Impact of agrochemicals on butterflies, the consequences for pollination and Conservational measurements: A review

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Introduction

Agriculture is the most common form of land use in India. India holds the second largest agricultural land among all the countries (IBEF) [1]. Around 60.3 per cent of India's land area is dedicated to agriculture (World Bank Data) [2]. As a result, a large portion of Indian biodiversity can now be found in agricultural landscapes. Agricultural fields and its surrounding complementary vegetation provide plant resources and unique ecosystems to butterflies, where they complete their life span. Butterflies possess specific host specificity because they share a unique inter-relationship with plants. Butterflies are one of the most beautiful, well known and easily identifiable groups of insects belonging to the order Lepidoptera. They are effective ecological markers of urbanization due to their sensitivity to environmental changes [3] and are critical components of global bioindicators [4]. Butterflies are significant plant pollinators in the local environment, helping to pollinate over 50 commercially important plant crops [5]. Butterflies play an important role in the ecology, particularly by recycling nutrients (N, P, and K) that crops require [6].

Modern agricultural fields are often subject to intensified use, characterized by increased field sizes, decreased crop diversity and reduced availability of semi-natural habitats. Furthermore, they are exposed to large pesticide inputs, which are intended to protect agricultural productivity from pests (Sciarra et al., 2015) [7]. Globally, agricultural producers use around 3 million tons of pesticides each year.[8] Butterflies are also affected by the changing environment in cultivated habitats [9] due to intensive cultivation activities, monoculture farming, ground burning, herbicides, insecticides, and inorganic fertilizers application [10] amidst agro-ecosystems. This has altered the habitat quality considerably and many native butterfly species facing severe threat due to non-availability of food and host plants during their development.

Insecticides and Butterfly Decline

The use of insecticides in India, particularly in agricultural practices, has raised significant concerns regarding their impact on non-target organisms, including butterflies. Various studies have highlighted the detrimental effects of specific insecticides on butterflies' abundance and diversity. Various studies have identified different classes of insecticides and their specific effects on butterflies.

Common Insecticides and Their Effects

1. Permethrin

Permethrin is a synthetic pyrethroid widely used for mosquito control. Permethrin is also used as an insecticide in agriculture to protect crops and kill livestock parasites. It is a broad-spectrum insecticide. Research indicates that while adult butterflies are exposed to lower concentrations than mosquitoes and other target pest during ultra-low volume (ULV) sprays, they can still suffer high mortality rates. In some cases, studies reported 100% mortality of adult butterflies following certain sprays despite lower average concentrations compared to mosquitoes [11].

2. Endosulfan

This broad-spectrum pesticide Endosulfan is a pesticide used to treat a variety of crops and as a wood preservative. Endosulfan is used to treat a wide range of crops, including cotton, tea, coffee, soybeans, sunflowers, vegetables, rice, pulses, and fruit. It is effective against a variety of pests, including aphids, fruit worms, beetles, leafhoppers, moth larvae, and white flies. But has been linked to a significant decline in butterfly diversity in areas like Kasaragod, Kerala. A study found that endosulfan spraying led to a 40-70% reduction in butterfly populations due to habitat contamination and loss of food sources. Although there are signs of recovery in butterfly populations since the ban on endosulfan in 2011, its long-term effects continue to pose risks.[12]

3. Neonicotinoids: Neonicotinoids are used as an insecticide to control sucking pests on a variety of

crops, including cotton, citrus, sunflower, mustard, and cucurbits. [13]. These systemic insecticides have been implicated in the decline of butterfly species globally. Studies suggest that exposure to neonicotinoids can lead to reduced survival rates and altered behavior in butterflies. The presence of these chemicals in agricultural landscapes has raised concerns about their cumulative effects on butterfly diversity and population. [14]

Mechanisms of Impact

1. Direct Exposure: Butterflies can be directly exposed to insecticides through foraging on treated plants or through spray drift from nearby agricultural fields. This exposure can lead to acute toxicity or sub-lethal effects, such as impaired reproductive success and developmental issues [15].

2. Habitat Alteration: The application of insecticides often coincides with flowering periods, which can diminish food resources for butterflies and disrupt their life cycles. The loss of floral diversity due to pesticide use further exacerbates the decline in butterfly populations [16].

3. Residue run-off: Numerous pesticides that are applied as seed coatings or outer protection leave residues in the soil during germination; if the chemicals in the coatings are soluble in water, they can readily seep into the soil and ground drainage system [17]; butterflies that exhibit mud pudding behaviour, can also be exposed to pesticide residue runoff in soil water [18].

Consequences on pollination

Few research has been conducted to better explain the decline of butterfly population and diversity in agricultural areas. There are several reasons for their decline. Most importantly, the indiscriminate use of pesticides in agricultural environments has direct and deadly impacts on their biology [18]. Butterfly populations in India have been dropping dramatically from the last decades [19]. Approximately 100 of the 1,501 butterfly species are threatened by habitat loss [20], chemical poisoning, and extinction [21]. Furthermore, in every butterfly species' life cycle, 95% of butterflies die before reaching adulthood owing to parasitic infestation, predator and parasitoids assault, habitat degradation, and pesticide/insecticide poisoning in agricultural settings [22].

Butterflies are vital pollinators for many crops and wild plants. The decline in butterfly populations can have cascading effects on ecosystems such as reduced pollination services, which may result in:

1. **Decreased Crop Yields:** Many fruits, vegetables, and nuts depend on pollination from butterflies and other insects. A reduction in butterfly populations could lead to lower yields and diminished quality of these crops. [23]
2. **Reduced Plant Diversity:** As butterflies decline, the competition among flowering plants for pollinators increases. This shift can favor certain plant species over others, potentially leading to a decrease in overall plant biodiversity. Plants that rely heavily on specific pollinators may face extinction if those pollinators become scarce. [24]
3. **Increased Reliance on Chemical Inputs:** Farmers may resort to using more chemical fertilizers or pesticides to compensate for reduced natural pollination, which can lead to further environmental degradation and harm other beneficial species. [21,25].
4. **Impact on Other Pollinators:** The loss of butterflies can disrupt the balance within pollinator communities. Since butterflies often interact with other pollinators, their decline may lead to reduced visitation rates for these species as well. This interconnectedness means that the decline of one group can negatively impact others. [24]
5. **Prey predator relationship:** For birds, shrews, and other invertebrates, caterpillars provide a vital source of food. Therefore, it is possible that other species are impacted by negative effects on their abundances.

Conservational measures

Although agricultural fields are exposed to agrochemical inputs, they serve as a crucial habitat for butterflies in agricultural landscapes and as a place where caterpillars develop. Low levels of agrochemicals can have a variety of effects on butterflies' population. Because of this, agricultural fields ought to be shielded from the use of any agrochemicals. Biopesticides, derived from natural materials such as plants, animals, and microorganisms, offer a more environmentally

friendly alternative to synthetic pesticides. Some key benefits of biopesticides include:

1. **Eco-friendliness:** Biopesticides decompose quickly and do not leave harmful residues in the environment.
2. **Target specificity:** They are designed to affect only specific pest species, minimizing harm to non-target organisms such as butterflies.
3. **Sustainable agriculture:** Their use can be integrated into sustainable farming practices, reducing reliance on chemical pesticides, and promoting biodiversity. [26]

Implementing Biopesticides in Conservation Efforts

To effectively conserve butterfly populations through biopesticide use, several strategies can be adopted:

1. **Integrated Pest Management (IPM):** This is an environmentally friendly approach; it combines biological control methods with careful monitoring and minimal pesticide use. It emphasizes the use of biopesticides as a first line of defence against pests [27, 28]. And its proper use may help reduce pesticide exposure to non-target organisms, including native pollinators like butterflies.
2. **Habitat Restoration:** Creating and maintaining habitats that support native flora can enhance the natural resilience of butterfly populations against pests without resorting to chemical controls [29]. Buffers, in field margins, by planting native grasses and wildflowers can be prepared.
3. **Education and Advocacy:** Raising awareness about the harmful effects of conventional pesticides and promoting biopesticide alternatives can help shift agricultural practices towards more sustainable methods.

Types of Biopesticides

1. Microbial Pesticides: Microbial pesticides consist of microorganisms that act as active ingredients against pests. They can include:

Bacterial Biopesticides: These are primarily used to control insects. The most notable example is Bacillus thuringiensis (Bt), which produces toxins harmful to certain insect larvae. Other examples include Bacillus subtilis and Pseudomonas fluorescens [30].

Viral Biopesticides: These utilize viruses, particularly from the family Baculoviridae, which infect specific insect hosts. When ingested, the virus disrupts the insect's gut cells, leading to its death [30].

Fungal Biopesticides: Fungi can infect insects through their cuticle without needing ingestion. Common fungal biopesticides include *Beauveria bassiana* and *Metarhizium anisopliae*, which can penetrate the insect's body and cause disease.[26]

2. Biochemical Pesticides

Biochemical pesticides are derived from natural substances that control pests through non-toxic mechanisms. This category includes:

Plant Extracts (Botanicals): These are derived from plants and can include compounds like pyrethrum from chrysanthemum flowers, which is effective against a variety of insects [31].

Semio chemicals: These substances affect insect behavior, such as pheromones that disrupt mating patterns or attract pests to traps. [26, 31].

Natural Insect Growth Regulators: These compounds interfere with the growth and development of insects, preventing them from maturing into reproductive adults.[31]

3. Plant-Incorporated Protectants (PIPs)

These are genetically modified plants engineered to express pest-resistant traits. For example, Bt cotton has been modified to produce the Bt toxin itself, providing built-in protection against certain pests without the need for external application of biopesticides [26].

Conclusion

The decline of butterfly populations poses a multifaceted threat to agriculture through impacts on pollination, biodiversity, ecosystem health, and economic stability. Addressing these issues requires concerted efforts in conservation, habitat restoration, and sustainable farming practices to ensure both butterfly populations and agricultural productivity are maintained. Excessive use insecticides, particularly neonicotinoids and pyrethroids, pose significant threats to butterfly populations. The transition from conventional pesticides to biopesticides can be a crucial step in butterfly conservation efforts. Continued research and advocacy are essential to ensure that these environmentally friendly solutions become standard

practices in agriculture. These practices will support butterfly populations as well as will also contribute to broader ecological health and economic viability for farmers. Continuous research is essential to refine these practices and maximize their benefits for both biodiversity and agriculture.

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