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RESEARCH ARTICLE

POLLINATION – ITS TYPE, THREATS AND ROLE IN ENVIRONMENT CONSERVATION

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ABSTRACT

Pollination is simply the transfer of pollen from the anther of one flower to the stigma of another or the same flower. After production of the sexual organs and associated structures, pollination is the first step in the reproductive process of higher plants. It is achieved by biotic and abiotic means. Abiotic pollination occurs by wind, water or gravity. Biotic pollination is effected by animals. Pollinating agents are essential for survival and reproduction of several wild plant species and in the recent years, there has been an increasing recognition of the importance of pollination, mostly by insects, in crop plants. The area covered by pollinator-dependent crops has increased by more than 300 per cent during the past 50 years. Few major crop species depend on animal pollinators. Animal pollination increases the quantity and quality of fruit production. Important Insect pollinators include honeybees, bumblebees, solitary bees, syrphid flies, wasps, beetles, butterfly and moths etc. Also commercially reared bumblebees are an important component of greenhouse tomato production. Plant-pollinator interaction in both wild and cultivated plant species is under threat as a result of indiscriminate pesticide use, habitat fragmentation and intensified cultivation practices. Pesticides are an important potential cause of biodiversity and pollinator decline. Climate change may affect the phenology and distribution ranges of both crop plants and their most important pollinators, leading to temporal and spatial mismatches. It is therefore important to identify the temperature sensitivity of the most important pollinators and their crop plants, and the environmental cues controlling the phenology and distribution of the identified species. Many wild plants in nature are being propagated through insect pollination which maintains the sustainability of ecosystems, environmental quality and help in the conservation of biodiversity. The pollinator species that do not visit crops play critical roles in natural ecosystems by ensuring wild plant seed and fruit set, thus sustaining wider biodiversity.

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INTRODUCTION

Pollination is simply the transfer of pollen from the anther of one flower to the stigma of another or the same flower. After production of the sexual organs and associated structures, pollination is the first step in the reproductive process of higher plants.

Two types of Pollination: Self pollination (Autogamy **&** Geitonogamy) **and Cross pollination (**Abiotic agents & Biotic agents)

Self Pollination: Pollen from an anther may fall on to the stigma of the same flower leading to self-pollination or autogamy.

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Geitonogamy: Pollen from a flower of one plant falls onto the stigmas of other flowers of the same plant. e.g., in maize.

Examples of Self pollinated crops:

Cereals and millets: Wheat, rice, barley, oats

Legumes: Pea, groundnut, gram, mung, cowpea, soybean, lentil

Vegetables: Tomato, okra, brinjal, potato, chillies

Forage crops: Burr clover, velvet bean, slender wheat grass

Oilseeds : Till, linseed

Fruit crops: Nectarine, citrus

Fiber crops: Jute (Singh, 2012)

Cross Pollination: Cross pollination is the transfer of pollen grains from the anther of one flower to the stigma of a genetically different flower. Cross pollination is performed with the help of an external agency are:

Agencies of pollination:

1.Abiotic
a)Wind (Anemophily) b) Water (Hydrophily)
2.Biotic
a)Insects (Entomophily) b) Birds (Ornithophily) c) Bats (Chiropterophily) d) Snails (Malcophily) e) Ants (Myrmecophily) f) Snakes (Ophiophily)
Entomophily: The pollen grains are transferred to a mature through the agency of insects like moths, butterflies, wasps, bees, beetles, etc.
e.g. : Toria, sarson, raya, kashmal, oee, safeda, punna, taramira, onion and cauliflower etc.

Characters:

1. They are showy or brightly coloured.
2. Most insect pollinated flowers have a landing platform.
3. The pollen grains are spiny, heavy and surrounded by a yellow oily sticky substance called pollen kit.
4. Stigmas are often inserted and sticky.
5. Some flowers provide safe place to insects for laying eggs, e.g.: Yucca.

Type	Anthophilous insect	Dependent plants
Cantharophily	Beetles	Magnolias, pond lilies, spicebush, goldenrods and Spirea etc.
Myophily	Flies	Orchids, mango
Phalaenophily	Moths	Morning glory, tobacco, yucca, and gardenia
Psychophily	Butterflies	Floricultural crops
Sphecophily	Wasps	Fig, goldenrod
Myrmecophily	Ants	Small's stonecrop, alpine nailwort and Cascade knotweed
Melittophily	Bees	Many horticultural & agricultural crops and forest plants

Importance of Entomophily

1) Increase in pollination efficiency.
2) Reduction of pollen wastage.
3) Successful pollination under conditions unsuitable for wind pollination.
4) Maximization of the number of plant species in a given area (as even rare plants can receive nonspecific pollen carried into the area by insects).

Threats to pollination:

1. Destruction of habitat and pollination landscapes
2. Parasites, pathogen and predators
3. Pollution
4. Introductions and competitive interaction
5. Climate change
6. Pesticides

Habitat destruction and pollination landscapes: There are three ways in which habitat destruction affects pollinator populations: (1) Destruction of food sources; (2) Destruction of nesting or oviposition sites and (3) Destruction of resting or mating sites. The most common means of habitat destruction are through the establishment of monocultures, overgrazing, land clearing, and irrigation. This section presents the issues of habitat destruction and considers agricultural landscapes and the livelihoods and importance of pollinators in different cropping systems. The destruction of food sources in agriculture results from removal of vegetation that provides the pollinators' food when crops are not in bloom **(Kevan *et al*., 1991).** Road-side and right-of-way sprayings of herbicides can reduce the diversity and abundance of alternative food supplies for pollinators. The destruction of nesting and oviposition sites in Manitoba led to the demise of populations of leaf cutting bees **(Megachildae)** which were left without nesting sites in stumps and logs as fields of alfalfa for seed production expanded. Landscapes dominated by annual crops (e.g., grains and oil seeds) are among the most intensively managed and most highly disturbed monocultures. Such high levels of disturbance hamper the establishment of pollinator populations **(Ellis and Ellis-Adam, 1995)** and most annual crops do not depend on insects for pollination. Cereals are wind-pollinated or set seed asexually, most beans are self-pollinating and many other crops do not require pollination because the harvests near roots, stems, leaves, and immature flowers. Nevertheless, some crops, such as canola, flax, safflower, sunflower, tomatoes, peppers, and strawberries require, or at least benefit from, insect pollination **(Free., 1993)**. A few field cucurbits (melons, cucumbers, squash, gourds, and pumpkins), some cole crops (some canola varieties, mustard, and oil seed radish) and some annual forage legumes require insect pollination and honeybees are the pollinators of choice. **Ricketts *et al*., (2008)** found a strongly significant negative effect of distance from natural habitat (due to habitat loss and/or conversion) on the richness and abundance of wild bees.

Parasites, pathogen and predators: The best known parasites and pathogens that have caused collapses of pollinator populations are the parasitic mites of European races of honeybees and the little studied epizootics of Thai sac brood, a virus disease of *A. cerana*. Parasitic mites, introduced into areas where they did not occur naturally, have evoked major concern. Tracheal mites (*Acarapis woodi*), native in Europe, and *Varroa jacobsoni* with *A. cerana* as its natural host have spread at alarming rates in North America and worldwide, respectively **(Connor *et al*., 1993)**. The numbers of feral colonies of honey bees has decreased significantly as mite infestations have become common throughout the USA. **Bailey and Ball, (1991)** provide up-to-date information on honeybee pathology worldwide. Diseases cause serious losses if not controlled through monitoring and treatment. American foulbrood, a bacterial disease of larvae, is the most serious disease challenging European honeybee keeping. Other brood diseases such as European foulbrood (bacterial), chalkbrood (fungal), and sacbrood (viral) are less problematic. The only disease of adult European honeybees that is of concern is dysentary (protozoan *Nosema*) which occurs in sporadic outbreaks.

Enhanced productivity of agricultural/horticultural crops

Horticultural crops	Increase in yield due to cross pollination (%)	Pollination requirements (No. of hives/ha)
Fruits		
Apple	18-69	2
Almond	50-75	5-8
Apricot	5-10	2.5
Citrus	7-233	2.5-3
Grapes	23-54	1-2
Peach	7-3788	1
Pears	240-6014	2-2.5
Strawberry	5-10	1-5
Plums	5-10	2.5
Vegetable (seed crops)		
Cole crops	100-300	5
Radish	22-100	5
Carrot	9-135	8 bees/sq. m.
Turnip	100-125	2.5
Cucurbits	21-6700	2-4
Onion	353-9878	--
Agricultural crops		
Oilseeds		
Mustard	13-222	2.5-5
Safflower	4-114	2
Sunflower	21-3400	2-4
Fodder crops		
Alfalfa	23-19733	5-10
Berseem	193-6800	2-5
Clovers	40-33150	2-5
Other crops		
Cotton	2-50	--

(Abrol, 2011)

For the Asiatic hive bee the viral disease Thai sacbrood has caused widespread losses **(Anderson, 1995)** as epidemics have swept parts of Asia, to be followed by resistance and recovery of populations **(Verma, 1990)**. Leaf-cutting bees also suffer from diseases. The most important is the chalkbrood fungal disease (caused by *Ascosphaera aggregata*) of the alfalfa leaf-cutting bee, *M. rotundata*. This disease has a major impact on the culture of alfalfa leaf-cutting bees.

Pollution: Agricultural chemicals, pollution seems to have exerted a minor influence on pollinators. Nevertheless, honeybees have been investigated as bioindicators to monitor pollutants. Honey or pollen or both may become contaminated with various industrial pollutants. The release of arsenic and cadmium may cause mass killings of honeybees and contaminate pollen, but not nectar **(Krunic *et al.*, 1989).** The accumulation of radioisotopes in honey and pollen following the Chernobyl disaster in April 1986 illustrates the value of honeybee colonies as samplers of local, regional, and global environmental quality **(Ford *et al.*, 1988). Bromenshenk *et al.*, (1991)** addressed the problem of population dynamics in honeybees with respect to pollution and so expanded concern for the health of pollinators beyond pesticide hazards.

Little information is available on the effects of pollutants on other pollinators. **Dewey, (1973)** showed that the highest levels of fluoride, associated with an aluminium reduction plant, were found in flower-visiting insects (from bumblebees to butterflies and hoverflies). Sulphur dioxide reduces activity of pollinators including honeybees and male sweat bees (*Lasioglossum zephrum*) but may not kill them.

Introductions and competitive interaction: Paton, (1993) concluded that there is justification for the concern that European honeybees have caused reductions in the pollination of some native plants, especially of those that are bird-pollinated, by removing the nectar sought by the birds and causing changes in their populations and foraging habits. Commercially reared bumblebees are an important component of greenhouse tomato production **(Kevan, 1999).** At least three regionally native species are being used, *Bombus terrestris* L. in Europe, *B. impatiens* Cresson in eastern North America, and *B. occidentalis* Greene in western North America. Protection of native populations is the primary concern and thus sensible constraints are applied mainly in the geographical areas of their use. Planned introductions of non-native bee species should be treated with great care, with attention paid to quarantine, and more importantly, to the possible ecological ramifications of escapes which are inevitable.

Climate change:

- Adaptation to the new environment
- Emigration to another suitable area
- Extinction

The first response is unlikely, since the expected climate change will occur too rapidly for populations to adapt by genetic change (evolution). As temperatures increase and exceed species' thermal tolerance levels, the species' distributions are expected to shift towards the poles and higher altitudes **(Hegland *et al.*, 2009).** Many studies have already found poleward expansions of plants **(Lenoir *et al.*, 2008)**, birds **(Zuckerberg *et al.*, 2009)** and butterflies **(Konvicka**

***et al*., 2003)** as a result of climate change. **Hegland *et al*., (2009)** discussed the consequences of temperature induced changes in plant-pollinator interactions. They found that timing of both plant flowering and pollinator activity seems to be strongly affected by temperature. Insects and plants may react differently to changed temperatures, creating temporal (phenological) and spatial (distributional) mismatches – with severe demographic consequences for the species involved. Mismatches may affect plants by reduced insect visitation and pollen deposition, while pollinators experience reduced food availability. Both *Apis mellifera* and *Pieris rapae* advanced their activity period more than their preferred forage species, resulting in a temporal mismatch with some of their main plant resources **(Hegland *et al.,* 2009).**

Precipitation: High precipitation may limit pollinators foraging activity. Optimal foraging conditions for pollinators are sunny days with low wind speed and intermediate temperature. Climate change is expected to alter existing precipitation patterns. Some areas will likely experience decreased rainfall, leading to more extensive drought periods. This water stress may decrease flower numbers and nectar production. Snow cover might also be reduced with increased temperatures.

Extreme climate events: Extreme climate events might have detrimental effects on both crop plants and pollinator populations. High temperatures, long periods of heavy rain and late frost may affect pollinator activity either by reducing population sizes or by affecting insect activity patterns.

Crop plant responses to climate change scenarios:

Changes in nectar and pollen amounts and quality: Pollen quality may change along with climatic conditions. It can be assessed by measuring post-pollination events such as counting the pollen germination rate on stigmas, measuring pollen tube growth and competition, and counting the survival of fertilized ovules, developed embryos and seed and fruit abortions.

Changes in phenology: Crop flowering phenology can be manipulated by altering climatic variables (temperature, precipitation, etc.). Important phenological events include the timing of flowering (e.g. duration and date of the first and last flowering), and frequency of flowering.

Pollinator responses to potential climate change scenarios:

Changes in pollinator behaviour: Pollinators may change behaviour in response to shifts in climate. It is likely that pollinators will change their activity patterns as temperature increases, in turn changing the efficiency of pollen removal and deposition. For this reason, it is important to investigate taxonomic differences in pollinators' ability to regulate body temperature and avoid overheating. Bumblebees are particularly prone to overheating if temperatures increase because of their large size, dark colour and hairy bodies.

Visitation quality: Numerous measures can be used to assess the visitation quality of pollinators, but for crop pollination, we suggest focusing on variables related to food production (e.g. seed set or fruit set).

Changes in pollinator distribution: The ultimate microclimatic limits for sustained flight activity are species specific, and may also differ between subspecies, races and populations of pollinators. Pollinators use several patches during the day for activities such as foraging, and the microclimatic limits may differ between these patches.

The economic value of crop pollination:

Pesticides: Most studies on pesticide toxicity and hazards to pollinators have dealt with honeybees, but these are poor bioindicators for effects on other pollinators, even bees **(Kevan and Plowright, 1995).** Improper pesticide and herbicide use is an important factor for pollinator decline. A number of plant species of the forest and forest margins suffer reduced fruit and seed set which in turn would be expected to impact wildlife by depriving them of natural quantities of food. Slower foraging of *Bombus impatiens* Cr. workers was observed after exposure to spinosad (a naturally derived insecticide) in pollen during larval development, at levels expected in agricultural systems treated with this insecticide **(Morandin, 2005),** and three neonicotinoids were found to have a negative influence on the foraging behaviour of *Bombus terrestris* L.

Role of Pollination in environmental conservation

Mechanisms of pollination have profound implications for the evolution, ecology and conservation of plants. The pollinator species that do not visit crops play critical roles in natural ecosystems by ensuring wild plant seed and fruit set, thus sustaining wider biodiversity of plants and higher trophic levels. Such species are very important for conservation of wild biodiversity and enhancing the flora and indirectly the fauna in the region. **McGregor (1976)** an eminent pollination scientist in United States had estimated that "One third of man's diet is derived directly or indirectly from insect pollinated plants". Many wild plants in nature are being propagated through insect pollination (Free 1993). It can be maintains the sustainability of ecosystems, environmental quality and help in the conservation of biodiversity. Pollinators are an element of crop associated biodiversity. To ensure reproduction, fruit set development and dispersal in plants, both in agro ecosystems and natural ecosystems. It can provide an essential ecosystem service to both natural and agricultural ecosystems. In agricultural ecosystems, pollinators and pollination can be managed to maximize or improve crop quality and yield.

Clean Air: Pollination helps Carbon Cycling/Sequestration which in turn help clean air. Flowering plants produce breathable oxygen by utilizing the carbon dioxide produced by plants and animals as they respire. Pollinators are key to reproduction of wild plants in our fragmented global landscape. Without them, existing populations of plants would decline, even if soil, air, nutrients, and other life-sustaining elements were available.

Impact of Pesticides

Trait	State	Expected insecticide impact	Potential consequence for wild flower pollination	Reference
Body size	Small	HIGH: (a) High surface area to volume ratio increases contact absorption. (b) Small bees tend to have shorter forage ranges and so those close to the application point of the insecticide will be more vulnerable	Plants relying on pollination by small bees may be disproportionally affected than those with larger pollinators able to fly longer distances.	Johansen (1972) Nunez *et al*. (2009) Greenleaf *et al*. (2007)
Sociality	Solitary	HIGH: Flight season species coincides with the application time of the insecticide then the impact will be high due to exposure. LOW: Flight season is outside the application time then the impact will be low.	Solitary bees are more often specialist pollinators than social species and so obligate out-crossing plants reliant on pollination by solitary bees may be vulnerable to local extinctions.	Heithaus (1979) Michener (2000)
	Social	HIGH: Pollinators are active during application time then the risk is high. LOW: The application time coincides with the activity of the pollinators.	The loss of generalist pollinators is predicted to have a greater impact on pollination networks and plant diversity than the loss of specialist pollinators.	Williams *et al*. (2010), Winfree *et al*. (2009) Thompson (2001) Memmott *et al*. (2004)
Floral Specialisa-tion	Polylectic	LOW: When collecting pollen/nectar from a variety of sources if one nectar/pollen source contains insecticide	Loss of generalist pollinators from a pollination network is expected to cause a greater overall decline in plant diversity compared to loss of a specialist.	Memmott *et al*. (2004)
	Oligolectic	HIGH: Forage plants are in or near a site where insecticide is sprayed. LOW: Forage plants are not near any cropped fields where insecticide is applied.	Oligolectic pollinator often visit generalist plants with a range of pollinators. The pollination network and plant diversity will be less affected by the loss of a specialist pollinator species.	Dewenter *et al*. (2006) Kremen and Ricketts (2000) Memmott *et al*. (2004)
Nesting (location and construction)	Ground nesting	LOW: Site is not close to area of insecticide application. HIGH: Near the crop; larvae can be more sensitive to the toxic effects of insecticides and may be exposed through run off if the insecticide is water soluble.	Plants that grow in or near crops that are sprayed with insecticide are more vulnerable than those in natural habitats where their pollinators are less likely to come into contact with insecticide.	Kremen and Ricketts (2000)
	Above ground nesting	LOW: Usually nest in stems/twigs either above the area of application or in habitat away from crop. HIGH: Nesting in hedgerow stems adjacent to a crop. Nesting in orchards which are sprayed with insecticide. Nesting materials (plant/mud) contaminated with insecticide.	Plants pollinated by above ground nesting pollinators are generally less vulnerable than those pollinated by ground nesting bees.	Alston *et al*. (2007)
Sex		Males may be more susceptible than females. In some species this may be due to their smaller size.	Male may contribute more long distance pollen flow. A reduction in this could reduce out-crossing and plant fitness.	Tasei (2002) Nunez *et al*. (2009) Neeman, Shavit, Shaltier, and Shmida (2006)

Water and soils: Flowering plants help to purify water and prevent erosion through roots that holds the soil in place, and foliage that buffers the impact of rain as it falls to the earth. The water cycle depends on plants to return moisture to the atmosphere and plants depend on pollinators to help them reproduce.

Ecological and economic consequences of pollinator declines: Pollinator loss will impact two broad groups of pollinator dependent flowering plants: wild flowers and cultivated crops **(Potts *et al*., 2010).**

Impact of pollinator decline on wild flower pollination: The decline in pollinator diversity and abundance can bring with it a decline in pollination services for wild plant populations, potentially affecting populations of animal pollinated.

Most wild plant species (80%) are directly dependent on insect pollination for fruit and seed set, and many (62–73%) of the plant populations investigated showed pollination limitation, at least some of the time, although this may vary markedly between sites and seasons. Obligate outcrossing animal-pollinated plants are particularly vulnerable to declines in pollination services, and such species have generally declined in parallel with their pollinators. Although there might be many ways for short-term compensation for poor pollination (e.g. clonal propagation), this cannot compensate in the long-term for a chronic loss of pollination services: in a meta-analysis of 54 studies (covering 89 plant species), the most frequent proximate cause of reproductive impairment of wild plant populations in fragmented habitats was pollination limitation. For example, local extinction of the super generalist honeybee as a result of disease is not unlikely and could lead to considerable species loss of plants. Asymmetric and nested network patterns are widespread and largely independent of community composition, geographic location and other factors; asymmetric networks are also suggested to have a high level of redundancy making them relatively robust to the loss of species and interactions. However, ongoing global change affects not only species occurrences, but also species interactions and interaction pathways. Thus, in the face of severe disturbance, plant–pollinator networks could also reach a tipping point and collapse despite their seemingly robust structure.

Impacts of pollinator declines on crop production: Insect pollination, mostly by bees, is necessary for 75% of all crops that are used directly for human food worldwide. Although many of the highest volume crops (e.g. rice and wheat) are wind-pollinated, a large proportion of fruit crops (e.g. apple, melon and berry) are potentially vulnerable to declines in apiculture and wild pollinator stocks. The cultivation of pollinator-dependent crops steadily increased between 1961 and 2006. Although the average yield increase over time is no lower than for pollinator-independent crops, a more detailed analysis has revealed that a large proportion of this annual yield increase can be explained by the use of commercial pollinators (usually honey bees) or hand pollination (a relatively rare practice). Until now, most growers have either matched their pollinator needs by renting honey bees, or utilized the 'free' services of wild bee species foraging in farm fields, a component of pollination services that has largely been overlooked in economic calculations. Despite the importance of pollination for crop production, there is still a lack of basic information about how species diversity, and the abundance and community composition of pollinating insects, contributes to seed and fruit yield and quality in most crops. The global annual economic value of insect pollination was estimated to be € 153 billion **(Gallei *et al*., 2009).** Complete pollinator loss would translate into a production deficit over current consumption levels of -12 per cent for fruits and -6 per cent for vegetables. Insect pollination, mostly by bees, is necessary for 75 per cent of all crops that are used directly for human food worldwide

Strategies for conservation (Patnaik and Stapathy, 2011)

1) Honey hunting should be discouraged
2) Native pollinators should be conserved
3) Avoid monoculture
4) Safe use of pesticides
5) Other Strategies

Honey hunting should be discouraged: Hunting of the natural nests of the three bee species viz., *Apis dorsata*, *A. florae* and *A. indica* and to some extent local sting less species, *Trigona* bee by certain forest tribal communities must be discouraged.

Native pollinators should be conserved: The native bee particularly the solitary bee as a complimentary to honey bee activity need immediate attention. Conservation of flower wasp, *Campsomeriella* spp, the leaf cutter bee, *Megachile gathela* Cam.(Family:- Megachilidae), the carpenter bee species *Xylocopa tenuiscapa* and *X. pubescens* and the mining bee, *Andrena ilerda* are important, work under inclement weather conditions and can act as efficient pollinators. Insect like flower wasp, *Campsomeriella* spp. and flower flies which have dual role in ecosystem i.e. they control pest as well as pollinate the crops.

Avoid monoculture: Pollinators can be encouraged by choosing plants that flower at different times of the year to provide nectar and pollen sources throughout the growing season. Planting in clumps, rather than single plants, to better attract pollinators and providing a variety of flower colors and shapes to attract different pollinators. At the farm level strategies adopt can include increased farm diversity, including crop diversity, and changes in sowing date, crops or cultivars.

Safe use of pesticides

1. Avoid the application of a pesticide to a crop in bloom
2. Pesticide dusts and small granules should not be left open or thrown carelessly anywhere
3. Use pesticides only when needed:
   - Don't apply any pesticides unless the crop is heavily infested
   - If necessary, use those insecticides which are non-toxic or less harmful
4. Use of safest formulation of an insecticide
   - Granular, emulsifiable and water soluble formulations are safest for bees as compared to dust formulation
   - Adding a solvent or an oily substance tends to make the sprays safer for the pollinators
5. The timing of application should be monitored for least effect on pollinator species:
   - Never apply pesticides while the crop is in bloom or while interplants, weeds or adjacent crops are in bloom
   - Never apply insecticides when pollinators are flying
   - Evening or late evening applications depending upon pollinator activities on the crop are relatively safe
6. Method of pesticide application:
   - Ground application is safer than aerial application
   - Fine sprays are safer than coarse ones
   - A combined application is often safer as well as cheaper than application of separate insecticides at different times
   - Do not spray directly onto hives
   - Repellants may be used to discourage pollinators from foraging on the treated crop like acetone, diethyl ketone, neem oil carbolic acid *etc.*

Others Strategies

- ✓ Agricultural inputs like irrigation, plant protection, fertilizer
  - Policy makers must go for inclusion of pollination as the key agri-hort. input
- ✓ Identification of important pollinators. Encourage local clubs or school groups to build artificial habitats such as butterfly gardens, bee boards and bee boxes. Support funding for research on pollinators and the economic benefits. Encourage government agencies to take into account the full economic benefits of wild pollinators

when formulating policies for agriculture and other land uses

- ✓ Stress the need to develop techniques for cultivating native pollinator species for crop pollination. Bring the importance of biological diversity to the attention of state and national representatives.

Conclusion

Pollination plays a vital role in the food supply and biodiversity conservation. Pollinators are a key component of global biodiversity by providing vital ecosystem services to crops and wild plants. Pollinators can be harmed by some pesticides used to manage insects, mites and diseases in crops. Premeditated strategies for climate change and pollinator conservation need to be devised. There is a continued need to improve our understanding of the nature, causes and consequences of declines in pollinator services at local, national, continental and global scales. Conserving pollinators directly conserves the future of biodiversity.

REFERENCES

Abrol, D.P. 2011. Honeybees and pollination. In: *the proceeding of Honey festival cum experience exchange workshop on prospects and promotion of apiculture for augmenting hive and crop productivity*, Ludhiana. p 58-63.

Alston, D. G., Tepedino, V. J., Bradley, B. A., Toler, T. R., Griswold, T. L., and Messinger, S.M. 2007. Effects of the insecticide phosmet on solitary bee foraging and nesting in orchards of Capitol Reef national park, Utah. Environmental Entomology, 36, 811–816.

Bailey, L. and Ball, B.V. 1991. Honey Bee Pathology, 2nd ed. Academic Press, London. p 193.

Bromenshenk, J.J., Gudatis, J.L., Carlson, S.R., Thomas, J.M. and Simmons, M.A. 1991. Population dynamics of honey bee nucleus colonies exposed to industrial polutants. *Apidologie* 22: 359-369.

Connor, L.J., Rinderer, T., Sylvester, H.A. and Wongsiri, S. 1993. Asian Apiculture *Proceeding 1st International Conference on Asian Honey Bees and Bee Mites*. Wicwas Press, Cheshire, CT, USA, p 704.

Dewey, J.E. 1973. Accumulation of fluorides by insects near an emission source in western Montana. *Environmental Entomology* 2: 179–182.

Ellis, W.N. and Ellis-Adam, A.C. 1995. Flower visitation, plant's life forms, plant's life forms and ecological charcteristicsm. *Entomology Society* 6:53–58.

Ford, B.C., Jester, W.A., Griffith, S.M., Morse, R.A., Zall, R.R., Burgett, D.M., Bodyfelt, F.W. and Lisk, D.J. 1988. Cesium-134 and Cesium-137 in honey bees and cheese samples collected in the US after the Chernobyl accident. *Chemosphere* 17:1153-1157.

Free, J.B. 1993. Insect pollination of crops (2^{nd} edition). Academic Press London, U.K. p 684.

Gallai, N., Salles, J.M., Settele, J. and Vaissiere, B.E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68: 810-821.

Greenleaf, S. S.,Williams, N. M.,Winfree, R.,&Kremen, C. 2007. Bee foraging ranges and their relationship to body size. *Oecologia*, *153*, 589–596.

Hegland, S.J., Nielsen, A., Lazaro, A., Bjerknes, A.L. and Totland, Q. 2009. How does climate warming affect plant-pollinator interactions? *Ecol Letters* 12: 184-195.

Heithaus, E. R. 1979. Flower-feeding specialization in wild bee and wasp communities in seasonal neotropical habitats. *Oecologia 42*, 179–194.

Johansen, C. A. 1972. Toxicity of field-weather insecticide residues to four kinds of bees. *Environmental Entomology*, *1*, 393–394.

Kevan, P.G. 1999. Pollinators as bioindicators of the state of the environment, species activity and diversity. *Agriculture, ecosystems and environment* 74: 373-393.

Kevan, P.G. and Plowright, R.C. 1995. Forest Insect Pests in Canada. In: Natural Resources Canada, Canadian Forest Services, Ottawa p 607–618.

Klein, A.M., Vaissiere, B., Cane, J.H., Steffan, D.I., Cunningham, S.A., Kremen, C. and Tasei, J. N. 2002. Impact of agrochemicals on non-Apis bees. In J. Devillers, & M.-H. Pham-Delègue (Eds.), *Honey bees: Estimating the environmental impact of chemicals* (pp. 101–131). London: Taylor & Francis.

Konvicka, M., Maradova, M., Benes, J., Fric, Z. and Kepka, P. 2003. Uphill shifts in distribution of butterflies in the Czech Republic: effects of changing climate detected on a regional scale. *Global Ecology Biogeography* 12: 403-410.

Kremen, C., & Ricketts, T. 2000. Global perspectives on pollinator disruptions. *Conservation Biology*, *14*, 1226–1228.

Lenoir, J., Gegout, J.C., Marquet, P.A., de-Ruffray, P. and Brisse, H. 2008. A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320: 1768-1771

McGregor, S.E. 1976. Insect pollination of cultivated crop plants. Agricultural Handbook p 496.

Memmott, J., Waser, N. M., & Price, M. V. 2004. Tolerance of pollination networks to species extinctions. *Proceedings of the Royal Society B*, *271*, 2605–2611.

Michener, C. D. 2000. *The bees of the world*. Baltimore: The John Hopkins University Press Morandin, L.A. 2005. Lethal and sub-lethal effects of spinosad on bumble bees (*Bombus impatiens* Cresson). *Pest Management and Science* 61: 619-626.

Ne'eman, G., Shavit, O., Shaltier, L., & Shmida, A. 2006. Foraging my male and female solitary bees with implications for pollination. *Journal of Insect Behavior*, *19*, 383–401.

Patnaik, H.P. and Satapathy, C.R. 2011. Insect pollinators and their conservation priorities-an overview with special reference to odisha. In: *the proceeding of Biennial group meeting of AICRP on honeybees and pollinators.* p 55-63.

Paton, D.C. 1993. Honeybees in the Australian environment. *Bioscience* 43: 95-103.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* 25: 345-353.

Singh, B.D. 2012. Plant breeding principles and methods. Ninth edition, Kalyani publisher Ludhiana. p 60-63.

Steffan-Dewenter, I., Klein, A. M., Gaebele, V., Alfert, T., & Tscharntke, T. 2006. Bee diversity and plant–pollinator interactions in fragmented landscapes. In N.Waser,&J.

Ollerton (Eds.), Plant–pollinator interactions: From specialization to generalization (pp. 387–407). Chicago, IL, USA: University of Chicago Press.

Thompson, H. M. 2001. Assessing the exposure and toxicity of pesticides to bumblebees (*Bombus* sp.). *Apidologie*, *32*, 305–321.

Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. In: *Proceedings of the Royal Society* B, 274: 303-313.

Valdovinos-Nú˜nez, G. R., Quezada-Euán, J. J. G., Ancona-Xiu, P., Moo-Valle, H., Carmona, A., & Ruiz Sánchez, E. 2009. Comparative toxicity of pesticides to stingless bees (Hymenoptera: Apidae: eliponini). *Journal of Economic Entomology*, *102*, 1737–1742.

Williams, N. M., Crone, E. E., Roulston, T. H., Minckley, R. L. Packer, L. & Potts, S. G. 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. *Biological Conservation*, doi:10.1016/j.biocon.2010.03.024.

Winfree, R., Aguilar, R., Vázquez, D. P., LeBuhn, G., & Aizen, M. A. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology*, *90*, 2068–2076.

Zuckerberg, B., Woods, A.M. and Porter, W.F. 2009. Poleward shifts in breeding bird distributions in New York State. *Global Change Biology* 15: 1866-1883.

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