Impact of pesticides on beneficial insects in various agroecosystem

ABSTRACT:

Beneficial insects play a vital role in natural pest control and pollination in agricultural crops. The use of synthetic pesticides in agricultural areas is harmful to both natural enemies and pollinators. Pesticides impair the survival of a variety of life cycle stages, limit reproductive capability, alter host fitness for parasitising or predation, reduce parasitoids' emergence from sprayed host eggs, and cause direct death. When natural enemies are decreased, pest population dynamics, such as resurgence and secondary pest eruption, may suffer even more devastating repercussions. Pollinator decline decreases agricultural yield. This study intends to investigate the side effects of synthetic and botanical pesticides on beneficial insects in order to provide a foundation for future research into the detrimental effects of synthetic and botanical pesticides on these insects. This information will aid in optimising pesticide use in integrated pest management programmes by implementing more sustainable and environmentally friendly methods such as the use of correct doses and selective insecticides in agricultural areas.

Keywords: Beneficial insects, pollinators, predators, parasitoids, agroecosystem, pesticides, harmful effects

INTRODUCTION:

In an agricultural or ecological environment, insects might be categorized as either beneficial or harmful (pests). Pollinators, pest insect predators, and parasites are among the agriculturally useful insects (parasitoids). They provide ecological services like agricultural pollination and biological control of crop pests. Due to the occurrence of pests and diseases, modern agriculture has recently introduced the use of herbicides and pesticides. Although pesticide toxicity to non-target organisms was known earlier, it really took off when Rachel Carson's 1962 book "Silent Spring" became widely read and raised awareness of environmental issues. Pesticide toxicity was eventually linked to numerous instances of non-target mortality and large-scale damage. Pesticide usage in agricultural fields has the possibility of hampering beneficial insect activity because it alters the species composition and quantity of these insects (Ndakidemi *et al.,* 2016). The majority of commercially available synthetic field agricultural pesticides have a broad-spectrum activity that kills both pests and beneficial insects. Carbamates, pyrethroids, organochlorines, and organophosphates are examples of broad-spectrum synthetic insecticides. Since their introduction in the 1940s and 1950s, these have been extensively employed (Gyawali, 2018). Organophosphates, along with carbamates and pyrethroids, are some of the most insect-toxic insecticides. Whereas pyrethroids specifically are sodium channel modulators that overexcite neurons, organophosphates, and carbamates are cholinesterase inhibitors that specifically inhibit cholinesterase (Visalatchi and Jeyabalan, 2019). Acephate, chlorpyrifos, malathion, and phosmet are examples of organophosphates, whereas cyfluthrin, fenvalerate, -cyhalothrin, and permethrin are pyrethroids (Pathak *et al.,* 2019). Aldicarb and carbaryl are examples of carbamates that have detrimental effects on an insect's ability to survive, grow, develop, reproduce (sexual ratio, fecundity, lifespan, and fertility), and behave (motility, orientation, eating, oviposition, and learning (Mitra *et al.,* 2011).

Certain insecticides, both natural and manmade, harm pollinators and natural enemies. According to, natural enemies and pollinators who are not the intended targets of pesticidal plants may be adversely affected because these plants' active components are identical to those found in synthetic pesticides. For instance, there has been evidence of a drop in the number of wild pollinators in several parts of the world (Giunti *et al.,* 2022). Pesticide use, which has negative direct and indirect effects on populations of beneficial insects, is one of the reasons for the drop. Several plants are poisonous and non-specific. For instance, nicotine derived from tobacco plant extract is categorised as WHO Class, which indicates highly harmful. Class II rotenone is found in species of Derris and Tephrosia. Rotenone and chrysanthemum-derived natural pyrethrum are extremely poisonous. When used, synthetic pesticides can kill unintended creatures, such as bugs' natural predators, parasites, and organisms that are good for the ecosystem's balance and health. Pesticide poisoning can result in population decreases and, as a result, pose a hazard to rare species by altering their behaviour (Aktar, 2009).

IMPORTANCE OF BENEFICIAL INSECTS IN VARIOUS AGROECOSYSTEM:

Insect pollinators are insects that visit flowers and feed on the nectar and pollen produced by flowering plants. During feeding, insects that visit flowers have the ability to transmit male gametes (found in pollen) to the female gametes, resulting in pollination (Serrão *et al.,* 2022). The majority of blooming plants in the globe, including many cultivated plant species like sunflower, cucurbitaceous vegetables, alfalfa, coriander, cardamom, ginseng, and apple, depend on insect pollination for reproduction (Singh, 2017). Many crops rely on pollination for fruit set and seed generation in order to provide a decent yield. According to estimates, insect pollination accounts for 35% of the world's agricultural production (Omar *et al.,* 2021). *Apis meliffera* L. (European honey bee) is in charge of pollinating the bulk of crops. Non-Apis bees are also significant agricultural pollinators, particularly for crops where honey bees are ineffective pollinators (e.g. alfalfa, squash). Crop pollination is controlled by a few non-Apis species (Getanjaly *et al.,* 2015).

Non-Apis species handled for pollination include bumble bees, *Bombus impatiens* Cresson (Hymenoptera: Apidae), which are used to pollinate cranberries (*Vaccinium spp*.) and greenhouse tomatoes (*Solanum lycopersicum* L.). Although bees are the most effective insect pollinators for the majority of plant species, other insects have been identified for their pollination efforts (Khalifa *et al.,* 2021).

Natural enemies are insect predators and parasitoids that attack and feed on other insects, notably insect pests of plants. Natural enemies contribute to a sort of pest regulation known as natural biological control by eating in this manner (Driesche *et al.,* 2009). Natural enemies account for 33% of natural pest control in farmed settings. Predaceous natural enemies are insects that are free-living, mobile, bigger than their insect prey, and capable of consuming many preys during their life cycle (Karp *et al.,* 2018). Nonetheless, parasitoids mostly belong to the orders Hymenoptera and Diptera, and their host ranges are thought to be more specialised than predators. Adult parasitoids that are free-living seek for a host and, depending on the parasitoid species, parasitize different life stages of their host (egg, larva, pupa, adult). Parasitoids can deposit a single egg (solitary) or several eggs (gregarious) on or within its host, after which the juvenile parasitoid(s) feed on their host to complete development, kill their host, and emerge as a free-living adult. Natural enemies in agricultural settings have the ability to keep crop pests from reaching economically destructive levels (Fei *et al.,* 2023).

WEED KILLERS:

Many insects feed on undesired weeds in the same way as they do on cultivated crops. In several situations, the presence of these insects has greatly aided in the elimination of weeds (Nicholls *et al.,* 2013).

SOIL BUILDERS:

Insects that dwell in soil build tunnels that allow smaller creatures, water, air, and roots to pass through. Earthworm activity can increase soil nutrient cycle, soil physical qualities such as soil structure and tilth, and the activity of other beneficial soil organisms. Tiny dung beetles construct dung tunnel walls and dung balls, which aid in soil quality maintenance. Insect excreta also enriches the soil (MacMahon, 1981).

Examples include beetles, ants, cutworms, fly larvae, crickets, termites, and wasps

TOXIC EFFECT OF PESTICIDES ON AGRO-ECOSYSTEM:

Plants or crops, soil, and water make up the majority of an agroecosystem. The ecosystem is active and sustainable due to dynamic interactions of the components' (Van der werf, 1996). Pesticides are used to reduce each organism to economic threshold levels or equilibrium positions when sustainability breaks due to a significant outbreak of pests or diseases. In this respect, pesticides function as a tool to maintain the viability of an ecosystem, but only when they are selective and only affect their intended targets. Sometimes, pesticides have an impact on non-target people in addition to the target species, undermining the sustainability of the ecosystem (Hassan *et al.,* 1985). Target and non-target subjects are not constant and universal in pesticide toxicity research. When weedicides are used, the biological control agent, beneficial organisms, detritivores, and organisms that depend on the plants for food and shelter become non-targets and the plants themselves become the target (Desneux *et al.,* 2007).

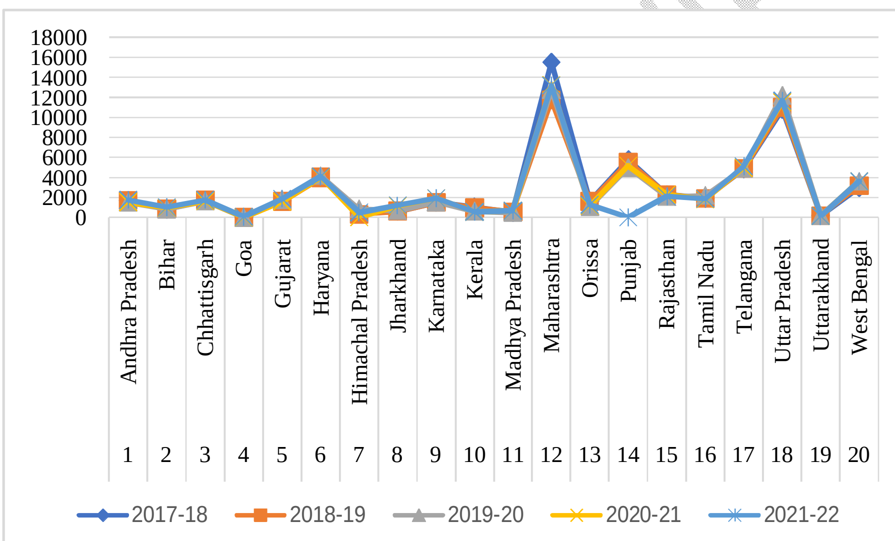

Fig. 1. State wise chemical pesticide consumptions

Source: States/Zonal Conferences on Inputs (Plant Protection) for Rabi & Kharif Seasons

TOXIC EFFECT OF HERBICIDES

Herbicides' effects on insects and other arthropods are frequently caused by the destruction of both target and non-target host plants (Mahmood *et al.,* 2016). Although agriculture has a detrimental impact on many soil organisms for the same reasons, conservation tillage to prevent soil erosion has led to an increase in herbicide use in several countries. Because the half-life of herbicides in the environment generally exceeds a month, and for certain compounds surpasses a year, insects inside fields and nearby borders exposed to drift are most likely to be exposed to herbicides in soil (Ustuner, 2020). Most herbicide impact reports reveal changes in insect survival or egg production as an indirect effect of an increase or decrease in host plant population. The loss of predatory arthropods and pollinators is often caused by the elimination of plant hosts, pollen, and nectar. Herbicides destroy nectar, shelter, nesting, and overwintering habitats (Sánchez-Bayo, 2021). In contrast to insecticides and fungicides, some herbicides, such as 2,4-D, may be compatible with biological weed control agents. Pest species have increased as a result of herbicide treatments that reduce natural adversaries. Some decreases are due to the chemicals' harmful effects on predatory and parasitic organisms (Lo *et al.,* 2010). For instance, consider the total parasitism rate by specialisation. *Aphidius rhopalosiphi* (Hymenoptera: Braconidae) wasps were reduced in plants treated with 0.1% DCBN, with the herbicide also producing a sex ratio bias [37]. Although most herbicides have little direct effect on arthropod populations, 2,4-D weed control treatments indirectly increased the density of sugarcane borer pests, which was attributed to reductions in the parasitoid *Trichogramma minutum* (Hymenoptera: Trichogrammatidae) caused by herbicide toxicity. Predatory mites are more vulnerable to herbicides like as paraquat, 2,4-D, terbacil, and glyphosate (Sánchez-Bayo, 2021).

IMPACT OF INSECTICIDE

Since the extensive usage of pesticides began in the 1940s, four major indirect impacts have been identified in the literature. Two of them relate pest control activities, which frequently fail due to a failure to consider the underlying ecology of agroecosystems. Another is tied to food chain poisoning, and a third indirect consequence is related to the stress that hazardous substances cause in organisms.

When insecticides are sprayed to a crop, target pests and other non-target insects are typically destroyed, but individual insects do not die instantly: the period to death can range from a few minutes to a few days, depending on the exposure dose each insect gets (Mitra and Raghu,1998). Meanwhile, natural adversaries eating on the afflicted species may get poisoned and lose their predatory skills, or even die. Predation of the spined soldier bug, *Podisus maculiventris* (Hemiptera: Pentatomidae), for example, was impaired and weight gain was reduced as the bugs fed on diamond moths, *Plutella xylostella* (Lepidoptera: Plutellidae), in cabbage plots treated with imidacloprid; interestingly, despite being applied at the recommended rates, the insecticide did not significantly reduce moth (Peterson, 2012). Survival of the ladybird *Cycloneda sanguinea* (Coleoptera: Coccinellidae) fed on aphids treated with thiamethoxam and imidacloprid was also significantly reduced in both laboratory and field settings while residues of dimethoate in preys aphids that had been treated at field exposure rates caused significant mortality levels in three carabid predators: *Pterostichus madidus, P. melanarius* and *Nebria brevicollis* (Coleoptera: Carabidae). This suggests that carabids eating in treated fields and field borders might be poisoned by the indirect method of devouring contaminated prey (Santos *et al.,* 2017).

Another indirect impact of predation is the augmentation of insecticidal actions. In microcosms, for example, the pesticide chlorpyrifos at 1 g/L directly decreased the biomass of herbivorous plankton (4 waterflea species) by 7-12% (Takacs *et al.,* 2002). When every species was present. The introduction of a predatory glassworm, *Chaoborus obscuripes* (Diptera: Chaoboridae), improved the insecticide's overall impact on water fleas. Apart from the direct effects of imidacloprid on benthic macroinvertebrate assemblages, sublethal levels of this insecticide on the caddisfly *Sericostoma vittatum* (Trichoptera: Sericostomatidae) and the midge *Chironomus riparius* (Diptera: Chironomidae) also compromised antipredator behavioural responses in both insect species. Although chlorantraniliprole inhibited the breakdown of leaves by the shredder caddisfly *S. vittatum*, Another indirect impact of predation is the augmentation of insecticidal actions. Sublethal pesticide doses, for example, might have severe repercussions in terms of mortality from predation in benthic insect populations, as well as create maladaptive responses in zooplankton species, which may limit their long-term survival in the field (Bhat *et al.,* 2022).

THE IMPACT OF SYNTHETIC PESTICIDES ON BENEFICIAL INSECTS:

DIRECT EFFECT:

Synthetic pesticides can be deadly to beneficial insects, with direct death being the most common. Predators and parasitoids are more vulnerable to pesticides than plant-feeding insects because plant-feeding insects may have detoxifying systems. Pesticides destroy natural enemies, both those that are resistant at the time of treatment and those that migrate into the sprayed region. There is also the possibility of pesticide build up to fatal levels if the pesticides do not kill the exposed natural enemies immediately after application. If the pesticide kills the host, the parasite larva that dwells within it will not develop. Cartap, imidacloprid, malathion, metamidophos, acephate, acetamiprid, and abamectin were shown to be fatal. These chemicals were responsible for more than 61% of the parasitoid Encarsia sp. mortality. It is found that the insecticides cartap, imidacloprid, malathion, metamidophos, acephate, acetamiprid, and abamectin enhanced the mortality of the emerging parasites (Kannan *et al.,* 2020).

INDIRECT EFFECT:

REDUCED ABILITY TO CAPTURE PREY:

Decreased Capability to Acquire Prey discovered that cypermethrin dosages lowered predators' ability to find and capture prey. The study also found that parasitoids exposed to pesticides lambdacyhalothrin and carbamates lowered. Aphids have the ability to guide themselves to host plants when attacked. Females of *Microplitis croceipes* (Braconidae), a parasitoid of *Heliothis* sp. (Lepidoptera: Noctuidae), decreased flying activity 20 hours after treatment with fenvalerate and methomyl. Mechanisms by which synthetic pesticides impair predators' capacity to capture prey must be investigated in order to optimise the future usage of selective synthetic pesticides (Fernandes *et al.,* 2010).

DECREASING FOOD SUPPLIES FOR PREDATORS, PARASITOIDS, AND POLLINATORS:

Pesticides can have an indirect effect by reducing the number of plants and insects that provide food for other beneficial insects. Herbicides can modify ecosystems by changing vegetation structure, resulting in a drop in beneficial insect populations. They have the ability to reduce plants that offer nectar, pollen, and honeydew to natural enemies, as well as eradicate non-pest species that serve as an alternate source of food for natural enemies and create favourable conditions for their survival. The eradication of hosts or prey, for example, via pesticidal effects, would result in a shortage of food supplies for natural enemies, forcing these natural enemies to flee in search of alternative prey or host. As a result, there will be no natural enemies to restrict insect activity (Kluser and Peduzzi, 2007).

FORAGING ACTIVITY OF POLLINATORS DECREASING:

Researchers researched the foraging behaviour of honey bees *(Apis millifera*) and observed anomalous foraging when the honey bees were exposed to the pesticide imidacloprid and could not return to the feeding spot in the same day in the same way as untreated bees did. Krischik, (2014) discovered that when bees were exposed to sublethal amounts of neonicotinyl pesticide, they lost their navigation and foraging abilities. found that when honey bees were exposed to imidacloprid levels more than 30 ppb, foraging rates dropped and handling time increased. Further study on the diminished foraging abilities of both pollinators and natural foes of pests caused by synthetic pesticides is the way ahead for protecting bees and thus encouraging biological control and pollination in agriculture (Mahfouz *et al.,* 2012).

RISK OF PESTICIDES TO BEES:

After explaining the different routes of pesticide exposure and their effects on bees, an assessment of the real hazards that current pest control agents and acaricides used for treating hives provide to honey bees is required. The greatest danger is from the chemicals' acute toxicity to bees, which results in their death in the short or medium term. As previously stated, further hazards include sub lethal effects that may affect hive function and the long-term survivability of colonies.

Hazards are often evaluated as damage probability based on acute toxicity and the frequency with which a chemical may impact bees. There are three scenarios to consider: pesticide spraying over agricultural fields ingestion of agrochemical residues found in pollen, honey, and water, which are collected and ingested by forager bees and transported to the hive, where they are processed into honey and beebread and fed to the other bees, the larvae, and the queen; and exposure to combs treated with acaricide products (Tosi *et al.,* 2022).

RISKS BY CONTACT EXPOSURE:

Apart from oral exposure, bee larvae may come into touch with residues deposited on the walls of comb cells, namely acaricides used to control Varroa. While the wax contains the largest concentrations of pesticide residues in a hive, the availability of such chemicals is assumed to be modest, with the exception of fumigated acaricides. The danger of the latter items to bee larvae should be evaluated by contact exposure rather than oral ingestion, as some writers do. In this example, the maximum residual dosage is calculated to be 5 mg of active chemical per cell for a single larva, and the contact LD50 is employed instead of the oral LD50 (Gyawali, 2018).

DECLINE OF REPRODUCTIVE ACTIVITY OF PREDATOR AND PARASITOIDS:

Sub-lethal effects of the pesticide Spinosad accumulated in the ovaries of the parasitoid, *Hyposoter didymator*, were documented in Reproductive Impairment of Predators and Parasitoids. It also decreased the insect's fertility and size. Males of *Thrichogramma brassicae* did not react to female signals when exposed to modest concentrations of the pesticide deltamethrin, whereas treated females diminished their ability to attract untreated males.

MANAGEMENT IN ORDER TO AVOID PESTICIDE IMPACTS:

The various hazards indicated above provide some insight into the sort of exposure most detrimental to the various bee castes in the hives. The most common cause of occurrences is spray drift involves forager worker bee mortality, but intake of tainted pollen, nectar, and water is at the foundation of the colony collapses disorder illness that affects many apiaries throughout the world, mostly impacting nursing workers and the queen (Sanchez-Bayo and Goka, 2016). Moreover, the acaricides employed in Varroa treatment represent a major risk, mostly to bee larvae, and hence to the long-term viability of the colonies. Being aware of these hazards can assist beekeepers and farmers in developing specialised management plans to prevent them. Being aware of these hazards can assist beekeepers and farmers in developing particular pesticide control programmes (Gill and Garg, 2014). Beekeepers should be aware of the landscape environment in which their managed bees graze, keeping in mind that a considerable part of land in both developed and developing nations is utilised for agricultural production, which uses pesticides of various types on a regular basis. While the use of these plant protection compounds cannot be halted because they are required for agricultural output, a sensible strategy must be taken to reduce the hazards of such agrochemicals to bees (Kuan *et al.,* 2018) Notwithstanding all measures, if an area where the crop or weeds were in blossom was mistakenly sprayed, the farmer should tell the affected beekeepers so that they may take necessary action. This should keep managed bees out of the sprayed area for the time being.

CONCLUSION:

The assessment of pesticides' possible dangers to non-target species is critical for improving ecosystem services (such as natural pest control or pollination) and, as a result, agricultural output. Further study is needed to identify the impacts of pesticides, both botanical and synthetic, on predators, parasitoids, and pollinators. Most of the negative effects, particularly of botanicals, are dose-related, indicating that additional study on the proper dosage is needed. It is also critical to study beneficial insects in a certain field setting before investing in a specific pesticide application to allow for safeguards as to the precise chemical and dosage to employ. For a while. Pesticides may cause harm to neighbouring flora foraged by bees, including hedges, roadside weeds, and trees such as fruit trees, eucalypts, and others, in addition to farming areas.

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