Consumption of pesticide leads to toxicity in pollinators: A Risk for the conservation of biodiversity

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Abstract:

Agriculture is the backbone of most developing countries, but crops are badly affected due to increased pests. To control these pests, different types of pesticides are used that protect the crops. But on the other hand, it severely affects non-target, beneficial organisms and pollinators. Pollinators are important for the agricultural sector as they facilitate production as well as yield by pollination services. They showed its importance by pollinating 84% of crops worldwide. Bees are among the most common pollinators that are also badly affected during their pollination services which result in decreasing their population. The increase in the pesticide application lowers the population of pollinators which affects the agricultural yield. Decreasing the food supply due to shortage will ultimately increase the demand for food and feed also. This review provides information on the importance of pollinators, the usage of pesticides, and their effect on pollinators.

Keywords: Pollinators, Agriculture, Pesticides, Pesticide consumption, Bees

Pesticides use in agriculture:

A substance or mixture of substances is the pesticides that are used to protect crops from pest attacks or any other diseases in agriculture (Nicolopoulou-Stamati *et al.*, 2016). Insecticides, herbicides, rodenticides, nematicides and fungicides are included in the category of pesticides (Sharma *et al.*, 2019). All pesticides cannot destroy all organisms; they are specified according to their characteristics and the effects that can be revealed from their names. The function of insecticides is to retard insect growth and their survival, rodenticides attack rodents, and fungicides tight against fungi, herbicide's function is to work against plants, weeds and grasses (Bernardes *et al.*, 2015). Competitors, pathogens, predators, parasites, and the availability of critical resources are all biotic and abiotic variables that influence these parameters in the wild (Klein A.-M. et al., 2007).

However, Pakistan has lost PKR 6.5 billion (US$ 85 million) in key agriculture (cotton, rice, sugarcane, and maize) annually due to the extensive presence of pests and crop diseases, and pest icide use has been increasing steadily. The role of pesticides is very important in agriculture because it can help in increasing the yield as well as food quality ultimately turn in lowering the loss of agricultural products (Tudi *et al.*, 2021). At the global level, crop protection intensity increases the considerable number of pesticides to 15 to 20 times as exemplified (Popp *et al.*, 2013).

Classification of pesticides is based on the structure of chemicals, target molecules and many more and they are classified as organo-phosphorus, organochlorine, pyrethroids, carbamates, rational, neonicotinoids and microbial pesticides. Their level of toxicity is also classified by the world health organization (WHO) (Hashimi *et al.*, 2020). One of the major challenges faced by

agriculture producers is the low yield due to pests, and pathogens (Oerke *et al.*, 2004). Pesticide consumption increased from 23,212 tonnes in 1994 to over 69,897 tonnes in 2002 (Nafees *et al.*, 2008). Consumption of pesticides is approximately two million tons per year globally, in which USA's share is 25%, Europe consumed 45%, and India consumed 37.5% (De *et al.*, 2014). The requirement for pesticides increases in Pakistan and most developing countries over the last decade (Khan M. A. *et al.*, 2002).

Pakistan's economy heavily depends upon agriculture. It is considered a mainstay that relies majorly on crops (Rehman *et al.*, 2015). The major crops are wheat, rice, maize, sugarcane, vegetables and fruits (Rehman *et al.*, 2015). In South Asia, Pakistan ranks second largest country while in the world it ranks thirty-sixth largest (Ahmad *et al.*, 2015). The total cropped area of Pakistan is 22.68 in 2018 (Abid *et al.*, 2021). The labour force that is indulged in agriculture is 30.2 and 67.2 per cent males and females respectively (Hussain *et al.*, 2022). The gross domestic product (GDP) of Pakistan was contributed by 18.5% by the agriculture sector by the Pakistan Bureau of Statistics 2018 (Hussain *et al.*, 2022). During the year 2009, Pakistan's GDP was 161.99 billion dollars (world bank) (Raza *et al.*, 2012).

According to the Economic Survey of Pakistan 2019-20, year wise percentage of growth (GDP) in agriculture (Jamal, 2021) is shown below.

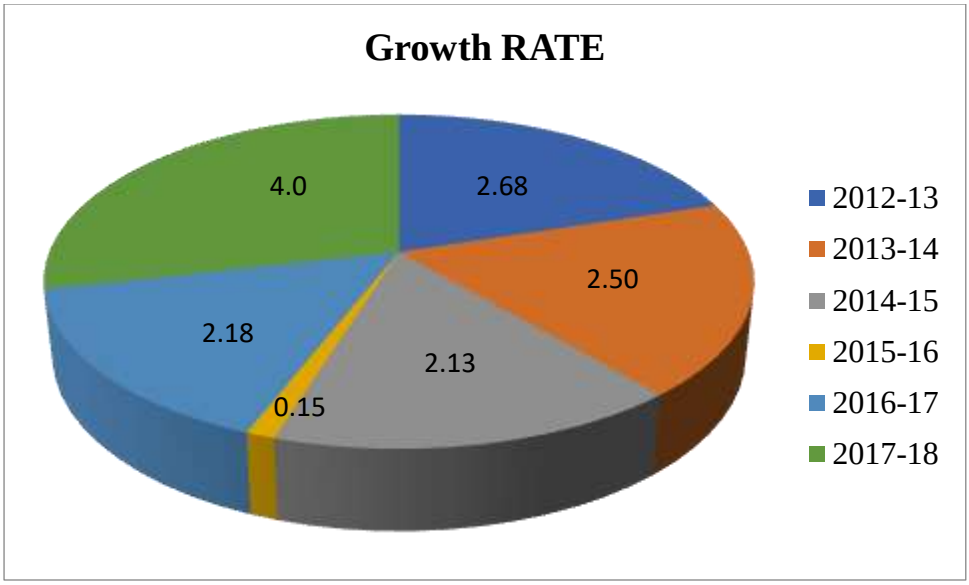

Figure 1. Agricultural gross domestic product growth rate of Pakistan

Pakistan ranked second among South Asian countries in the major use and overall consumption of pesticides (Waheed *et al.*, 2017; Yadav *et al.*, 2015). Pakistan also ranked second in South Asia in purchasing chemical substances, with 27% usage of pesticides on fruits, and vegetables and there is a 25% increase in the application of pesticides yearly (Aslam *et al.*, 2004). Among Asian countries, China ranked first that consumed 1,807,000 tones, India 55,120, Malaysia 49,199 and then Pakistan stood in fourth position using 27,885 tone, Thailand 21,800, Vietnam 19,154, South Korea 19,788, Bangladesh consumed 15,833, Myanmar 5583 and Nepal used 454 tones and Bhutan consumed the least amount that is only 12 tones (according to the FAO 2017) (Sharma *et al.*, 2019). In Pakistan, over 30 various types of fungicides, 5 different types of acaricides, 39 various types of weedicides, 6 different types of rodenticides, and 108 different types of insecticides are in use (RAMZY *et al.*, 2021). There is a threatening situation in Pakistan because of over 69.0 percent use of pesticides in the previous twenty years which means about 10 sprays on a single crop (Khan M. I. *et al.*, 2020). According to the Economic Survey of Pakistan, the total area is 2489 thousand hectares, the production and yield of cotton are 10671 thousand bales and

730 kg per hectare respectively, and the pesticides imported or consumed for this crop were 12806 tons during the year 2016 to 17 (Khan M. I. *et al.*, 2020).

Table 1. Percentage usage of different pesticides in Pakistan (Khan M. I. *et al.*, 2020)

Pesticides	**Percentage usage**
Insecticides	74
Herbicides	14
Fungicides	9
Acaricides	2

Pesticides are widely used, contaminating water, soil, and air, as well as accumulating in crops (e.g., fruits and vegetables). Pesticides are primarily transferred by wind and rain from their treatment sites to nearby crops and land, where their prevalence may be detrimental. Pesticide amounts in a given area are mostly determined by the intensity of agrochemicals and the crop varieties grown there (Fenik *et al.*, 2011).

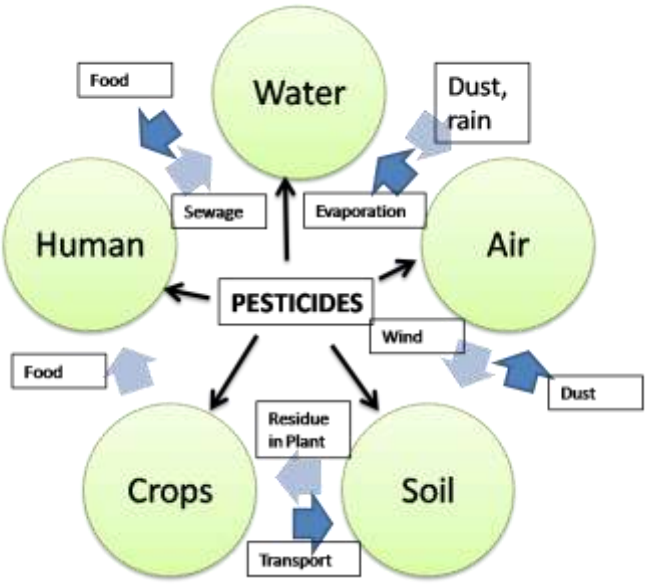

Figure 2. The cycle of pesticides in the environment.

Pollinators with pollination services:

Pesticides target specific organisms as insecticides target pest insects but unfortunately, non-target pollinators come under this attack and affect the food crop globally by around 35% (Badawy *et al.*, 2015). Pollinators mediate the exchanging of pollen from flower to flower helping the production of seed and fruit in around 88% of flowering plants are termed as pollinators. Bees are specialized in the transport of pollen and also account for many services for pollination in wild as well as cultivated plants (Sponsler *et al.*, 2019). Plants that are incompatible and cross-pollinated plants require pollination for the maintenance and conservation of biodiversity via the reproduction of seeds. Bees while collecting nectars can also take part in pollination where pollen grains attach to their body with special hairs, thus pollinating flowers while moving from flower to flower (Martin, 2015). Around 300 commercial crops are grown worldwide and among them, 84% are pollinated by insects which shows the importance of pollinating insects (Stanley *et al.*, 2016). Honey bees, an important pollinator for agriculture provide about 200 billion dollars in pollination and bees or other beneficial insects, pollinated two-thirds of crops and wild flowering plants (Chen *et al.*, 2019). Animal pollinators are required by most flowering plants (Gullan *et al.*, 2010). Insects such as flies, bees, moths, butterflies, wasps, thrips, beetles and moths are the most common animal pollinators. Important pollinator groups, i.e., bees visit around 90% of important 107 world crops. Bees that are important in pollination of crops are the solitary bees, stingless bees, bumblebees, eastern honey bee i.e., *Apis cerana*, and western honey bee i.e., *Apis mellifera* (Potts et al., 2016). Important pollinators; moths and butterflies pollinate flowering plants in the wild ecosystem.

Eusocial pollinators such as bumble bees are considered important pollinators for plants such as tomatoes and honey bees for vegetables as well as fruits (Berenbaum, 2007). There is a higher demand for crop-pollinating bees as global production of crops requiring insect-mediated pollination rises (Isaacs *et al.*, 2017). Insect-pollinated flowers produce various signals and facilitate insects to relocate rewarding flowers and insects can easily carry the pollen to the same flower species. The signals that flowers produce for flowers include colour, odour, texture, taste and shape that can be combined into different patterns named syndrome for pollination (Frankie *et al.*, 2009).

Table 2. Pollination syndrome trait (Halder *et al.*, 2019)

Trait	Bees	Beetles	Birds	Butterflies	Flies	Bats	Moths	Wind
Color	Bright white, yellow, blue.	White to dull white or green.	Brightly coloured. (Red, yellow, orange etc.)	Brightly coloured. (Red, yellow, orange etc.)	Pale and dull to dark brown or purple.	Dull white, green or purple.	Pale and dull red, purple, pink or white.	Dull green, brown, or colorless; petals absent or reduced.
Nectar Guides	Present	Absent	Absent	Present	Absent	Absent	Absent	Absent
Odor	Fresh, mild, pleasant.	None to strongly fruity or fetid	Odorless (birds have a poor sense of smell)	Faint but fresh	Putrid order, like rotting meat, dung, humus, sap and blood.	Very fragrant - fermenting or fruit-like odor.	Strong sweet; emitted at night.	None
Nectar	Usually present.	Moderate nectar producers.	Ample; deeply hidden.	Ample; deeply hidden.	Usually absent	Abundant; somewhat hidden.	Ample; deeply hidden.	None
Pollen	Limited; often sticky and scented	Ample	Modest	Limited	Modest in amount	Ample	Limited	Abundant; small, smooth, and not sticky
Flower Shape	Shallow; have landing platform; tubular.	Bowl-shaped	Large funnel like; cups.	In clusters and provide landing platforms.	Shallow; funnel like or complex.	Regular; bowl shaped.	Regular; tubular without a lip.	Regular: small and stigmas exerted.
Time	Day	Day	Day	Day	Day	Night	Late afternoon Night.	Both
Example	Mango, Litchi, Apple	Strawberry	Vanilla	Papaya	Mango	Banana, Guava.	Papaya.	Anola

Importance of pollinators in agriculture:

Pollinators are worth €153 billion (217 billion US dollars) globally, accounting for 9.5 per cent of global agricultural products utilized for human consumption in 2005 (Irshad *et al.*, 2014). Insect-

pollinated crops are worth $ 4.5 billion in the United States (Pimentel *et al.*, 1993). With over €50 billion in value, vegetables and fruits were the most valuable crop groups in terms of insect pollination, followed by edible oil crops, stimulants, nuts, and spices (GallaiSalles *et al.*, 2009). Insect pollinators are worth 954.59 million US dollars in Pakistan's Himalayan area (Irshad *et al.*, 2013). Eight agricultural commodities of Brazilian exports worth € 7 billion, which is equal to € 900 million, t 370 million, to € 1 billion in East Africa, Uganda and the Netherlands respectively (Irshad *et al.*, 2014).

Over 75 per cent of the 115 crops whose pollen vectors were identified in a recent global survey rely on animal pollination in a certain way. Thirteen of the top crops that benefit from animal pollination are completely reliant on pollinators, 30 are highly dependent, and 27 are moderately reliant. A few crops are dependent on pollinators for reproduction; without pollinators, a crop may only be produced by hand pollination. Cocoa, one of the most significant cash crops in tropical nations, kiwifruit, passion fruit, annona and sapodilla fruits, vanilla, squashes and pumpkins, cantaloupes and watermelons, and Brazil- and macadamia nuts are among them. As a result of animal pollination, most crops had a 5 to 50 percent boost in yield (mainly bees) (GallaiVaissière, 2009).

Toxicity of pesticides to pollinators:

Honey from honey bees (an important pollinator) contributes largely to the food market and provides a handsome income source worldwide (Hashimi *et al.*, 2020). Production of Beeswax; 65k tons and honey; 1.6 million tons in 2013 reported by the food agriculture organization (FAO) (Rortais *et al.*, 2017). Bees and the population of pollinator insects increased by plant biodiversity, although communities of plants were decreased by herbicides (Hashimi *et al.*, 2020). These important beneficial insects come under risk due to the use of different chemicals on plants. As

this pollinator feeds on plants to collect nectar and make honey but due to chemical toxicity, they were affected badly during their duty (Hashimi *et al.*, 2020) which results in weakening the immune system (Martin, 2015). Some insecticides including organophosphates, neonicotinoids, carbamate, phenyl pyrazoles, and pyrethroids that are commonly used act as toxicants for bees that affect their nervous system leads a loss of coordination then paralysis and ultimately death occurs (Hashimi *et al.*, 2020). Bees get pesticide toxicity by droplets of pesticides falling on them directly or might these particles transfer via wind from sprayed fields or bees fly across the field that is treated with pesticides. Insecticides are enough in killing the bees in all the above cases due to the concentration of chemicals that may be sufficient for bee death.

There are many factors when bees are at great risk including when they are caught in spray drift, residues of agrochemicals present in honey, water, pollen, larvae, feed and hive and exposure of bees to acaricide-treated combs (Sanchez-Bayo *et al.*, 2016).

Agriculture practices:

Inappropriate usage of insecticides, pesticides and herbicides, taking regular insecticide (such as imidacloprid) as an example for coating seeds and roots then absorbing insecticide poses a serious risk for pollinators like honey bees and other insects by translocating this to each plant part including the pollen and nectar (Kluser *et al.*, 2007).

Agricultural insecticide issue and pollinators:

The main hurdle in the way of pollinators is the use of agrochemicals. Different types of pollinator communities can be destabilised before and after their application in crop fields due to low and variable pollinators that will cause certain effects on pollination that lead to the pollen-limited

production of seed and fruits which ultimately results in decreasing the yield of crops (Garibaldi *et al.*, 2011; Klein A.-M. J. F. E. *et al.*, 2009). There are many examples of species populations which are driven by biotic environmental pressures such as pests, predators, and parasites in our natural world. Not even a single cause but there are multiple interacting factors which have been suggested under the category of lethal and sublethal stresses. To protect crops to control the broad spectrum of pests, insecticides are applied there. The main target of insecticides is pests, but unfortunately, some non-target organisms come under the attack of insecticides and affect nearly 35% of the global food crops (Velthuis *et al.*, 2006). The adverse impact that broad-spectrum insecticides have on non-target beneficial insects is widely known to be a major cause of pollinator decline in cultivated areas (Badawy *et al.*, 2015). Not only the killing of non-target organisms by the adverse effect of pesticides and insecticides (in particular) but also related to the induction of abnormal behaviour and function.

Conclusion

Exposure of living organisms to xenobiotics is one of the negative outcomes, resulting in a variety of individual and community problems. The indispensable agriculture sector of Pakistan provides the GDP and employment percentage of the labour force is 19.2 and 38.5 per cent respectively and the population dependent on agriculture for their subsistence is over 60 to 70 per cent (PES 20-21). This can alleviate the feeding of rural as well as urban populations of Pakistan. The use of pesticides on the one hand can alleviate plants from vector-borne diseases but on the other hand impact severely on non-target or beneficial organisms. Proper guidance and usage of agrochemicals should be considered during the time of application. Effective pesticides should be produced that are specific for target organisms and produce minimum side effects for other non-

target and beneficial organisms like pollinators (honey bees) that ultimately help in sustaining non-target organisms

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