Chapter

Neonicotinoid Insecticides: A Threat to Pollinators

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Abstract

Pollination is the fundamental requirement for healthier fruit set. More than 90% of flowering plant species in the hot and humid regions required pollination. Many plants species required animal pollination. Among these animals, insects play a vital role in pollination, and among the major insect pollinators, hymenopterans, honeybees, and bumblebees are regarded as the best pollinators of the crops around the world. Declining population of these important pollinators day by day is a major threat, and this declining is due to a variety of stressors. Among these possible reasons including environmental conditions, parasites, predators, malnutrition, and diseases, many researchers pointed finger at pesticides as playing a major role especially neonicotinoid. Neonicotinoids move in the environment and can be found throughout the areas where they are not applied. Neonicotinoids can drift offsite directly exposing bees and contaminate nontargeted areas when applied as spray. During plant uptake, neonicotinoid spreads through plant tissues and disrupts the physiology of pollen eaters, nectar feeders, and the insects that feed upon plant tissues. Therefore, the use of neonicotinoid is the major reason for the decline of bees in the world. So it is requested to all farmers and researchers to please find ways to kill pests not pollinators.

Keywords: pollinators, honeybees, bumblebees, insecticides, Neonicotinoid

1. Economic importance of pollinators

Consideration on sustainable growth generally agrees that environment still harbors much kind of living things that are potentially and unswervingly significant to mankind. Their lucrative utilize is now pending for the discovery of their worth or the formulation of how they should be propagated. There are about 25,000 species of bees [1] recognized in the world and only few play an important role in pollination producing fruits and seeds. Most of the world wide plant species depend upon animal pollination for their fertilization [2]. Among animal pollinators (any animal which transfer pollen between plants enabling fertilization and sexual reproduction from anther of male flower part to the stigma of female flower) insects provide better service of pollination [3]. Insect pollinators include bees (honey bees, bumblebees and solitary bees), flies (Carrion flies, flesh flies and hover flies), pollen wasp, ants, mosquitoes, beetles, butterflies and moths [4, 5].

Among these major insect pollinators; hymenopterans, honey bees and bumblebees are regarded as the best pollinators of the crops around the world. It has been introduced globally due to its economic importance of honey production (honey bee) and pollination of the crops [5]. Bees are known to pollinate among 71 most familiar crops out of hundred plant species that accounts for 90% of world's food supply [6]. However, honey bees and bumblebees are the principal pollinators of the crops and it has been used successfully as pollinators in crop systems around the world [7, 8].

Many fields of current agriculture hang on pollinators. In each pollination season, these important pollinators mostly honey bees, bumblebees and native bees bring billions of U.S dollars in economic value. In several esteems, they play as a key role in the world economy [9]. But it is very important to know the real value of these important little creatures. About $230 and $580 billion U.S. dollars' worth of annual worldwide food production depend on the direct influence of these important pollinators [10].

Managed bees (domesticated bees by the beekeeper) are the greatest regarded pollinators in relations of agricultural economics. These pollinators (honeybees and bumblebees) can deliver pollination to almost any crop. Almond crop is entirely reliant upon honey bee pollination. Without these pollinators, yield for many fruit crops including watermelon, squash, blueberries and other fruits would be greatly reduced [11, 12]. According to the statistic presented by USDA, a honeybee colony value 100 times more to the public than to the beekeeper it mean that the value they deliver extends well beyond their actual price. Bee's pollination has aided make vegetables, nuts and fruits more accessible to consumers. There are many others species of insects called as wild species like leaf cutter bees, mason bees, alfalfa bees are not documented for their input to current agriculture. But these pollinating insects provide supplement to managed bees colonies but also pollinate some crops more professionally than their managed bees. Throughout blooming season honeybees and other native insects partner to deliver pollination for many crops. Although the economic values of their pollination is much less than managed bees, but the role of wild bees is important [11].

2. Ecosystem essentials

Preserving our indigenous flora, including wild for example bluebells, poppies, cornflowers and, along with trees, also be contingent on pollinator populations. This is much closer relationship between the declining of pollinator's population and the plant they pollinate and this relationship goes parallel throughout the world [13, 14]. It is estimated that in Europe and UK about 76% of plants that are pollinated by or called as liked by bumblebees have declined in recent decades. Pollinator's population declines spell bad news for previously declining wildflowers, which are pollinated mostly by insects and among them one fourth are endangered. In short wildlife also depends on these important pollinators, declining of wild flora means declining of wildlife including birds their shelter. Even though the insects themselves provide a significant link in the food chain as prey for other insects, birds and other animals that feed on insect [15, 16].

3. Current declines in pollinator populations

To maintain the plant genetic diversity pollination is very important for plant reproduction [12]. Due to its important role in agriculture many scientist worked on population dynamics of these important pollinators. There are many reason behind the decreasing population of these important pollinators such as bats, beetles, flies birds and bees, the main reasons behind this are habitat destruction [17, 18] and the introduction chemicals sprayed on crops in form of pesticides [11, 19]. Monitoring programs of NASS led by the USDA have documented the decline in managed bee's population since 1947, making them the most important example of pollinator decline in North America [11, 20]. Reasons behind the decline of these important pollinators including managed and wild bees are of mites that feed on honeybee larvae and adult body making them weak, pathogens, use of antibiotics to control these pathogen and pesticides [21–23]. Among these all factors pesticides paly vial role for the declining of population. A huge amount of these pesticides are sprayed on crops for the control of insect pest that damage crops, and bees are non-target organism on these sprayed crops. When bees visit on these sprayed crops to collect pollen and nectar become contaminated. Among these pesticides many are neurotoxic in nature such as parathion, diazinon, and carbaryl play vial role in population decline [21].

However, the population of honeybee is declining day by day due to intemperate uses of pesticides [8]. Generally the bees are exposed to these pesticides; which are either used to control the parasitic mites and the pathogens attacked in the hives or to control the diseases and pest in the crops on which the bees are visited for pollen and nectar [21]. The experiments conducted in Europe and the United States found the miscellaneous range of pesticides on healthy and unhealthy bee's colonies along with their pollen, honey and bee waxes [12]. One possible cause of distressing bee mortality is the use of very active systemic insecticide called neonicotinoids [19].

4. Neonicotinoid, a real threat to pollinators

Neonicotinoids; systemic insecticides, easily soluble in water but slowly break in the environment. These insecticides are absorbed by the plants through roots system and become the part of plant. The photo-degradation, half-life of neonicotinoids is about 30 ± 4 days when exposed to sunlight [24]. It is highly toxic to insects as compare to mammals and birds because they are unable to cross the blood-brain barrier due to the lack of a charged nitrogen atom and the uncharged molecule can penetrate the insect blood–brain barrier [25]. It is derived from nicotine, which is accountable for bees decline and are highly selective neuro-active insecticides [26].

Neonicotinoids were introduced into the market in 1990 [27]. This new class of insecticide is neurotoxic, includes imidacloprid, thiamethoxam, dinotefuran, nitenpyram, acetamiprid, thiacloprid and clothianidin [28]. The first commercial neonicotinoid was imidacloprid meanwhile clothianidin and thiamethoxam were the first two introduced insecticides in early 2000s in the market [27]. Neonicotinoids are systemic poisons acquire by plants through their root system and they may endured in the plants for weeks to months and mostly depends on the abiotic conditions and application rate [29, 30]. Neonicotinoids are used to protect a variety of vegetables, fruits, and major crops like corn, cotton, potato, rice, etc. against sucking insects like aphids, whiteflies, thrips, leaf- and plant hoppers [31]. In Pakistan, these insecticides are recommended for the control of sucking pests of cotton, as they are most effective against thrips, jassid, and whitefly [32, 33].

The insecticides having the neonicotinoid compounds were applied on 140 different crops in more than 120 countries around the world. The excessive use of the neonicotinoids has been reported as the major factor in declining of both domestic and wild bees. Neonicotinoids are broad spectrum insecticides and are moderately to highly effective and toxic to bees that depends upon the presence of active ingredient in the insecticides [34]. Neonicotinoids are mainly used in seed and soil treatment and sometimes they also directly applied to plant foliage [27]. Many of the neonicotinoids are highly toxic to the insect pollinators and also to the honey bees. It changes the behavior that results in the behavioral disturbances, orientation difficulties and impairment of social activities [35–41].

Neonicotinoids also affects the CNS (central nervous system) of the insects as it binds agonistically to the post-synaptic nicotinic acetylcholine receptors that results in the spontaneous discharge of nerve impulses and eventual failure of the neuron to propagate any signal [42]. The neonicotinoids and their metabolites have the capability to persistent in the soil and aquatic sediments [43] and their persistence at shallow depths could increase the chances of aquatic life and other wildlife including honey bees could get exposed to the insecticide [44].

The neonicotinoids are considered to be most effective insecticide other than organophosphates and carbamates [45]. Imidacloprid is the most widely used insecticide and has drawn more attention on the health of bees than other neonicotinoids. More than 400 products of this insecticides accounting for about 15th of the globally insecticide marketed [46]. Honeybees are exposed to neonicotinoids in different ways from ingestion, contact and inhalation [47]. The pollen foragers which are different from the nectar foragers; they do not consume pollen by itself but it brings to the hives to consumed for the nurse bees and larvae hence the nurse bees and larvae exposed to neonicotinoids and their metabolites [48].

The forager bees used honey from their hive before they leave for foraging. It depends upon the distance that it will travel from their hive to foraging field, the forager bees have to consume more or less amount of nectar or honey from their hive for energy and foraging. Therefore the foragers may ingest more or less amount of residues of neonicotinoids [49]. The colony become contaminated when the worker bees come into contact with pollen or nectar contaminated with neonicotinoid and transport them to the hive, where they are normally observed in honey and bee bread [50, 51]. Bee hives made up of trees treated with neonicotinoids could have residues which may cause trouble for bees [52]. Oral route of neonicotinoid uptake is highest in forager honeybees, winter honeybees and larvae [53, 54]. Serious pests of citrus in Pakistan and other Asian countries are mostly control by using various classes of neonicotinoids. The foraging bees visiting citrus flowers get exposed to the residues of neonicotinoids which are responsible for damaging their physiology [55].

Neonicotinoids increased worker mortality and queenlessness over time. The toxicity of the neonicotinoids increases when it encountered with fungicides. In corn growing areas, the health of honey bees are reduced when are exposed to neonicotinoids in the field [56]. The irretrievable and cumulative damage to central nervous system of insects is often caused by neonicotinoid insecticides. There is no safe level of neonicotinoids and even only a very minute quantity of these systemic poisons could have long lasting drastic effects [57]. The activities of the acetyl cholinesterase is increased by the thiamethoxam at each developmental stages of the insects and the activities of glutathione-S- transferase and carboxyl esterase para increases at the pupal stages and reduced the survival of larvae and pupa that results in the decreasing of percentage emergence of honeybees [58]. The effects of thiamethoxam cause the reduction of forager bees returning to the hive [59]. When honey bees are exposed to a sub-lethal doses of imidacloprid and clothianidin that results in the reduction of foraging activities as well as longer foraging flights [60]. The bees become detract when it became exposed to nonlethal doses to thiamethoxam and causes high mortality at levels that may collapse the colony.

Among distinctive behaviors of honey bees, foraging is one of idiosyncratic behavior of the *Apis mellifera*. This type of behavior is like an association between the bee colonies and the ambient environment [59].

5. Conclusion

After World War II, we started using pesticides on a large scale, and this became necessary because of the monocultures that put out a feast for crop pest. Recently, researchers from Penn State University has started looking at the pesticides residue in the loads of pollen that bees carry home as food, and they have found that every batch of pollen that honeybee collects has at least six detectable pesticides in it, and this includes every class of insecticides, herbicides, fungicides and even inert and unlabeled ingredients that are part of the pesticides formulation that can be more toxic than the active ingredient. One of these classes of insecticides, the neonicotinoids is making headlines around the world right now you have probably heard about it. This is the new class of insecticides, it move through the plant so that a crop pest, a leaf eating insect would take a bite of plant and get a lethal dose and die. In most agricultural settings, on most of our farms it's only the seed that's coated with insecticides and so a smaller concentration move through the plant and gets into the pollen and nectar, and if a bee consumes this lower dose either nothing happens or the bee becomes intoxicated and disoriented and she may not find her way to home.

5.1 Strategies to conserve the pollinators

Every one of us needs to behave a little bit more like a bee society, and insect society, where each of our individual actions can contribute to grand solution and emergent property. So let the small act of planting flowers and keeping them free of pesticides be the driver to large scale change. Please find the ways to kill pest not bees.

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