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Review

Bees as Pollinators – Biodiversity and Conservation

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Insects provide numerous primary environmental services from recycling of nutrients to pollination, beside their fundamental contribution to food resources of many vertebrate animals. Consequently insects should be at the core of any commitment of the world to the International Convention on Biodiversity. Pollination is one of the most important mechanisms in the maintenance and conservation of biodiversity and in general life on earth. Pollination also benefits society by increasing food security and improving livelihoods, hence pollinator diversity is important. Two thirds of the world's 3000 species of agricultural crops require agents for pollination. Pollinators provide an ecosystem service that enables plants to produce fruits and seeds. Pollinators are found in diverse groups of the animal kingdom, including birds, bats, reptiles, insects, etc. Among the several animals, insects particularly honey bees, dominate in providing pollination services to several plants. Several other pollinators including carpenter bees, bumble bees, megachilids, halictids, sphecids, andrenids, syrphids, etc. are known to occur in the country. We have always under evaluated their contribution perhaps because of our limited insight into their behaviour mechanism for nesting. But today the modern beekeeping suffers from a magnitude of problems, including parasitic mites, honey bee diseases, inability of honey bees to work at low temperature and adverse climatic conditions. These difficulties threaten the honey bees general utility as an agricultural pollinator. Therefore, Conservation of biodiversity of honey bees and wild pollinators is important to realize the potential yields of several cross-pollinated crops, hybrid seed production, crops grown under poly-house conditions and in conservation of rare and endemic species in the country.

Keywords: Bees, biodiversity, pollination, conservation.

INTRODUCTION

Insect pollination of agricultural crops is a critical ecosystem service. Fruit, vegetable or seed production from 87 of the 115 leading global food crops depends upon animal pollination (Klein *et al*., 2007). The value of insect pollination for worldwide agricultural production is estimated at 153 billion, which represents 9.5% of the value of the world agricultural production used for human food in 2005 (Gallai *et al*., 2009). In India, about 80 per cent or more of the crop plants depend or stand benefited from insect pollination. The benefit accrued to nature in general and mankind to particular by pollinators is enormous. Specific plant-pollinator relationships have been built during the co-evolution of angiosperms and insects. The role played by specific species of pollinators in the conservation of rare species of orchids is documented. About 750 to 1000 bee floral plants are estimated to be growing in India. Of the 160 million hectare of the cropped area, more than 55 million hectare is under bee dependent crops. Beside, our mountains, forests, pastures, undulated and uncultivated lands, wastelands, ponds, rivers and lakes are inhabited by diverse vegetation and flowering plants. Even in cultivated fields, where more than 65 per cent of the crops are insect pollinated, there exists a wide plethora of flowering weeds, herbs, shrubs, creepers and bushes which are valuable to the pollinators. Such a diversity of existing flower forms requires a diversity of pollinators for effective and efficient pollination. Considering the fact that intensification and diversification are pre-requisite for sustenance of agriculture and are likely to be vigorously followed to support the needs of burgeoning population, in such a scenario, the services of pollinators become of pivotal significance in enhancing the crop productivity of both natural and agro-ecosystems.

The *Apis mellifera* has occupied dominating position in commercial pollination around world because this is highly social bee. But of the other hand wild bees are also valuable pollinators. We have always under evaluated their contribution perhaps because of our limited insight into their behaviour mechanism for nesting. The other reason may be that we are more reliable on the easily manageable honey bees which provide by-products also. But today the modern beekeeping suffers from a magnitude of problems, including parasitic mites, honey bee diseases, unability of honey bees to work at low temperature and adverse climatic conditions. These difficulties threatens the honey bees general utility as an agricultural pollinator (Torchio, 1990) This contributes to the concern to beekeepers, growers of insect-pollinated crops, and policy-makers over recent widespread declines in honey bee populations (Colony Collapse Disorder).

Wild and domesticated non-*Apis* bees effectively complement honey bee pollination in many crops. Examples of management of non-*Apis* species for agricultural pollination include the use of bumble bees, primarily for the pollination of greenhouse tomatoes, the solitary bees *Nomia* and *Osmia* for the pollination of orchard crops, *Megachile* for alfalfa pollination, and social stingless bees to pollinate coffee and other crops. The value of the alfalafa leaf cutting bee *M. rotunda* (F.) as a better pollinator than honey bees for alfalfa has been clearly demonstrated by Richard, 1987. he concluded that the real impact of introduction of *Megachile* bees stating that alfalfa seed yield increased from 50 kg/ha to 350 kg/ha and with more careful handling it can be raised upto 1000 kg/ha.

There are about 19,000 described species of bees in the world (Linsley, 1958) and, with the exception of one species, *Apis mellifera* L., the domestic honey bee, all of them are grouped under the general term "wild bees." These include:

Short-tongued bees

Family	Important genera
Andrenidaea	*Andrena, Panurginus, Perdita, Pseudopanurginus*
Colletidae	*Colletes, Hylaeus*
Halictidae	*Agapostemon, Dufournea, Halictus, Nomia*
Melittidae	*Hesperapis, Melitta*

Long-tongued bees

Anthophoridae	*Anthophora, Melissodes, Nomada, Xylocopa*
Apidae	*Apis, Bombus, Euglossa, Melipona, Trigona*
Megachilidae	*Anthidium, Lithurgus, Megachile, Osmia*

Cross pollination plays important role in increasing the plant diversity and the survival of plant species through mixing of gene pool of plant population. Many self-pollinated plant species will perish if occasional cross-pollination does not take place. On the other hand, some plant species are exclusively dependent on cross pollination for reproduction and there exist various reproductive barriers like self incompatibility /self sterility, low pollen viability, asynchrony in floral events, monoecy, dioecy, heterostyly, etc. that necessitate cross pollination. Insects help in crop pollination in plants having heavy and sticky pollen which cannot be blown by wind and also where pollen is produced in limited quantity and its wastage is not affordable e.g. in apple, pear, peach, cucurbits, onion, etc. In order to maximize agricultural/ horticultural production, several inputs such as improved seeds, improved implements, irrigation, cultivation, fertilizers and pesticides have been recommended. But these components when fully exploited may not even give marginal returns, necessitating, therefore, looking for other possible strategies. One such possibility is planned pollination through bees. Pollination is a vital step in the reproduction of flowering plants which leads to fertilization and fruit/ seed setting. Though several insects visiting crop blooms may cause pollination, but bees have true symbiotic relationship with plants and significantly contribute towards crop pollination. However, bee pollination as input for crop production is mostly ignored. Bees are considered to be the best agents of crop pollination because they visit the flowers purposely to gather pollen and other floral rewards, have high floral constancy (thoroughness), their body is body profusely hairy, are amenable, are non-pests of crops in immature and adult stages and honey bees also provide honey and other valuable bee products.

Honey Bees as Pollinators

Bees pollinate 16 per cent of the total of 0.25 million plant species. Worldwide, 90 per cent food supply is contributed by 82 commodities assigned to plant species and bees are pollinators of 63 (i.e.70%) of these plant species and are the most important known pollinators of 39 (48%) of these plant species. One-third of human diet is derived directly or indirectly from bee pollination in developed countries.

The honey bee genome has already been sequenced and it emerges that India is endowed with the greatest biodiversity as far as honey bee species are concerned. In fact, the centre of origin of *Apis* is the Indian subcontinent and it is from here that different species have radiated to other parts of the world including the European honey bee, *Apis mellifera* L. Out of the eight commonly known *Apis* species, five (*A. cerana*, *A. florea*, *A. dorsata*, *A. andreniformis*, *A. laboriosa*) are indigenous to India and *A. melllifera* has been introduced into our country. A plethora of other bee species (>1000) and bee floral diversity (750-1000 bee floral plants) is known to occur in the country. The depletion in population of honey bees and other pollinators in various agro-ecosystems due to habitat destruction, pesticide applications, plant diversity loss, mechanization and poor agricultural practices is a matter of serious concern for the country.

Beekeeping is popular in several parts of the country though it is mostly seen as a honey producing enterprise. As an enterprise beekeeping or rearing of *Apis* species in hives is an ideal, low cost, eco-friendly, non-land based enterprise which does not compete for resources of farming systems, provides sustainable livelihood to the rural/ indigenous people and can be adopted by landless people. It is the most suited for integrated agriculture and generating employment for rural people, youth and women. Further it forms an important input for increasing crop production in several cross-pollinated crops.

Ample yield increases in fruit crops have been recorded from honey bee pollination in India (apple 25-55%, peach 2.6 times, plum 2.5-3.7 times, apricot 48%, litchi 2-3 times, citrus 22%). The National Bee Board has, however, of late, reported exponential increases in fruit yields (apple 180-6950%, pear 240-6014%, cherries 56-1000%, strawberry 17.4-91.9%, litchi 4538-10246%, orange 47-900%, citrus 7-33.3% and guava 70-140%). At the global level, 33 fruit crops have been identified which need bee pollination for increase in their yields. In India, 12 crops including eight fruit crops (almond, apple, citrus, coconut, guava, grapes, mango and papaya) are most dependent on honey bee pollination. Based on the requirement of 2-3 colonies/ ha, depending upon the acreage under these crops in India, it has been estimated that 737 lakh honey bee colonies will be required for optimizing crop pollination. This would have resulted in the additional production of these crops worth Rs 3000 crore annually. However, the number of hive bee colonies in the country is too less, i.e. only 17 lakh necessitating 720 lakh additional hive honey bee colonies to obtain optimum pollination of these crops.

As per the latest estimates by the National Bee Board of India, India needs 1500-2000 lakh honey bee colonies for pollination of various crops. Realizing the importance of managed bee pollination of crops in India, ICAR has considered bees as important input for crops pollination and hive products as secondary/ by-products. Ministry of Agriculture under National Horticulture Mission has launched a 50 per cent subsidy scheme on procurement of honey bee colonies for horticultural crops pollination with the precondition of the farmer to be a fruit/ vegetables/ flowers grower. Planned crop pollination is considered the most important input as all other inputs will be just useless if pollination does not occur just like all human senses fail if sense of coordination, i.e. brain fails. Crop pollination is the last chance to increase yields. All post pollination inputs (growth regulators, herbicides, fungicides or insecticides) are designed not to increase yield but to conserve yield losses. Because of yield optimizing benefits, bee pollination can play in important role in maintaining a sustainable and profitable agriculture with minimum environmental disruptions. Value of bee pollination goes beyond the production of agricultural crops as bees also pollinate non agriculture, forest and ornamental plants that control erosion, beautify the environment and conserve wild life through food production. Thus, it is high time looking at yield plateaus to realize the role of honey bees as pollinators and their conservation and augmentation. Extension of eco-friendly concept of ‘Bees as input in crop production’ without degrading our environment is possible only through growers’ participatory awareness campaigns.

Importance and Management of Wild Bees as Pollinators

There is great biodiversity as far as bee species are concerned. Several wild pollinators including carpenter bees, bumble bees, megachilids, halictids, sphecids, andrenids, syrphids, etc. are known to occur everywhere in the world. Native bees are very efficient as they are active early and later part of the day, collect both pollen and nectar, enable buzz pollination as opposed to contact pollination by honey bees, keep honey bees moving between flowers, no rental fees needed like for honey bee colonies and they can supplement honey bees if honey bee colonies are difficult and hard to acquire. There is a need to document and characterize the biodiversity of honey bees and other pollinators. The diversity of stingless bees, especially in the NE parts of the country is enormous. These bees can be exploited for controlled pollination of crops and can also be ideal for export to other countries. Similarly bumble bees can also be reared in controlled conditions and used for pollination of crops grown under protected cultivation, like strawberry, capsicum, etc. The documentation, characterization and utilization of the biodiversity of honey bees and other pollinators have not been systematically attempted as for several other insects in the biodiversity rich areas of Western Ghats and eastern Himalayas. The impact of habitat destruction, alien species invasion, monoculture, chemical use, etc. on the pollinators is also not clear.

Numerous species of wild bees can be found almost anywhere plants grow, for example, the Melissodes bees (Melissodes spp.) in cotton fields (Butler et al., 1960). Wild bees doubtless provide, in the aggregate, millions of dollars to the economy of agriculture. Their value to range, forests, fields, and ornamental flowers is impossible to measure, but it should not be overlooked. The demonstrated value of the few species over which man has learned to exercise some control is sufficient to support the claim that this group of largely overlooked insects is an essential segment of our agriculture as well as our general ecological environment. As such, more intensive study should be made of the various species to determine the practicability of their preservation, culture, and use on various insect-pollinated crops.

The time of day that wild bees forage differs with the species involved. Those that feed only at dawn are referred to as matinal bees. Crepuscular bees feed both at dawn and near dusk. A few species are nocturnal in their foraging, but the great majority feed when the sun is shining, because that is when the majority of the flowers are open (Linsley, 1960).

The distance that the different species of wild bees may forage must vary enormously. Janzen (1971) reported that an individual *Euplusia surinamensis* (L.) returned to its nest from a distance of 23 km (14.3 miles). He calculated that another individual flew as much as 24.4 km (15.2 miles) to and from the foraging area. By comparison, the alkali bee (*Nomia melanderi*) may forage 4 or 5 miles from its nesting site (Stephen, 1959); whereas the alfalfa leafcutter bee (*Megachile pacifica*) usually forages within only a few hundred feet of the nest (Bohart, 1962b). Visitation to plants by wild bees is highly variable. Some species visit many different families of plants, others visit only a few closely related families, and still others visit only a single species or closely related species. In different instances, each type of activity would be advantageous.

Only to a limited extent has man learned how to manipulate a few species in a few genera of wild bees. He can construct nesting sites and transport immature leafcutter bees (*Megachile pacifica*) and alkali bees (*Nomia melanderi*). These bees are used in large-scale pollination of legume crops in the Western States in USA. Alfalfa nectar and pollen constitute the primary source of food for most female alkali bees. They visit a few other plant species, for example, clovers, mint, onions, Russian thistle, salt cedar, and sweetclovers. In alfalfa seed producing areas, however, most of the nests are provisioned with nectar-moistened pollen balls derived from alfalfa. While foraging, alkali bees do not trip the alfalfa blossoms as rapidly as do the leafcutter bees, but almost every blossom they visit is tripped. Because of the large number of flowers the females visit, they become highly effective. Bohart and Knowlton (1967) stated that two large nesting sites in Utah, one of which had an estimated 200,000 nesting females, "provided good pollination for the alfalfa-seed fields within a radius of at least 2 miles." The males visit flowers for nectar only and only occasionally trip the flowers.

The alfalfa leafcutter bee derives its food and nesting material primarily from alfalfa; however, it will forage on sweet clovers (*Melilotus* spp.), white clover (*Trifolium repens* L.), some of the wild mints (*Mentha* spp.), and a few other species. Goplen (1970) reported that this bee preferred purple alfalfa flowers to yellow flowers to a degree that influenced pod and seed set. The effect of this preference in commercial seed production has not been determined. The adult does not forage at temperatures below 70 deg F (Hobbs, 1964). The female visits flower after flower in rapid succession, tripping almost every flower visited, 11 to 15 per minute. She forages no farther from her nest than necessary, usually within the field where the nest is located, and most often within a few hundred feet of the nest. The male visits flowers for nectar only and seldom trips a flower. Hobbs (1967) stated that alfalfa fields can be thoroughly pollinated in 3 weeks with about 40,000 females per acre. Klostermeyer (1964) indicated that at least 2,000 females per acre were necessary for each 500 pounds of clean alfalfa seed produced. Other figures fall between these extremes.

Members of the Apidae subfamily Meliponinae or "stingless bees" are social insects. Some species have clusters of as many as 80,000 individuals; other species, less than 100. Numerous species of the genera *Melipona* and *Trigona* are induced to nest in prepared domiciles, such as hollowed-out gourds, hollow tree sections, or manufactured hives, from which a few ounces to a few pounds of honey may be harvested. Some of these colonies are also placed near crops needing pollination. Stingless bees were kept by man centuries before the arrival of Columbus or the common honey bee (Bennett, 1964). Some species produce an acceptably delectable honey, as much as half a gallon per colony per year. Others produce less desirable, thin (35 percent moisture versus half that amount in our domestic honeys), strongly acid honeys. One species (*Trigona* (*Lestrimellita*) *limao* Smith) produces a honey used to induce vomiting (Bennett, 1965). The most common species used in miliponiculture is *Melipona beechii* Bennett. Stingless bees are of great economic significance in Mexico as well as Central and South America. They are distributed widely over the tropical and subtropical areas of the world. They are also cultured for the production of honey and "wax". These bees have been studied taxonomically by Schwarz (1948) and behaviorally by several workers, especially by Nogueira-Neto (1948, 1951), Kerr (1946, 1948, 1951), Sakagami (1966). Meliponiculture was reviewed and discussed from the practical standpoint by Ordetx and Perez (1966).

Slight progress has been made in inducing numerous species of bumble bees (*Bombus* spp.) to nest in specially prepared boxes or nests that can be transported to fields to be pollinated. Bumble bees (*Bombus*) are important pollinators of crops and native plants. There are dozens of species of bumble bees (*Bombus*) in the world. Most of them are excellent pollinators of a wide variety of crop, although in some plant species they cut a hole in the base of the corolla and "rob" the nectar without effecting pollination. There is much interest in conserving and augmenting wild populations of bumble bees for pollination. A number of workers have described its biology and management. Bumble bees can be induced to occupy manmade nests or hives, such as the 6-inch cube hive used by Hobbs (1964) and hives, cans, or tile used by Fye and Medler (1954) and others. They can also be induced to live, mate, nest, and hibernate in greenhouses to a degree that they can be useful as pollinators of small plots (Pedersen and Bohart, 1950). Holm (1966) reported that 31 species have been colonized. Unfortunately, their culture is considerably hampered by their nest abandonment each fall. This characteristic prohibits the maintenance of colonies, such as is the case with honey bees or Meliponinae; storage of immature stages as with leafcutter bees, or even maintenance of the immature stages in the area, as with the alkali bees.

Bumble bees are further hampered by diseases and parasites; predators such as mice, skunks, badgers and birds, and man-created problems such as pesticides and the destruction of nesting sites. Their usefulness under natural conditions can be increased by the individual grower or the community where their services are desired. They can be "encouraged" in an area by providing nests and nesting areas for them. Their enemies can be controlled and consideration can be given in the use of herbicides and insecticides. Crops can be planted or wild flowers encouraged on which they can forage during periods when food might otherwise be unavailable.

Osmia bees (*Osmia cornifrons*) can be induced to nest in bamboo canes, which are then transported to fields to be pollinated. Bohart (1972) reviewed the information on *Osmia* pollination. He stated that *O. cornifrons* (Rad.) has been successfully managed for apple pollination since 1958 in northern and central Honshu, Japan. The bees are captured away from fields or orchards treated with insecticide, taken to the orchard, and released at the time of apple bloom. The bees nest in bamboo and hollow reeds placed by the growers on shaded platforms in or near the apple orchards. These bees usually begin to fly about 2 weeks before apples come into bloom. They fly at temperatures as low as 45 degree F., some 20 degree below that at which honey bees fly.

Levin (1957) induced *O. lignaris* Say to nest in specially prepared tubes, 3/8 by 4 by 6 inches, bored in lumber. Levin and Haydak (1957) were able to rear the same species on bee-collected pollen but not as efficiently as on *Osmia*-collected pollen.

Free and Williams (1970) showed that *O. rufa* (L.) tended to be gregarious and could be induced to nest in drinking (soda) straws. It showed a preference for *Rubus* spp. and other specific plants, indicating that it could be used to advantage

Large carpenter bees (genus *Xylocopa*) are wood-nesting generalist pollinators of broad geographical distribution that exhibit varying levels of sociality. Their foraging is characterized by a wide range of food plants, long season of activity, tolerance of high temperatures, and activity under low illumination levels. These traits make them attractive candidates for agricultural pollination in hot climates, particularly in greenhouses, and of night-blooming crops. Carpenter bees have demonstrated efficient pollination service in passionflower, blueberries, greenhouse tomatoes and greenhouse melons. The carpenter bees (*Xylocopa* spp.) have not been cultured in a true sense although their nesting in certain areas has been encouraged by placement of soft timbers in which they can construct nesting tunnels. Because of their large size (almost an inch in length and about half as wide), they resemble large bumble bees but do not have a true pollen basket on the hind leg. They are usually metallic black. Logs of softwood, in which carpenter bees can construct nest tunnels, are provided near plantings of passion fruit (*Passiflora* spp.) to encourage these bees to nest near and pollinate the flowers. Current challenges to the commercialization of these attempts lie in the difficulties of mass-rearing *Xylocopa*, and in the high levels of nectar robbing exhibited by the bees.

Bohart (1971), have suggested some steps to increase the wild bee populations at least in the eastern half of the United States, include:

1. Opening up of forested areas, which created more favorable conditions for bees.
2. Paving highways, which concentrated moisture along roadsides.
3. Introduction of "weeds" upon which the bees forage.
4. Growing numerous crops upon which the bees forage.
5. Bringing desert areas into bloom (with irrigation).

Plantings, on which wild bees may forage or reproduce, are also made and protected from fires, floods, overgrazing, or insecticide exposure. Otherwise, little is known about manipulation of the thousands of other species of wild bees.

In the context of conservation of pollinators, it is worthwhile to consider the International Initiative for the Conservation and Sustainable Use of Pollinators, established under the convention on biological diversity that envisages the following initiatives:

- Monitor pollinator decline, its causes and impact on pollination services.
- Address the lack of taxonomic information on pollinators.
- Assess the economic value of pollination and the economic impact of the decline of pollinator services.

- Promote conservation, restoration and sustainable use of pollinator diversity in agriculture and related ecosystems.

To conserve, characterize and utilize genetic resources of pollinators, the following aspects are to be borne in mind and addressed:

a) Characterisation of the indigenous Indian honey bee species, *A. cerana* from different ecological regions of the country.

b) Understanding the diversity and characterisation of non *Apis* species, like *Trigona iridipennis* and others.

c) Genomic studies on native honey bee species and utilising information from the sequenced genome for trait improvement.

d) Identification of better traits in *A. cerana* like pest/ disease resistance, good honey yielding and brood rearing capacity, hygienic behaviour, less swarming, gentleness, better and long distance foraging, etc. from different parts of the country.

e) Genetic improvement of *A. cerana* combining several positive traits to realise more hive products like honey, wax, propolis, pollen, royal jelly, bee venom, etc. and make them better pollinators in different agro-ecologies.

f) Understanding the genetic, biochemical, physiological, molecular, ecological and morphological aspects of these positive traits in honey bees so that the underlying basis could be utilised to breed and improve the stock.

g) Developing molecular markers to study the diversity of honey bees and positive traits like disease resistance, yield, better pollination, etc.

h) Breeding and mass queen rearing of improved stock of *A. cerana* and *A. mellifera.*

i) Maintenance of a germplasm/ gene bank for honey bees and pollinators.

j) Study the impact of various habitat destruction parameters, climate change, loss of biodiversity, etc. on pollinator diversity.

k) Understanding the diversity of specific pollinators and pollination mechanisms in conserving rare and endangered species like orchids, forest flora, etc.

l) Developing a policy on use of pesticides in different ecosystems that affect pollinator efficiency.

m) Developing a policy on import of hive products, frozen semen of *A. mellifera*, etc. to enable safe entry.

n) Developing an integrated policy for the conservation of biodiversity including rare and endangered species and specific pollinators that enable their conservation.

o) Developing a policy on breeding of crops with greater pollinator selectivity.

CONCLUSION

The efficiency of insects as crop pollinators would depend on their biological characteristics in relation to the crop and the environment in which they are needed. Each insect species which has been used as a pollinator so far would have its specific characteristics, which might be favorable or unfavorable from the standpoint of the user. Our dependence on a few honey bee species that has been bred and managed intensively could give rise to several problems in managing the pollination services. Few species may not provide the same benefits as a rich community of functionally distinct species. It has been shown that greater the diversity of pollinators better the pollination, emphasising the need to conserve functional diversity and maintain high biodiversity in agricultural landscapes. There is a need to give a fresh look at our strategies on clean cultivation, multiple cropping, farming systems, conservation of forests, etc. Unfortunately pollination is seen as a 'free ecological service' provided by pollinators, forgetting that nothing is free in nature and every service nature provides demands a cost and we must provide for it in terms of resources like food, shelter, ecology, etc. for the pollinators. The awareness to study, conserve and use other pollinators requires new taxonomic and biological work to determine which species are important as native pollinators of specific crops in different regions. The urgent need to reshape our strategies to address these issues is the need of the hour to make pollination an input in increasing crop production and conserving biodiversity.

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