International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 12-05-2021, Accepted: 28-05-2021, Published: 12-06-2021
Volume 6, Issue 3, 2021, Page No. 165-169

Environmental and anthropogenic menaces to insect pollinators

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Abstract
Flowers are completely dependent on the vectors to move pollen. An abundance of insect vectors or pollinators determines a greater proportion of early flowers, results in greater quality of fruit with earlier and more uniform crops. Insect pollinators face many important pressures due to environmental changes such as climate change, alien species, pest, pathogens, fire, grazing and mowing etc. Many anthropogenic constraints such as land-use change (habitat loss, degradation and fragmentation), use of pesticides, electro-magnetic pollution, genetically modified crops, are primarily responsible for the decline of insect-pollinators. In this review, we have focused on many challenges faced by insect pollinators through environment and human interventions. Research on socio-cultural aspects of insect pollinators' declines is increasing but further research is required.

Keywords: anthropogenic, climate change, human intervention, insect-pollinators

Introduction

As the global surface temperatures rise, global precipitation rates are predicted to increase. The localized increase in rainfall patterns may considerably affect interactions between plant-pollinator in many ways (Lawson and Rands, 2019 [20]). It has been estimated that over 80% of all flowering plants depend on biotic pollinators, especially bees. The vital role of bees as providers of pollination services in developing countries like India cannot be ignored, although this service is mostly feral here. In western countries, pollination has been industrialized, bee keepers ship their hives from one place to other to meet the requirements of the fruit and vegetable demands. It is only in plantations, in various areas, where farmers have colonies of *Apis cerana* and *Apis mellifera* (in North India) for pollination purposes and rarely seen in South India regions. This is done even without determining whether this bee species is the most valuable pollinator for those crops or not. As several growers are not aware of the contribution of wild pollinators towards production of their crops and farm profitability, active participation of researchers and extension specialists is required to educate them about the benefits of pollinators and consequences of their decline (Pannure, 2016 [27]). Considering that increasing human population is rapidly resulting into habitat destruction, the establishment of protected areas is an important conservation tool. Pollination, a crucial link in the survival of ecosystems, as well as habitat conservation and urban planning need to be understood thoroughly to develop suitable strategies for conservation of the Indian biodiversity. We can take some specific steps that will benefit native pollinators directly. Habitat should be protected for nesting, feeding, resting, overwintering and migration for all life cycle stages i.e., larvae, pupae and adult.

Environmental Hazards to Pollinators

Climate change

The Climate change caused by accumulating atmospheric Green House Gases (GHG) seem to change the phenology of both flowering plants and insect pollinators thereby reducing the efficiency of the latter in pollination. The adverse consequence of the pollinatory role of the major group of pollinators, the insects, will certainly have a more negative impact on the agricultural, horticultural and other plant production and that will in turn affect the global economy in future (Swaminathan, 2019 [37]). Climate change affects pollinators and pollination in a number of ways. Changing climate can cause changes in range shifts of pollinators and plants (Kuhlmann, *et al*., 2012 [17]), changes in phenology, alterations in plant chemistry, and many other factors which could all lead to increased extinction with some species being more sensitive than others. Research by the EPA (Environment Protection Agency) shows that Colony Collapse Disorder (CCD) is associated with changes in bee habitats and malnutrition, caused indirectly due to climate change. Climate change can generate a mismatch in the seasonal timing of interacting plants and their pollinators owing to species specific shifts in their phenology. In future if the global warming continues in the same quicker phase as it is seen now, a significant mismatch in this regard would occur between partners of pollination hindering the crop reproduction (Bartomeus, *et al*., 2011) [3]. In Southern Colorado Rocky Mountains, it was observed that early increase in ambient temperature with snow melting triggers a warmer and drier condition. Hence, this results in decreased amount of wild flower blooming with a subsequent decline in pollinator populations including bees (Aldridge, *et al*., 2011) [1].

Alien species

Invasion by alien species is a world-wide crisis and forms one of the main drivers of global change. Studies in the Indian Himalayan Region (IHR) are indicative of lack of empirical evidences on different described aspects of plant invasion in IHR and might aggravate the problem of invasion management in the region. Among different invasive species, *Lantana camara*, *Ageratina adenophora*, *Parthenium hysterophorus* and *Ageratum conyzoides* have been reported from the majority of the IHR states. The evidences suggest possible encroachment by alien species in hitherto invasion resilient higher Himalaya, mainly with emerging trends of increasing temperature and human disturbances (Pathak, *et al*., 2019 [29]). Alien pollinators introduced by mistake or for agricultural purposes can discard native pollinator communities by outcompeting indigenous insects for resources or by dispersing pests and disease (Woods, *et al*., 2011 [40]). A manipulative field experiment was used to investigate the impact of the alien plant *Impatiens glandulifera* on an entire community of co-flowering native plants. Though, the pollen transport networks were dominated by alien pollen grains in the invaded plots, the higher visitation of pollinators may not translate in facilitation for pollination (Lopezaraiza-Mikel, *et al*., 2007 [22]).

Pest and pathogens

Several environmental stressors do not directly destroy bees, but they alter their physiology and behavior, eventually impacting colonies and populations (Gomez-Moracho, *et al*., 2017) [11]. Honey bees are infected by various viruses, a few of which have been associated with population declines. These include the deformed wing virus, the Israeli acute paralysis virus and the acute bee paralysis virus, which are usually spread by the mite *Varroa destructor* (Lodesani, *et al*., 2014) [21]. Trypanosomatids, such as *Crithidia* spp., in bumblebees and honey bees are extracellular parasites that join to the surface of the gut epithelial cells where they reproduce and discharge new parasitic forms in the faeces (Mcart, *et al*., 2014) [23]. The *Varroa destructor* mite is the primary vector of many viruses (*Picornavirales*) incriminated in honey bee colony losses. By feeding on bee hemolymph, *V. destructor* represses host immunity and increases host virus load. Apart from this, pathogens associated with colony mortality vary spatially (Runckel, *et al*., 2011) [34]. A *Paenibacillus larva* is a spore-forming Gram-positive bacterium responsible for the American Foulbrood disease which can cause winter colony mortality in honey bees. The bacteria colonize the midgut of the larvae where they proliferate, disrupt the epithelium and break down the host into a brown and viscous colloid containing millions of highly resistant spores that contaminate the nest (Genersch, 2010) [10].

Fire

Pollinators tend to be promoted after a wildfire event (Carbone, *et al*., 2019) [4]. Plant-pollinator interaction richness increased with the diversity of fire histories within foraging range, though only when the local environment was burnt last by low- or moderate severity fire (Ponisio, *et al*., 2016 33]. Early postfire successional species are typically short-lived, that mature and flower earlier than woody long-lived species. Consequently, pollinator communities are likely to decrease with postfire age (Pausas and Keeley, 2014 [30]). Fire has played an important role in several native ecosystems, and controlled burns are an increasingly general management tool. Effects of fire management on arthropod communities are extremely variable. Moretti, *et al*., (2006) [25] found that it can take 17-24 years for insect communities in burned areas to recover to pre-burn composition. Fire can have severe impacts on population levels and unless there are sufficient refuges from the fire or adjacent habitat, recolonization of a burned site may not be possible. Hence, studies have found a negative or mixed response of invertebrates to fire.

Grazing and mowing

Species of plants under heavy grazing pressures lead to fall in the number flowers and henceforth, of pollinator insects. Tadey, (2020) [38] reported herbivore density to have a stronger negative effect on flowering phenology affecting plant health than climatic variables. Temperature and precipitation were found to have a positive effect on flowering phenology and plant health. As these plants are pollinator generalists and attract a large number of pollinators, they were dominant in the interactions in the studied grasslands and likely increase pollinators' abundances. Therefore, the dominance of Asteraceae species, their importance as a food source for many pollinators, and the high accessibility of their floral resources explains why species abundances is a major determinant of interaction frequencies in comparison to morphology and phenology in grassland community. The plant–pollinator network structure in southern Brazilian grassland is not dramatically affected by grazing disturbance, but rather determined by species abundances and identity (Oleques, *et al*., 2019 [26]). Harmful effects of the various mowing frequencies were observed on the biodiversity of flora and fauna. Pollinators are threatened due to land use change and agricultural intensification (Johansen, *et al*., 2017 [14]). Grazing and mowing can have harmful impacts on pollinators but when carefully managed, they can be useful. Livestock grazing can greatly alter the structure, growth, and diversity of the vegetation community, which in turn can affect the associated insect community (Kruess and Tscharntke, 2002 [16]). It is understandable that both grazing and mowing result in mortality of immature stages i.e., both egg and larval stages.

Anthropogenic Hazards to Pollinator species

Land use change (habitat loss, degradation, fragmentation)

During the twentieth century, many pollinating insects across taxa and regions have declined. Anthropogenic influences have greatly increased the global deposition of Nitrogen (N) to soils during the past century, this is increasingly recognized as a threat to global biodiversity (David, *et al*., 2019 [9]). Plant-pollinator communities may deal with upcoming habitat fragmentation by responding to species loss with opportunistic partner switches, past effects of fragmentation on the current structure of host-parasitoid networks may strongly affect their strength to co-extinctions under future habitat fragmentation(Grass, *et al*., 2018 [12]). The species diversity, species abundance, distribution and species composition of flower-visiting insect species on an Azorean Island were found to vary only slightly across the land-use gradients (Picanco, *et al*., 2017 [31]). The role of self, wind and insect pollination to *Coffea canephora* production in the landscape was evaluated in the region of Kodagu, South India. The proportion of flowers that developed into fruits was maximum when hand cross-pollinated (44%), followed by open- (insect and wind combined, 33%) and wind- (22.1%) pollination treatments. Pollination by bees thus increases fruit production by 50% over that achieved by wind (Krishnan, *et al*., 2012 [15]).

Pesticides

In India, there are numerous reports and evidences on the negative impacts of pesticides as a threat to humans. India being a huge country has framed laws to tackle the problems arising from chemicals besides their manufacturing, regulation and policies designed (Dar, *et al*., 2020 [7]). For survival, mustard (*Brassica juncea*) plants are mainly dependent on bees. Number of pesticides are broadly used in oilseed *Brassica* and the reports are mostly focused on neonicotinoids (Challa, *et al*., 2019 [5]). An extremely toxic class of systemic insecticides, neonicotinoids modeled after nicotine interferes with the nervous system of insects, causing tremors, paralysis and eventually death at very low doses (Walker and Wu, 2017 [39]). The area of pollinator dependent crops in Kolhapur, an agriculturally sound region of India, is increasing irregularly and crop pollinators are under threat of pesticides and other harmful chemicals used in agriculture farming. Thus, there is need to make a survey of pollinating insects which comprise incredibly rich biodiversity (Sathe and Gophane, 2015 [35]). It is possible to conclude that as the frequency of pesticide application increases, its impact on honey yield minimization, killing flowering plants, pollination service, population, absconding, foraging behavior and others will increase. Colony collapse disorder problem and its management is of priority to save pollinator insects. It is caused by different factors, neonicotinoids, insecticides and pesticides exposures are one among the factors for the occurrence (Henry, *et al*., 2012 [13]). Insects are viewed from the damaging perspectives and are aimed at killing them through some means including indiscriminate use of deadly chemicals.

Electromagnetic pollution

Some recent evidence revealed the effects of ALAN (Artificial light at night) on pollinator communities, indicating its role as a major threat to pollinators. Knowledge about the impact of AREMR (anthropogenic radiofrequency electromagnetic radiation) on invertebrates and other pollinators is inadequate and is hindered. The abundance and composition of wild pollinators in natural habitats are affected by electromagnetic radiation from telecommunication antennas. Anthropogenic EMR (Electro Magnetic Radiation) emissions are proliferating, but more research is required to study its adverse impacts on pollinators and pollination (Kumar, *et al*., 2020 [19]). Worker bees failed to return to their hives when their navigation behavior is interfered by the mobile microwaves. There is an urgent need to understand the complexity of interaction involved in the influence of electromagnetic radiations particularly due to cell towers on honeybee biology and to work out a strategy of minimal environmental implications (Patel and Mall, 2019 [28]). Honeybees exposed to EMR tend to suffer dramatic physiological and behavioral changes in both laboratory and field-based experiments. Exposed honeybees manifested increased hyperactivity, aggressiveness and irritability (Dalio, 2015 [6]), resulting in a premature swarming process.

Genetically modified crops

Genetically modified crops are granted regulatory approval only after strict food or feed safety assessment, such as allergenicity, toxicity and compositional analysis, etc. Concerns have been raised regarding its security to the environment and human health due to potential risks related to gene flow, genetic drift, unfavorable effects on non-target organisms, evolution of resistant weeds and insects, and toxicity and allergenicity (Kumar *et al*., 2020 [18]). Indirectly, important class of insects ends up being exposed to genetically modified organisms and their cultural tracts (Monteiro *et al*., 2019 [24]). *Apis mellifera* being the most frequent visitor in maize plants can be explained by Pires *et al*., (2014) [32] who studied genetically modified cotton and observed that the visitation rates of *A. mellifera* were abundant as compared to other species of bees on the crop. Along with having an abundant presence in several environments, *A. mellifera* is considered a dominant species. Genetically modified (GM) plants are rapidly becoming a general characteristic of recent agriculture as the transition to engineered crops has a variety of economic and ecological potential benefits.

Human activities causing pollution

Heavy metals released from industry and transport can pollute aquatic and terrestrial environments, inducing further eco-toxicological effects in various organisms. Insects play vital ecological roles in maintenance of ecosystem structure and functioning and deliver such ecosystem services as food provisioning, plant pollination, dung burial, pest control and wildlife nutrition (Skaldina and Sorvari, 2019 [36]). Changes in the carbon-nutrient balance in plant tissues as a result of increase in carbon dioxide will decrease the nutritional quality of plant tissues and change production of secondary compounds. Predicted effects for insect herbivores with chewing mouth parts include increased first-instar mortality, increased development time and consumption, and decreased digestive efficiency and performance (Bale, *et al*., 2002 [2]).

Conclusion

In the country where bee protection policies exist, policies should be expanded to protect wild bees because of the pollination services they provide and not just to support managed species or diversity. Organic farming should be encouraged to remove the dependence on synthetic pesticides (Dar, *et al*., 2020 [7]). Environmental interference in pollination would definitely produce untoward effects on global economy in terms of food production. A realistic way to ensure pollinator conservation is to promote and enhance its value to society (Das, *et al*., 2018 [8]). Our dependence on a few honey bee species that have been bred and managed intensively could give rise to several problems in managing the pollination services. It has been shown that greater the diversity of pollinators better the pollination, emphasizing the need to conserve functional diversity and maintain high biodiversity in agricultural landscapes. 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. We make following recommendations on pollinator species conservation:

- Habitat connectivity should be maintained or restored to ensure that pollinators have sufficient habitat to meet their needs.
- Native species should be planted, as native plants and insects have evolved closely together and are best adapted to the needs of many pollinators.
- Estimation of proportion of crops pollinated by insect

pollinators should be done.
- Effects of pollinators on production increase should be recorded.
- Key pollinating species for different crops need to be identified.
- Use of herbicides and insecticides should be minimized, and least-toxic chemicals should be used when pesticides are necessary.
- Pollinator plant relationships should be valued for sustainable agriculture.
- Public awareness should be created towards pollinator species and their conservation.

Acknowledgement
The authors would like to express their gratitude to Avinash Agrawal and Abhilasha Bhagora for their help in collecting literature and Sahil Gupta for the valuable comments on the manuscript.

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