NEW ERA AGRICULTURE MAGAZINE

Toxic effect of pesticide on agriculturally important insects

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Introduction:

Pesticides have been developed to protect our lives from mice, mosquitoes, flies, insects, and pests. They are used in schools, homes, offices, parks, public lands, agriculture, wood lots, and so on. They are widely used in the field of agricultural, municipal, home, and medical purposes in the world. They can be found in our soil, water, air, food, and even in breast milk. Pesticides are a hidden threat to humans, animals, insects, as well as to all ecosystems. They control pests and play an important role in crop productivity and prevent vector borne-diseases in humans, but they also extremely pollute our surroundings. These toxic substances are found in soil, water, air, plants, food and feed. Their residues enter plants and animal products and accumulate in humans and animals by the food chain. They endanger our lives and put down our health, as well as demolish beneficial organisms in the environment. Currently, modern agriculture should deal with some important global issues, such as population growth, food security, agrochemicals risks, pesticide resistance, natural environment degradation, and climate change. These chemicals protect crops and crop commodities from pests including weeds, insects and diseases. They increase the effectiveness of agricultural production, and so they are called plant protection products. Pesticides are an essential compartment of agricultural management; they take an important part in increasing the yield and quality of crops. These chemicals control pests, diseases, and weeds more easily, cheaply, and effectively; therefore, they are used extensively in the world. However, the usage of pesticides has increased crop productions, but the extensive, unselective, excessive, and wrong use of these chemicals caused heavy damage to the ecosystem, extending toxicity and pollution in the environment especially to the agriculturally important insects.

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Effects of Synthetic Pesticides Use on Beneficial Insects

1. **Lethal Effects (Direct Effects):** Synthetic pesticides can cause lethal effects to beneficial insects and the main lethal effect is the direct killing. Predators and parasitoids tend to be more susceptible to pesticides than plant-feeding insects because, plant feeding insects may possess detoxification mechanisms produced by plants. Pesticides kill natural enemies including those in resistant stages at the time of application and those which will migrate into the sprayed area. There is also possibilities of accumulation of the pesticides to lethal levels if the pesticides do not kill the exposed natural enemies immediately at the time of application. The parasite larva that lives inside the host will not develop if the host is killed by the pesticide. Lethal effects of the insecticides cartap, imidacloprid, malathion, metamidophos, acephate, acetamiprid and abamectin are causing damage to environment. These pesticides caused more than 61% of mortality of the parasitoid *Encarsia* sp. It has been reported that the pesticides cartap, imidacloprid, malathion, metamidophos, acephate, acetamiprid and abamectin increased mortality of the emerged parasites. Side effects of five pesticides namely Profect (w.p.), CAPL-2 (mineral oil), Lambda-cyhalothrin, Spinosad and Fenitrothion (Sumithon) on the immature stages of the parasitoid wasp *Trichogramma evanescens*, these pesticides caused mortality of the emerged adults within few hours post emergence. Furthermore the higher concentrations of Sulphur pesticide in agricultural fields increased mortality of adult parasitoid wasp *Trichogramma* and reduced the fitness of the emerged wasps. In Fig.1 nationwide and worldwide usage of different chemical has represented.

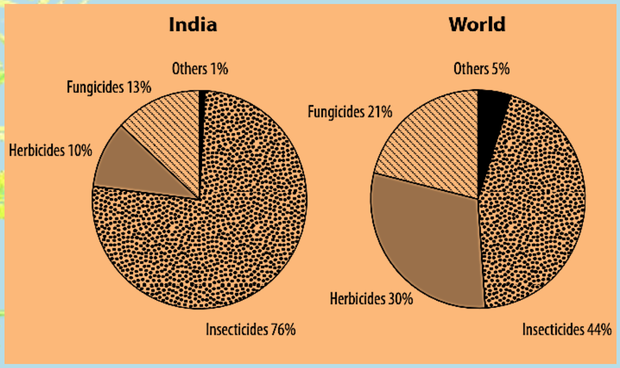

Fig.1 source: National Institute of Health

2. **Non-Lethal Effects (Indirect Effects):** Non-lethal effects of pesticides include weakening of the insects (predators and parasitoids), changing their behavior and lengthening the development period of the immature stages which will lead to the reduced prey consumption and reproductive ability. Other indirect effects are as follows.

- **Reduced Ability to Capture Prey**: Doses of cypermethrin reduced predators' capacity of finding and capturing prey. The study further reported that parasitoids submitted to insecticides lambdacyhalothrin and carbamates treatments reduced their capacity of guiding themselves to the host plants with aphids attack. When treated with fenvalerate and methomyl, females of *Microplitis croceipes* (Braconidae) which is a parasitoid of *Heliothis* sp. (*Lepidoptera*: *Noctuidae*) reduced flying activity 20 hours after the treatment. Mechanisms through which the synthetic pesticides reduce the ability of predators from capturing prey need to be studied to give the basis of optimizing the future use of selective synthetic pesticides.

- **Reduced Food Resources for Predators, Parasitoids and Pollinators:** Pesticides can have indirect effects by decreasing plants and insects which are food sources to other beneficial insects. Herbicides can change the habitats by altering vegetation structure ultimately leading to the decline of beneficial insect's populations. They can suppress plants which are used to provide nectar, pollen and honeydew to natural enemies and also eliminate the non-pests species that serve as alternative source of food for natural enemies and which provide favorable conditions for their survival. The elimination of the hosts or prey for instance by pesticidal effects will lead to the natural enemies lack food resources and therefore these natural enemies will have to leave in search of alternative prey or host. Thus, there will be no natural enemies to suppress the activities of pests. Dosage of imidacloprid above 20 PPB has been reported to reduce the ability of bumble bees and honey bees to step into food sources. There is limited knowledge on the types of synthetic pesticides that reduce the food resources for beneficial insects and therefore exploring these pesticides would help in conserving predators, parasitoids and pollinators.
- **Oviposition and Feeding Repellency of Predators and Parasitoids:** Some inorganic insecticides present on foliage may bring physical irritation to predators and parasitoids especially the small ones. Insecticides may cause repellency for feeding and oviposition. The insects will rarely oviposit on plants sprayed by pesticides. Insecticides may cause physiological changes by affecting the nervous and hormonal balance of beneficial insects. The natural enemies may reduce the probability of finding their hosts for oviposition because of the

indirect disturbance caused by the repellent effect of insecticides.

- **Reproductive Impairment of Predators and Parasitoids:** sub-lethal effects of the insecticide Spinosad which accumulated in the ovaries of the parasitoid, *Hyposoter didymator*. It also reduced the rate of fecundity and size of this insect. When submitted to low doses of the insecticide deltamethrin, the males of *Thrichogramma brassicae* did not respond to the signals of females, while treated females reduced the capacity of attracting untreated males. Wettable sulfur which is effective against mites and thrips and hydrated lime which is effective against leafhoppers can cause infertility which may be one of the main factors for the reduction of arthropod longevity. Infertility in adults may also influence the dynamics of populations as mating does not generate fertile eggs.

Impacts of Botanical Pesticides on Beneficial Insects

1. **Lethal Effects (Direct Effects):** Several botanical pesticides have caused mortality to beneficial insects due to their toxicity. These include among others citronella, eucalyptus, garlic, pyrethrum and neem products. Very high mortalities of *Venturia canescens* for the LC25 value of pyrethrum. At the LC50, pyrethrum was highly toxic to *V. canescens* and caused 100% mortality. 100% mortality of egg-larval parasitoid *Chelonus oculator (Braconidae*) occured when subjected to the LC50 value of pyrethrum. When larvae of *Ephestia kuehniella* as parasitoid hosts were treated at LC50 and LC25 values of Azadirachtin, very few adult parasitoids emerged which indicated a strong detrimental effect on the parasitoid. effects of botanical insecticides naphthoquinones from the Chilean plant *Calceolaria andina* L. (*Scrophulariaceae*), and derivatives from *Azadirachta indica* and pyrethrum products on the behaviour and mortality of whitefly *Trialeurodes vaporariorum* and the parasitoid *Encarsia formosa*, at lower concentrations, pyrethrum caused mortality to both the adults of *Trialeurodes vaporariorum* and its parasite *Encarsia formosa*. Moreover mortality of lady beetles in bean fields when treated with Neem oil (fresh) @ 2.5 ml/L water, Neem oil (stored) @ 2.5 ml/L water. Rotenone and neem reduced the numbers of adult anthocorid *Orius laevigatus*, a predator of flower thrips, *Frankliniella occidentalis*. 10% neem seed kernel extract caused the mortality of lady bird beetle, *Adonia variegata* by 73.3% compared with 65.0%

mortality caused by 5.0% neem oil. When bees *Apis millifera* (adult workers) were subjected to the diet exposed to botanicals citronella oil, eucalyptus oil, garlic extract, neem oil, or rotenone, they suffered from 42% to 60% higher mortality rates compared with the uncontaminated food control. Andiroba oil showed no significant effect on adult workers' mortality. The higher mortality rates were also observed in worker larvae exposed to dietary andiroba oil, garlic extract and neem oil, but rotenone, citronella oil and eucalyptus oil had no significant effects on mortality rates of the worker larvae.

2. **Non-Lethal (Indirect Effects):** Non-lethal effects of botanical pesticides may inhibit the ability of natural enemies to establish populations, suppress the capacity of natural enemies to utilize prey, reduce prey availability, affect parasitism or consumption rates, decrease reproduction, inhibit ability of natural enemies to recognize prey, influence the sex ratio (females:males), and reduce mobility, which could impact prey-finding. Beneficial arthropods' activities will consequently be promoted if more knowledge will be provided in understanding the non-lethal effects and the botanical pesticides that cause these effects.

- **Reduced Parasitism Rates:** Azadirachtin and pyrethrum have been reported to seriously affect the development and behavior of parasitoid *Venturia canescens* (Hymenoptera: *Ichneumonidae*). Side effects of neem products on parasitism rates of *Trichogramma pretiosum* and *Trichogramma minutum* on *Helicoverpa* eggs. Neem at 500 ppm deterred the adult of *E. formosa* from ovipositing. Also when subjected to the whitefly nymphs treated with Pyrethrum, the adult *E. formosa* was discouraged from ovipositing on the treated nymphs and consequently low percentage of parasitized nymphs. The naphthoquinones also discouraged the parasitoids from ovipositing. Effects of azadirachtin and pyrethrum, observed that the emergence rates of the egg-larval parasite Chelonus oculator were reduced when treated with azadirachtin at LC50 and LC25 values and pyrethrum at LC25 value. Establishing the relationship of the botanical pesticides with the parasitism rates is crucial in influencing the beneficial insects' activities in agricultural fields.
- **Feeding and Stabbing Repellency of the Parasitoids and Pollinators**:

repellent effects of oil of *Azadirachta indica* (*Meliaceae*) on the parasitoid *Uscana lariophaga* (Hymenoptera: *Trichogrammatidae*) is found. Neem seed kernel extract (10%) caused repellency in feeding by 72.0% of ladybird beetle *Adonia variegate,* while neem oil (5%) caused a reduction in feeding by 68%. The *Delphastus pusillus*, a predatory ladybird beetle avoided the eggs of whitefly, *Bemisia tabaci* for one day when subjected to the treatment of neem (Margosan-O). The feeding was resumed the next day. Studies on the stabbing behaviour of the parasitoid *E. formosa* and highlighted that when the host nymphs *(Trialeurodes vaporariorum*) were subjected to the treatments of naphthoquinones and pyrethrum extracts, the botanical insecticides discouraged the adult *E. formosa* from stabbing into treated nymphs. Also the sublethal doses of neonicotinyl insecticide starting around 10 PPB caused bees to lose navigation and foraging skills. It is therefore of great importance to investigate more botanical pesticides that cause stabbing and feeding repellency on beneficial insects and the ways beneficial arthropods are affected from the botanicals. This will allow for optimized and sustainable use of botanical pesticides while avoiding or minimizing side effects on beneficial insects.

- **Parasitoid, Predators and Pollinators' Developmental Impairment**: sub lethal effect of botanical pesticides on predators, parasitoids showed that the malformation in development of the natural enemies caused by these botanical pesticides may result into decrease in their parasitism and predation efficiency. Disorder in internal organs of the larvae and adults of the predator *Mallada signatus* (Neuroptera: *Chrysopidae)* after being exposed to sublethal doses of botanical insecticides with azadirachtin. The study on the effects of azadirachtin and pyrethrum on the development of the parasitoid *Venturia canescens* (Hymenoptera: Ichneumonidae) showed that sub lethal doses of azadirachtin prolonged the development time of *V. canescens* from parasitized *Ephestia* larvae, third and fifth instar.

Pesticide Toxicity to Pollinators

Pollinators perform a good job in the ecosystem. Cross pollinated and self-incompatible plants need pollination to sustain and conserve biodiversity through seed production. Bees not only collect nectars, but they also take part in pollination. The pollen grains are attached to the specialized hair on the body of the bee, thus, when bees move from flower to flower accidentally pollinate flowers. All over the world, approximately 300 commercial crops are grown, of them about 84% are insect-pollinated, which expresses the importance and value of pollinating insects. Globally, honeybees are important for agroecosystems, they take part more than $200 billion in pollination services and 2/3 crops and most wild flowering plants are pollinated by bees and other beneficial insects. Honey contributes greatly to the food market and a good source of income, globally. Food Agriculture Organization (FAO) reported that 1.6 million tons of honey and 65,000 tons of bee wax were produced in 2013. Plant biodiversity enhances bees and other pollinator insects' populations, but herbicides decrease the plant communities, as well as their adverse effects, are also represented in birds, mammals, fish, insects, amphibians, reptiles, and humans. These toxicants demolish the plant biodiversity kingdom. The United States Fish and Wildlife Services (USFWS) estimated that one-fifth honeybee colonies are killed by pesticides in Europe. Moreover, 67 million birds and 6-14 million fish are killed by agrochemicals each year in the world. Dose and time of exposure contribute to toxicity. These two factors are very important for bee intoxication. In the United States, out of 6 million, 3 million bees' colonies have been decreased due to agrochemical usage during 63 years.

Pesticide Toxicity to Animals

The scattering of pesticide residues in our environment, kill greatly non-human biota, such as bees, birds, amphibians, fish, and small mammals. The pesticides further decline the population of animals, such as marine mammals, alligators, fish, fish-eating birds. It is considered that thousands of Arctic seal's deaths had a connection with the accumulation of persistent chlorinated hydrocarbons, such as DDT, Polychlorinated biphenyls (PCBs), and dioxins, in the food chain. These chemicals are accumulated in fat and they weaken immune systems of animals. Similarly, it is thought that the mortality of striped dolphins in the Mediterranean, Beluga whales in Saint Lawrence estuary, and sea lions in the Pacific Ocean are caused by the accumulation of toxic pollutants

Pesticide Toxicity to Beneficial Microorganisms

Pesticides are sprayed on plants and soil to control pests; therefore, they are mixed with soil and residue of plants that are added to the soil. The pesticides are transformed by physical, chemical, and biological processes in soil. Some chemicals products are highly toxic to soil living organisms. Various reports stated that insecticides exert adverse effects on the microbiological properties of soil. They alter the enzymatic activities of organisms. For instance, buprofezin is caused adverse effects to invertase in soil. The enzyme activity is stimulated after a single addition, but there is a progressive decline after three repeated applications. The contaminants have adverse effects on microorganism's growth. They interfere in the microbial metabolic functions. One report indicates that compost having Pentachlorophenol (PCP) chemical inhibited microbial abundance in soil. Separate and combined pesticide usage in low concentration reduces and alters the community of microbial diversity. According to WHO Pesticide toxicity level is mentioned in **Table.1.**

most of the pesticides are non-specific and may kill the organisms that are harmless or useful to the ecosystem. In general, it has been estimated that only about 0.1% of the pesticides reach the target organisms and the remaining bulk contaminates the surrounding environment (in table. 2 target organism of different pesticide has been mentioned). The repeated use of persistent and non-biodegradable pesticides has polluted various components of water, air and soil ecosystem. Pesticides have also entered into the food chain and have bio accumulated in the higher tropic level. More recently, several human acute and chronic illnesses have been associated with pesticides exposure.

WHO CLASS	INTENSITY	SIGNAL WORDS	EXAMPLES
la	Extremely hazardous	Very toxic	Aldicarb, Parathion, Mercuric Chloride
lb	Highly hazardous	Toxic	Acrolein, Cadusafos, Ca-arsenate
Ll	Moderately hazardous	harmful	Alachlor, Bentazone, Copper f sulfate
lll	Slightly hazardous	Caution	Hexaconazole, Atrazine, Butachlor
U	Unlikely to present acute hazard		Mancozeb, Captan, Bifenox

Table.1 Source: WHO Pesticides toxicities categories according to the world health organization

Loosening the grip of pesticides

Ideally, the applied pesticides should only be toxic to the target organisms, should be biodegradable and eco-friendly to some extent. Unfortunately, this is rarely the case as

"Over the past era there has been an increase in the development of pesticides to target a broad spectrum of pests. The increased quantity and frequency of pesticide applications have posed a major challenge to the targeted pests causing them to either disperse to new environment and/or adapt to the novel conditions. The adaptation of the pest to the new environment could be attributed to the several mechanisms such as gene mutation, change in population growth rates, and increase in number of generations etc. This has ultimately resulted in increased incidence of pest resurgence and appearance of pest species that are resistant to pesticides medical purpose, and municipality; therefore, many people are exposed to them in working place, as well as their residues transfer from one organism to another through the food web. Some chemicals destroy specific organisms but many other's effects are broad and demolish a great number of organisms; therefore, they draw calamity for nature, by diminishing beneficial insects, microorganisms, animals, fish, and so on.

TARGET	PESTICIDE	TARGET	PESTICIDE
Fungi (yeast, molds)	Fungicide	Nematodes	Nematicide
Bacteria	Bactericide	Acarids (mites, ticks)	Acaricide
Insects	Insecticide	Rodents	Rodenticide
mosquitoes	Repellants	Gastropods (slugs, snails)	Molluscicides
Termites and ants	Termiticide	Slime	Slimicides
Algae	Algicide	Fish	Piscicide
Birds	Avicides	Weeds	Herbicide

Table. 2: Pesticides and their target organism

Conclusion

Pesticides are used in agriculture to protect plants from pests; therefore, agricultural products have been increased via the usage of these chemicals. Although their application plays an important role in crop productivity, their excessive usage also pollutes our surroundings. Our soil, water, air, food, feed, and other sources have been polluted by the heavy application of pesticides. They are widely applied in agriculture, home, They kill organisms, prevent their growth, and cause various diseases and birth defects. These toxicants enter into the human body through oral, dermal, lungs, and eyes as chemical substances and affect a living organism. These chemicals influence kidneys, lungs, skin, liver, spleen, gastrointestinal tract, cardiovascular system, and nervous system. Cancer, mutation, and some other common diseases have been linked with pesticides. Toxic effect on insect causes severity in incidence of a particular effect. In order to reduce and control the even worsening situation we should adopt integrated pest management practices, should use biological control method etc.