoptera (such as moths or butterflies), bugs, and staphylinid beetles at the edges of arable fields. In organic plots, average numbers of spiders and carabid or staphylinid beetles were almost twice as high as those in conventional plots.

Pesticides which are highly toxic to bees, bumblebees include other beneficial insects include carbamates (*e.g.* aldicarb, benomyl, carbofuran, methiocarb), organophosphates (*e.g.* chlorpyrifos, diazinon, dimethoate, fenitrothion), pyrethroids (*e.g.* cyfluthrin, cyhalothrin), and neonicotinoids (*e.g.* imidacloprid, thiamethoxam, clothianidin). Recently, clothianidin used in seed treatments have caused widespread bee poisoning. Imidacloprid residues in plants can negatively alter bee behaviour.

Practices that promote the conservation and management of the pollinators

The selection of environment-friendly pesticides is an important agricultural management practice, with critical implications for pollinators. The current status of information on pesticide toxicity for pollinators is available through the Pollination Information Management System, along with profiles of best practices in managing wild pollinators for crop production. Adaptive modifications initiated by agriculturists, horticulturists, and foresters can help to minimize the negative impacts of a decline in insect pollinator populations. In the particular case of legumes, a sustainable approach was suggested by Palmer through provision of suitable floral resources among the crops themselves could help preserve and enhance the local bee fauna by creating new foraging places and nesting sites for solitary and social bees. Another approach involves the careful introduction of selected native pollinators, as in the case of the weevil (*Elaeidobius kamerunicus)* for the African oil palm in plantations in Asia.

At the field scale, pollinator-friendly practices include minimizing the use of farm chemicals through organic

Apis mellifera

Apis dorsata

Bumble bee

Stingless bee

Leaf cutter bee

Carpenter bee

Pollination and insect pollinators

production, integrated pest management, or finding alternatives to agrochemicals. A reduction in the use of herbicides, as well as pesticides, is recognized as having benefits for keeping pollinators in the crop fields. One innovative mango farmer in Ghana switched to removing the weeds manually instead of chemically, despite a seven-fold increase in costs. Herbicides killed the weeds to their roots, whereas they were quick to regenerate with the rains when cut manually; by allowing the weeds to selectively flourish when the mangos were in bloom that could attract more pollinators into fields and boost fruit yields.

SUMMARY

The consequences of pollinator decline are likely to impact the production and costs of vitamin-rich crops like fruits and vegetables, leading to increasingly unbalanced diets and health problems. Maintaining and increasing yields in horticultural crops under agricultural development is critically important to health, nutrition, food security and better farm incomes for poor farmers.

Low-intensity or diverse farming systems may provide suitable resources for many bee species, that in turn can provide pollination services for agricultural production. The Global Action on Pollination Services for Sustainable Agriculture provides guidance and relevant tools to use and conserve pollination services that sustain agro-ecosystem functions, and to formulate policies that will ensure sustainability of these ecosystem services. To this effect, the Global Action on Pollination Services for Sustainable Agriculture addresses a range of issues such as knowledge management of pollination services; the preparation of profiles from around the world, for best practices for the management of pollination services; working with other institutions to overcome the taxonomic impediment to pollinator conservation and use; and exploring other issues such as pollinator diversity and abundance on farms as well as linkages to climate change.

Thus, pollinators are essential for sustainable production. In spite of the essential contribution made by the pollinators are, they have been hardly given due attention and little has been done for their conservation and management. Therefore, efforts should be made towards conservation and management of the diversified group of pollinators for enhancing the crop production.

"Keeping honey bees and conserving other insect pollinators by farmers definitely gives direct additional income returns and are precious services to the mankind"

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Flowers always make people better, happier, and more helpful; they are sunshine, food and medicine for the soul.

– Luther Burbank