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Impacts of Insecticides on Pollinators of Different Food Plants

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Abstract

The present review emphasized on decline of pollinators by application of insecticides. The pesticides affect badly to important pollinators alters their foraging behaviour and other important activities. The chemical composition of pesticides, methods and time of their application can alter toxicity to pollinators. To avoid this decline of pollinators the pesticides should be applied to affected plants only and should not apply in day time when pollinators remain active. Besides these above mentioned practices, other important measures like crop rotation, use of organic pesticides, use of bio-controller agents and weeds destruction are also considered good for pest destruction.

Keywords: Insecticides; Fertilizers; Environmental; Taxonomy; Toxicity

Introduction

Insects are the most dominant over all other terrestrial animals in numbers and are cosmopolitan. They were the first organisms to successfully colonize land; therefore considered as an ancient group of animals in animal world. They are found throughout the world in all bio-geographical regions and ecological zones. The insects play a major role in maintaining the cycle of nutrients, soil regeneration and protection, pollination of phanerogamic plants as well as natural regulation of pests. From ancient time, insects were most beneficial to humankind in many ways. Insects play different functional roles, important in sustaining the dynamics of ecosystem process [1]. These animals are highly sensitive to changes in environmental conditions viz. temperature and humidity etc. [2].

Insects are considered as good pollinators of flowering plants; approximately 75% of all crop plant species are entomophilous. Though many flowering plants are capable of self-fertilization, the majority of them depend on pollination by insects in order to set fertile seed and maintain genetic diversity. The mutual advantage of this interaction led to the evolution of a great variety of pollination mechanisms, some very complicated and highly specific, involving many structural, functional and behavioural adaptations in both insects and plants. Among pollinators honey bees are of great significance; strongly feed on melliferous plants and collect nectar and pollens [3]. The presence of complex communication system allows the honeybee colony to find and collect pollens and nectars with high efficiency. They are most valuable agent in cross pollination of crops contributes high yields in agriculture [4].

Moreover honey bees, many other insects including hoverfly, butterfly, beetles, mosquitoes etc. are also good pollinators. The hover flies are the good pollinating flies and also known as flower flies, because of close association with flowers. They are considered as pollinators of a variety of fruit crops including apples, pears, cherries, plums, apricots, peaches, strawberries, raspberries and blackberries. The male mosquito feeds on sugary nectar to perform swarming flight and other activities. Females also drink nectars prior to mating. In accordance of the basis of body size the mosquitoes can pollinate small flowers of orchids. The butterflies also come under category of good pollinators, besides the butterflies, many species of moths do their share of carting pollen between flowers, too. Due to nocturnal habit, the moths tend to visit specific flowers like jasmine.

Among beetles the important pollinators are soldier beetles, jewel beetles, blister beetles, long horned beetles, checkered beetles, tumbling flower beetles, soft winged flower beetles, scarab beetles, sap beetles, false blister beetles and rove beetles etc. ascertained good as pollinators. The work on biology and taxonomy of pollinators in mango orchards have been carried out in India [5-7], these studies have revealed that insects of orders Diptera and Hymenoptera play major roles in pollination of this fruit. [8] Carried out study on behavior of honeybees and revealed that several foraging insects including the European honey bee significantly increased pollination and fruit set (Figure 1).

Figure 1: Diagrammatic presentation of relationship between pollinators and crop production.

Honey bee and pesticides

Day by day increasing human population calling for more and more demands in terms of food, space and good ecological conditions etc. Among all these priorities, the food production is prime need, therefore human uses pesticides and chemical fertilizers to produce more and more foods. Anciently nobody was aware to adverse impacts of pesticides and chemical fertilizers on human health. The usage of chemical fertilizers and pesticides reached at alarming situation. Honey bees and beekeepers are suffered more prominently due to practices used in agricultural development [9-11]. It has been analysed that decline of honeybee population is due to application of insecticides like organochlorine, carbamate, organophosphorus and pyrethroid. The damage to honey bee colony by application of pesticides not only depends by toxicity of chemical substances, number and methods of insecticides application, time of application, weather, but also by type of nectar, type of food flower collected, season of damage and number of honeybee in colony [4]. Different scientific studies investigated that the combination of pesticides like prochloraz-deltamethrin act as devastating insecticide for honey bee, even if the dose used is 50 times lower than recommended [12]. It has been shown that pyrethroid insecticides and fungicides exhibit synergism if applied to honey bees and increases the toxicity 10 to 100 folds [13,14].

Insecticides derived from plants sources such as nicotine, quassin, veratrine, anabasine, rotenone, ryan, tephorosia, pyrethrins considered as safe pesticides, because these insecticides do not exhibit large negative influence on pollinators [15]. By the observations of all above studies, integrated pest management methods should be used for crops, while chemical fertilizers and chemical pesticides should not be used. Biological controlling methods and biological products are considered as safe for pest control [16].

Effects of pesticides on honeybees

The one third of global agricultural production depends upon pollinators especially honey bees, nevertheless their significance, these pollinators die with alarming speed. Different factors including disease, parasites, climatic factors and flora are responsible for decline in honey bee population. Sometimes beekeepers himself cause honeybees poisoning by use of honeybees protecting agents. It is also revealed that excess use of pesticides is key factor in deterioration of honeybee population [17].

Application of pesticide and chemical fertilizers in agricultural land area and fruit trees is a continuous challenge because each year there are much advance pesticides or chemical fertilizer coming out with new formula, one only being potentially devastating for bees. Entomophilous pollination of agricultural crops is a natural and clean method, which does not need any additional investment growth in the production of seeds, fruit and vegetables. Chemical insecticide treatments should be banned in plantations and crops during flowering, but if this is indispensable, the application will be made under conditions which ensure the full protection of honey bees. Contamination to a single worker bee by pollen may disrupt the whole colony.

In recent years, the population of honey bee and other pollinators has been decreased throughout the world [18]. Population of honey bee have been affected and declined by different factors, among these, the use of organo-synthetic pesticides are considered as the prime factor [19].

More than seventy per cent of world's crops are pollinated by bees; absence of pollinators leads to loss of productivity concerned with majority of flowering plants including fruit trees, crop plants and ornamental plants like melons, peach, orange, zucchini, pumpkins, summer squash, apples, berries, carrots and onions etc.

Effects on foraging behavior

Many studies related to plant-pollinator relations have focused how the floral species can affect diversity and abundance of pollinators. It has been concluded that the association of plants and pollinators significantly affected by the quality of the soil. The visitation pattern of pollinators influenced by soil quality, similarly flowers production [20,21], pollen [22], nectar production [23], [24,25] also affected by change in quality of soil. It has been reported that bees living and foraging near agricultural fields, specifically corn field are exposed to pesticides in several ways throughout the foraging seasons in Indiana [26]. In another study it was reported that the use of different pesticides like imidacloprid and clothianidin could lead to a significant reduction of foraging activity [27]. The foraging activity was disturbed by use of imidacloprid at sub-lethal levels, similar effects were also observed after use of neonicotinoids and some other pesticides [28,29]. Conducted a study and revealed that important pollinator of neotropical areas (stingless bees) experienced threat of extinction because of these pesticides and deforestation. [30] have reported that during rearing of worker bees in brood comb containing high levels of many pesticides leads to multiple health effects like reduction in life period of adult, increased brood mortality, delayed larval development and higher fecundity of Varroa mites. They have also reported the delayed development in the early stages of worker bee that leads to reduced adult longevity by four days in bees exposed to pesticides during developmental phase.

Effects on colony death

The colony collapse disorder (CCD) is worldwide and its management is of first priority to save pollinator insects [31]. It is characterized by the abrupt vanishing of adult honeybees from hives contain ample food like pollen, honey and nectar. In regard to ecological and economic value of pollinators, there is a call to take instantaneous action to spot and rectify anthropogenic activities responsible for the decline in numbers of pollinators in order to uphold crop production and environmental conservation. The relation of CCD with many factors has been reported, which causes pathogen infestation, beekeeping practices (including malnutrition) and pesticide exposure in general [32-40]. Several scientific studies has revealed that declining of bee colonies is an outcome of exposure to pesticides especially to the systemic neonicotinoid insecticides [11,41-43]. The colony collapse disorder (CCD) reported in the United States in 2006 [35] that is concerned with losing important perennial pollinator on the global scale.

Mullin et al. [10] have reported the pesticide contamination in bee hives and analysed hundreds of pollen, wax, foundation, immature (brood) and adult bee samples for different pesticide contaminations. They also reported higher levels of residues inside the hives treated with fluvalinate, coumaphos and amitraz in order to reduce pest of apiculture like Vorroa mite. Mullin et al. considered fluvalinate (LD_{50} level of 65.85 μg/bee) relatively safe pesticide for honey bees.

Authors	Pesticides	Impacts
Gill et al. [28]	Imidacloprid and pyrethroid cyhalothrin	Combined exposures to neonicotinoid and pyrethroid pesticides impaired bumble bee foraging behavior and increased worker bee Combined exposures to neonicotinoid and pyrethroid pesticides impaired bumble bee foraging behavior and increased worker bee mortality, increasing the likelihood of colony collapse.
Goulson et al. [29]	Various neonicotinoids	The review provides a comprehensive overview of numerous environmental risks posed by the widespread use of the neonicotinoid class of chemicals.
Henry et al. [57]	Thiamethoxam	Nonlethal exposure of thiamethoxam to honey bees was found to cause high levels of mortality due to homing failure, putting colonies at risk of collapse.
Krupke et al. [26]	Clothianidin and Thiamethoxam	Research identified a variety of exposure paths for honey bees to agricultural pesticides from cornfields with neonicotinoid-treated seeds. The main route of exposure identified is dust clouds laced with neonicotinoids that are produced by planting machinery. Dust exhausts forms when treated seeds are abraded as they move throughout the seed planting equipment. Dust can directly affect bees flying near planting equipment and can also settle on the soil surface of neighboring fields and flowering plants (such as dandelions) where bees typically forage in the spring. Once the treated corn reaches maturity and flowers, bees are also exposed by visiting corn plants that have neonicotinoids in their pollen.
	Imidacloprid	To determine whether environmentally realistic levels of imidacloprid were capable of making a demographic impact on bumble bees, worker bumble bees were exposed to imidacloprid through dietary doses and evaluated for reproductive effects. Adverse impacts were recorded with respect to bumble bee fecundity, thereby raising concerns about the impacts of neonicotinoids on wild bumble bee populations.
Matsumoto [61]	Clothianidin and Dinotefuran	The results from this study indicate that neonicotinoid and pyrethroid exposure reduced successful homing flights amounts far below the median lethal dose in the field. Neonicotinoids were more toxic in this capacity and impaired homing abilities at lower levels of exposure than the pyrethroids.
Pettis et al. [60]	Imidacloprid	Honey bee colonies were exposed to sublethal doses of imidacloprid and were then infected with the gut pathogen Nosema. Infections of Nosema in colonies that were exposed to imidacloprid were significantly greater than those in control hives. This research suggests interactions between pesticides and pathogens could contribute to colony collapse and bee kills even though the individual bees may not test positive for lethal levels of pesticide contamination. Bees living in neonicotinoid-contaminated hives may be more susceptible to pathogens.
	Imidacloprid	Imidacloprid was detected in 89% of the surface water samples, with concentrations exceeding EPA's chronic invertebrate aquatic life benchmark in 19% of the samples. Many of the concentrations detected also exceeded the maximum accepted contaminant levels established by European authorities. Results of these tests indicate that imidacloprid moves offsite from agricultural applications and contaminates surface waters at concentrations that could harm aquatic life.
Eitzer [26]	Imidacloprid and Thiamethoxam	Neonicotinoid levels in nectar and pollen of squash plants were measured after neonicotinoid applications either in the soil before planting or via irrigation of young plants. Results showed neonicotinoid levels that were within the range that can cause sublethal effects in honey bees and bumble bees. Levels in squash during this experiment were higher than those that have been found in other measurements of canola and sunflower nectar and pollen from plants grown with treated seeds.
	Clothianidin and Thiamethoxam	This study quantified the levels of neonicotinoids in the dust released from planting equipment. Levels found confirmed that bees can be directly exposed to lethal and sublethal quantities of neonicotinoids during corn planting season.
	Imidacloprid	The authors exposed bumble bees to field-realistic levels of imidacloprid in the laboratory and found that treated colonies had a reduced growth rate and suffered a reduction in queen production. This research suggests that neonicotinoid exposure may be significantly negatively impacting bumble bee populations worldwide.

Table 1: Pesticides and their impacts reported by different workers.

Safe methods to reduce pest

It has been revealed that vermi-compost affects soil composition and plants and ultimately physiology and behaviour of pollinators. They have also revealed that vermicomposting provide good quality nutrition as compared to chemical fertilizer, therefore effectively increased the flower visiting period of pollinators (Tables 1 and 2).

Organic Pest Control: Several pesticides usually obtained from plants or other natural materials considered safe for pest control and they might break down faster in the soil as compared to chemical

pesticides. However, all organic pesticides are not safe for bees. Different pesticides, fungicides and herbicides and their toxicity to bees mentioned below in the (Table 3).

S.No.	Name of pesticides
1	Aluminium Phosphide
2	DDT
3	Lindane
4	Methyl Bromide
5	Methyl Parathion
6	Sodium Cyanide
7	Methoxy Ethyl Mercuric Chloride (MEMC)
8	Monocrotophos
9	Endosulfan
10	Fenitrothion
11	Diazinon
12	Fenthion
13	Dazomet

Table 2: Pesticides restricted for use in India.

S.No	Non toxic	Moderately toxic	Highly toxic
1	*Bacillus thuringiensis*	Boric acid	Diatomaceous earth
2	Garlic	Neem	Insecticidal soap and oil
3	Kaolin clay	Ryania	Pyrethrins
4	Corn gluten	Adjuvants	Rotenone
5	Gibberellic acid	Horticultural vinegar	Sabadilla
6		Copper	Spinosad
7		Lime sulfur and sulfur	Copper sulphate

Table 3: Different pesticides, fungicides and herbicides and degree of their toxicity to bees.

The mutual relationship between flowering plants and pollinator animals is very important for every type of ecosystem [44], approximately 87.5% of flowering plants dependent upon animal-mediated pollination [45,46]. It has become of prime importance to save and conserve pollinator animals including insects to insure the security of crops and ultimately crop dependent animals like human being.

In present scenario the important pollinators is now facing the situation of threaten worldwide [35,47-50]. Because of mutual interaction between pollinators and flora, the quantitative and qualitative reduction in number of flowering plants can be assumed as prime reason for pollinators decline [48-51]. Several studies revealed that use of vermicompost improves the soil quality, which in turn enhance the resistance power of plants to herbivores pests including aphids and caterpillars [52-55] carried out study on growing corns from insecticides coated seed and reported that bees consume these guttation drops from such plants, encountered death within few minutes. [56] has conducted a study and has revealed that an insecticide spinosad obtained from bacteria (Saccharopolyspora spinosa), if applied in hive in low quantity have no any adverse effects on developmental stages and adult honeybee. [57] conducted a study and revealed that honey bee exposure to thiamethoxam alters its homing and consequently death rate of colony of honey bees (Table 3).

The association of pesticide exposure and adverse health outcomes in Bumble bees (Bombus spp.)

A study was conducted to report the toxicity of pesticides viz. imidacloprid, clothianidin, deltamethrin, spinosad and novaluron on bumble bees namely *Bombus impatiens* (Cresson), *Megachile rotundata* (F.) and *Osmia lignaria* Cresson. The clothianidin and imidacloprid are more toxic to all three species of bumble bees, followed by deltamethrin and spinosad and novaluron [58-62].

Colony vitality/brood development

A scientific study carried out on the effect of insecticides like imidacloprid, chlorpyrifos, carbaryl and cyfluthrin on bumble bees. It has been also concluded that toxicity of pesticides to bumble bees can be minimized in irrigated field as compared to dry condition [62-65].

Conclusion and Recommendations

By reviewing above several studies, it has been concluded that our civilization has affirmed a war on pollinators. Exposure of lethal and sub-lethal level of pesticides may be harmful to pollinators in terms of abnormal foraging activities, impaired brood development, neurological or cognitive effects [66-70]. Although application of insecticides are almost detrimental to beneficial insects, but still it is necessary to destroy vast number of pest species of insects. However the methods, chemical composition and time of pesticides application can also make difference in their toxicity to pollinators. Pesticides should be applied to affected plants only and only in late evening when bees not remain active. Pest population can be controlled by crop rotation from year to year, because most of pests are specific to particular plants. Some insects are beneficial to us indirectly or directly, because every insect is not a pest. In fact, some insects are helpful to us by feeding on the harmful insects. To reduce the pest population, garden should be clean and tidy, because clean garden inhabit fewer pests. More pest harbors in weeds and grass around garden. Bee keepers and gardeners should be aware about location of bee hive before pesticide application [71-73].

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