

# An Alternative Approach to Synthetic Insecticides: Bio-Pesticides

Amaninder Kaur Riat\* and Arpinder Kaur

Department of Zoology, School of Biosciences and Bioengineering, Lovely Professional University, Phagwara.

EmailId: amaninder.21097@lpu.co.in

## Abstract

Crop production grown for human consumption is at extreme radical level due to infestation of harmful pests which host on plants. A chemicals pesticide has been used by the farmers to protect their crops from pests. Continuous use of chemicals leads negative impact on environment, leads toxic compounds affecting humans health and warm blooded animals. A synthetic chemicals harmful implication leads to search for an alternative approach. Utilization of naturally occurring substances as plants, animals or living organisms conducted biopesticides which includes microbial pesticides, certain biochemical formulations or genes of genetically modified plants that encodes insecticidal toxins. Biopesticides are the environmentally safe pesticides targetable to particular pest often sounds effectively to pest issues. Many biopesticidal products has been firmly registered in Indian market and processed for further practices. A bacterium, Fungi, Viruses and nematodes works efficiently against target pests. The present review intended to deal with the incessant problems and drawbacks of chemical pesticides and synthetic pesticides and to highlight the priorities and potential of active substances, mostly biopesticides to control pests.

**Keywords:** Bio-pesticides, Microbial pesticides, plant incorporated protectants, Biochemical pesticides.

## INTRODUCTION

Agriculture plays an important role in satisfying the growing food demands in developing countries of the world. Apart from satisfying the demands of users it also helps in improving economy of the country. Several technologies were innovated to maximize the productivity of crop yield. Fertilizers and pesticides development have assisted much in this regard. But the devastating activities of numerous pests like fungi, bacteria, nematodes, and weeds introduced naturally and artificially into agriculture which leads an extreme decrease in the crop yields [1]. Crop yield decreases by pests also incorporate with other issues like indigent soil, weather conditions and farmers limited access to technology. Despite having crop protection activities about 40% reduction of world crop productivity has been eliminated due to pests. Crop production grown for human consumption is at extreme radical level due to infestation of plant pathogen, especially fungi, weeds and animal pests [2].

Protection of crops against the plague of pests, chemical pesticides has solemnly used from the last past half decades. Continuous utilization of synthetic pesticides leads an obstructive impression on environment, leads several toxicity to the humans and warm-blooded animals. Damage to crops by pesticides not only affect the crop production but also threaten the human health and its regular use creates a serious ecological problem. Synthetic pesticides use also becomes difficult to control pest problem. Management strategies fail due to

unrestricted prophylactic use of pesticides through which the pest develops heritable resistance [3]. An approximate close to 200 species of weeds developed resistance to the herbicides [4] and over 500 species of arthropods that are resistant to insecticides [5].

Instead of using chemical and synthetic pesticides to control pests, an authoritative method should be adopted using biofertilizer, biostimulant, biopesticides which works in eco-friendly manner and have antioxidant activity against harmful pests as an alternate to chemicals. Naturally occurring substances was extracted from plants which works effectively, perishable and does not have any residual impact on environment. Development of farming biocontrol pesticides is increasing as their effectiveness against the pests becomes significant as chemicals have negative effect on crop yield [1].

The present review intended to deal with the incessant problems and drawbacks of chemical pesticides and synthetic pesticides and to highlight the priorities and potential of active substances, mostly biopesticides to control pests.

**BIOPESTICIDES**

Biopesticides are the eco-friendly pesticides formulated from naturally occurring materials as animals, plants, bacteria, and living organisms which includes phytochemicals, natural enemies, microbial products or semiochemicals by products. An inappropriate use of large spectrum of pesticides can be radical to the health of living creatures and surroundings. Yet, use of Biopesticides can control the pests in environmentally protection manner by its non-toxic mechanism [6]. For the crop protection Biopesticides occupies a particular group in Integrated Pest Management (IPM). Biopesticides are the environmentally safe pesticides which are targetable to particular pest often sounds effectively to pest issues. Now certain plant products becomes a major source uses as a biopesticides. Having considerable advantages of biopesticides certain researches and developments have been done in this field and proved to be very beneficial alternative to the chemical pesticides. Biopesticides have advantages in which mostly researches has been done analogous to this regards as products are:

- Non- toxic as it does not affect beneficial insects.
- Formulated to reduce the population of destructive pest.
- Decompose quickly and often largely avoided the pollution.
- Occupies particular group in Integrated Pest Management (IPM) to control major pest menace while a crop yield remains high.

**BIOPESTICIDES IN INDIA:** Biopesticides represents about 2.89% of the overall pesticides in year 2005 in India and in coming years it expected to have annual growth rate of nearly 2.3%. Approximately 500 pesticides are duly recorded by CBI in market of India, yet certain issues on its quality control of products are the major obstacle.

**Table 1: Biopesticides registered under Insecticidal Act, 1968 for use in the country [7].**

S.no.	Names of Biopesticides under the Insecticidal Act, 1968	COMMENTS
1.	<i>Azadirachtin indica</i>	Neem based products are formulated to target pests. Azadirachtin are the compound extracted from neem tree effectively works against pests
2.	<i>Ampelomyces quisqualis</i>	Anamorphic fungus, hyper parasite of powdery mildews, used as active

		ingredient in commercial fungicide.
3.	<i>Bacillus thuringiensis var. israelensis</i>	Used as biological control agent, kills various species of mosquitoes and have no effect on other organisms.
4.	<i>Bacillus thuringiensis var. kurstaki</i>	Works effectively against Lepidopteran pests, commonly known as Garden dust or caterpillar killer.
5.	<i>Bacillus thuringiensis var. galleriae</i>	Bioinsecticide to control adult beetles.
6.	<i>Bacillus sphaericus</i>	Target variety of mosquito larvae by producing an inclusion body which is toxic to pests.
7.	<i>Metarhizium anisopliae</i>	Fungus grown in soil used as biological insecticide to control pests causing malaria.
8.	<i>Nuclear Polyhydrosis Virus of Helicoverpa armigera</i>	Used in management of pests host on chickpea, sunflower, cotton.
9.	<i>Nuclear Polyhydrosis Virus of Spodoptera litura</i>	Produces crystal inclusion body which contains progeny to virus particles target last larval stage of pests.
10.	<i>Pseudomonas fluorescens</i>	Gram negative bacterium which prevent host plant from target pests.
11.	<i>Pyrethrins (Pyrethrum)</i>	Organic compound have potent to kill pests.
12.	<i>Trichoderma harzianum</i>	Used as fungicide, have foliar application, seed treatment and soil treatment of various diseases causing fungal pathogen.
13.	<i>Trichoderma viride</i>	Used as biofungicide, provide protection against disease caused by fungal pathogen.
14.	<i>Verticillium lecanii</i>	Naturally occurring entomopathogenic fungus works effectively against pests.

**TYPES OF BIOPESTICIDES:** Biopesticides has been diversified into three groups[7]: i. Microbial pesticides

ii. Plant incorporated protectants

iii. biochemical pesticides

**A. MICROBIAL PESTICIDES:** Microorganisms such as Bacteria, Algae, Fungi and Protozoa were used as mobile component for naturally controlling abrasive insects, weeds or certain diseases affecting plants. A microbial pesticide becomes as an important component in managing plant pathogens and each of them having active ingredient is specific for its target pests. Different kinds of fungi were used to control and kill the target insect pests. Bacterium *Bacillus thuringiensis* or Bt is most widely known microbial pesticide which produces protein crystals to kill pests. In recent years, Bt transgenic crop varieties have been superseded. Bt sprays was made for the management of fruits and vegetables crops [8].

**Microbial pesticides: a. Bacteria**

**b. Fungi**

**c. Viruses**

**d. Nematode**

**Table 2: ENTOMOPATHOGENIC BACTERIA**

MICROBIAL AGENTS	TRADER NAME	TARGET PESTS
<i>Bacillus thuringiensis aizawai</i>	Florbac, Design	Armyworm, Wax moth caterpillars
<i>Bacillus thuringiensis kurstaki</i>	Dipel, Foray, Bioworm, Worthy attacks, Bactospeine, Thuricide	Certain larvae of moths and butterflies
<i>Bacillus thuringiensis israelensis</i>	Bactimos, Aquabee, Gnatrol, Skeetal (effective against mosquito larvae developing in tires and other artificial containers)	Sciaridae, <i>Psorophora ciliata</i> susceptible mosquito genera: <i>Anopheles</i> and <i>Culex</i> species.
<i>Bacillus thuringiensis tenebrionis</i>	Raven, TridentII, New leaf potato (genetically engineered potatoes) w/Btt. Endotoxin)	<i>Leptinotarsa decemlineata</i> larvae, <i>Xanthogaleruca luteola</i> .
<i>Lysinibacillus sphaericus</i>	Vectorex CG, Vectorex WDG	Extensively used in controlling mosquitoes larvae mainly <i>Anopheles</i> and <i>Culex</i> .

[9]

The scientists revealed that the Entomopathogenic bacteria have been used for a long time to explore their pathogenic relationship with insect pests [10]. Many studies have been done on Entomopathogenic bacteria to control Diptera, Lepidoptera and Coleoptera infectious insect pests. Industrial and Academic screening activities have provided a way for the innovating new biopesticides by utilizing *Bacillus thuringiensis* species for future [11]. Infestation of harmful pests has been controlled in environmentally safe manner without leaving any residue by pesticidal effect of bacteria. Many species belonging to genus *Bacillus* infected the harmful pests by producing pesticidal toxic action coded with *cry* proteins. *Bacillus thuringiensis* has been utilized as an important weapon in controlling insects pest hosting on crops. About 2% global insecticidal sales of bacteria in the market were amounted in the end of twentieth century whose shares in pesticidal market were expanding gradually.

**Table 3: ENTOMOPATHOGENIC FUNGI**

MICROBIAL AGENTS	TRADER NAMES	TARGET PESTS
<i>Beauveria bassiana</i>	Botanigard, Daman, Naturalis, Botanigard	Foliar feeding pest (soil dwelling pests).
<i>Beauveria brongniartii</i>	Uyir, Brongniartii	Black vine weevil
<i>Hirsutella thompsonii</i>	UnMite, AL Mite	<i>Meloidogyne</i> , coconut mites
<i>Metarhizium anisopliae</i>	Myco-Meta, Meta cure, Metar-Q	Beetles & Caterpillar pests, Termites
<i>Paecilomyces lilacinus</i>	Attracap Bio-Nematon, MelaCon	Root knot and cyst worms.
<i>Paecilomyces fumosoroseus</i>	Paecilotropico WP, Biofum, Peak Bardan	Silver leaf whiteflies, Thrips
<i>Verticillium lecanii</i>	Vertifire-L, Bio-fire, Bioline/Verti-star	Waxy skin insects and sucking pests

<i>Metarhizium brunneum</i>	Attracap	Agriotes spp.
<i>Lecanicillium lecanii</i>	Lecatech-WP, Varunastra	Leaf miners, Scale insects

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Nowadays, a fungi biopesticides constitutes a fastly developing natural biological control phenomenon in research fields to maintain quality of crops, food production and eliminate excess usage of undesirable chemical pesticides. Fungi do not require ingestion to infect and kill the host. Entomopathogenic fungi are considered to be important natural enemies of many pests of agricultural crops [12].

**Table 4: ENTOMOPATHOGENIC VIRUSES**

MICROBIAL AGENTS	TRADERS NAME AND TARGET PESTS	COMMENTS/ UTILIZATION
<i>Helicoverpa zea nucleopolyhedrovirus</i>	Gemstar LC, Helicovex, Helicop <b>Target pests:</b> Cotton bollworm, Corn earworm, Tobacco budworm.	Virus invades inside the body after being ingested by the insect which multiplies leads to death.
<i>Spodoptera litura nucleopolyhedrovirus</i>	Biokill-S, Somstar-SL <b>Target pests:</b> Tobacco cutworm, cotton leaf worm.	Mainly used for crop protection and in organic farming.
<i>Adoxophyes orana granulovirus</i>	Trebon <b>Target pests:</b> Larvae of <i>Adoxophyes orana</i> (Summer fruit tortrix worm).	Mainly top fruit are target host, have potential to control insect pests.
<i>Cryptophebia leucotreta granulovirus</i>	Cryptogran, Gratham <b>Target pests:</b> Orange moth, orange codling moth, citrus codling moth, false codling moth.	Feed on cotton and macadamia nuts of citrus species.
<i>Helicoverpa armigera nucleopolyhedrovirus</i>	Samstar-Ha, Biovirus-H, Helicovex <b>Target pests:</b> False loopers- noctuid caterpillars	Used in organic farming, provides protection to crops.

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Virus pathogenicity is mainly related with the host cell containing infectious particles having production of crystalline occlusion bodies. Baculovirus establishes pathogenic emergence with insect pests and shows potential as biological control [13]. Nucleopolyhedrovirus and Granulovirus are two mainly used baculoviruses as pesticides. Researches had been done for the future in order to discover new biological control pesticides with the utilization of Entomopathogenic viruses.

**Table 5: ENTOMOPATHOGENIC NEMATODES**

MICROBIAL AGENTS	TRADER NAMES	TARGET PESTS
<i>Steinernema carpocapsae</i>	Capsanem, Exhibitline SC, Optinem-C, Nemstar, NemaGard, Palma-life,	Cutworms, pickle worms, cranberry girdler, webworms, woodborers.
<i>Steinernema feltiae</i>	NemaTrident-F, Nemapom, Nemaflly,	Various insects such as scarid flies,

	Optinem-F	fungus gnats, leaf miners
<i>Steinernema kraussei</i>	Kraussei-System	Sawflies, vine weevils and other soil insects.
<i>Heterorhabditis downesi</i>	NemaTrident-CT	Black vine weevil, Cranberry girdler, strawberry root weevil.

[9, 14]

Different methods developed for the production of nematodes improved varieties and its efficacy on biological control against pests. In market segments various species of nematodes was commercialized targeting pest species [13].

**B. PLANT INCORPORATED PROTECTANTS (PIPs):** The pesticide in which a genetically modified plant has been utilizes to produce pesticidal substances are known as plant incorporated protectants. Gene of Bt pesticidal proteins were injected into own genetic material of plants which manufactures substances to kill the target pests. Crops were protected from the destruction of phytophagus arthropod pests with the insecticidal toxins genes of genetically modified plants. From the last few decades, the innovation on genetically modified crops has been increasing and their genes were introduced into different species

In 1996, firstly the commercialization of *Bacillus thuringiensis* was conducted in the United States. Transgenic plants contains insecticidal endotoxins which targets the major pests reducing the productivity of crops as these toxins covers the locations of plants at greater extent which are obscure to foliage showers [15].

Face of agriculture was changed with the development of recombinant DNA and plant transformation technologies by transfecting insect control agents into plant incorporated protectants (PIPs). Different types of Bt toxins were innovated by understanding their mode of action which support well into future [16]. More than 60 cry proteins were recognized and each with having different strains of Bt.

**Table 6: Strains of *Bt* with different *Cry* Proteins:**

CROPS/COMMODITIES	DIFFERENT <i>Cry</i> PROTEINS AND TARGET PESTS	COMMENTS / UTILIZATION
Maize (Hybrids)	Cry1Ab, Cry1Ac, Cry9c <b>Target pests:</b> Lepidoptera ( <i>Ostrinia furnacalis</i> , <i>Mythimna sparata</i> , <i>Helicoverpa armigera</i> ). Cry3Bb1 <b>Target pests:</b> Coleoptera (Corn rootworms larvae).	<i>Bacterium</i> produces delta endotoxins have insecticidal effects, provides resistance against pests to genetically modified crops. For future purposes researches have been formulated utilizing cry1Ac proteins to innovate vaccine against amoeba ( <i>Naegleria fowleri</i> ) [17, 18]. Cry1Ab have potential to produce relative effect cry toxic as insecticidal properties on transgenic modifications [19, 20].
Cotton	Cry1Ac <b>Target pests:</b> Lepidoptera (Cotton bollworm).	Effects soil microbial communities.

<p>Potato</p>	<p>Cry3A or Cry3C <b>Target pests:</b> Coleoptera (Colorado potato beetle larvae).</p> <p>Cry4 <b>Target pests:</b> Diptera and certain flies</p>	<p>Provides protection or resistance to Colorado potato beetle larvae and certain flies.</p>
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**C. BIOCHEMICAL PESTICIDES:** Pesticides which are obtained from utilizing substances such as fatty acids, plant extracts and other components that occurs naturally as pheromones to destroy the population of infectious pests in an environmentally safe manner by harmless action. An Alternative to synthetic pesticides, biopesticides are conveniently utilizes that inactivate or kill harmful pests.

**Biochemical pesticides: a. Plant extracts**

**b. Peptidomimetics**

**c. Insect pheromones**

**PLANT EXTRACTS:** Optimizing effects of different plants were now emerging as a new component to control pests and protect the environment from pesticidal pollution. Mostly neem based botanicals were proved to be more effective in reducing the pests. Neem based pesticides was obtained from neem tree *Azadirachta indica* (Family Meliaceae) by utilizing their different parts. Neem seed kernel extracts for controlling pod destruction and population of *Helicoverpa armigera* larvae in chickpea. Formulations of Neem were effective in controlling the eggs of peach fruit [21]. Azadirachtin are the crucial component of neem which contains a tetranortritarpinoid that exhibit the metamorphosis of insects [22].

**POTENT ACTIVE INGREDIENT OF NEEM:**

- Meliantriol
- Salannin
- Desacetyl salannin
- Nimbin
- Desacetyl nimbin
- Nimbidin
- Azadirachtin

Highest synergistic insecticidal effect against *Aleurodicus dispersus* was obtained by optimizing ethanolic extract of neem and acetone extract of crown flower as compared to other formulations [23]. Sucking and chewing insects was greatly affected by the *Azadirachta indica* (neem) extract. Several root rot diseases has been controlled by Pyrethrum extracted from dried flowers of *Chrysanthemum cinerarifolium* fastly work to reduce wide range of insects. Plant extracts works safely and has very little residual effect.

**PLANT PRODUCTS USED AS BIOPESTICIDES AND THEIR TARGET PESTS[24]:**

1. **Limonene & Linalool** are monoterpene compound develop as a vital constituent of crucial oils of diverse aromatic species. Used in mosquitoes repellent products to prevent non-target species.

**Target pests:** Flies, paper wasps, house crickets, several types of flies.

2. **Neem** seeds and leaves contain certain bioactive compounds which work effectively in reducing harmful pests and diseases.

**Target pests:** Larvae of lawn pests, sucking pests, scarab beetles.

3. **Pyrethrum/Pyrethrins** are the pesticidal compound extracted from plants produces toxic action against pests.

**Target pests:** Ants, Aphids, Roaches, Fleas, Flies and Ticks.

4. **Rotenones** are chemicals free pesticide used in powdered dust forms dusting on leaves to reduce pests for infestation for several days.

**Target pests:** Pests feed on leaves as Caterpillars, and some soft bodied sucking insects.

5. **Ryania** are organic pesticide made from ground stem of *Ryania speciosa* control harmful pests.

**Target pests:** Caterpillars

**PEPTIDOMIMETICS:** Chain of small proteins that mimic peptides were considered as important tool in innovating drug and appeal in insecticidal designing. Binding target insectophore grafted into backbone structure becomes critical for peptide residue that uses non-peptide organic scaffold in order to produce peptidomimetics. Such structures mimic topologically having effective moieties corresponding to insectophore [15]. The researches and development on peptidomimetics insecticides becomes a challenging as in insect toxicity bioassays non-critical residues were determined which becomes a steric hindrance for averting vertebrate toxicity. Despite of that, a non-critical residue becomes an essential for providing insect target subtype selectivity [25].

**INSECT PHEROMONES:** Pheromones are secreted chemical factors of opposite sex of same species to produce a social response which affects the behaviour of the receiving individuals [26]. Many species have chemically elucidated pheromones as codling moth (Sex pheromones).

When sex pheromones have been used with traps combinations, it determined that:

- What kinds of insects were there in crops
- What measures should be taken for plant protection
- What actions reduce the damaged crops

Insect population can be reduced by kill or attract technique or with pheromone traps or some by synthetic attractants. Number of insect pests can be controlled more effectively by mating disruption. In the early 1970, pink bollworm *Pectinophora gossypiella* (Saunders) was

beneficially controlled with the sex attractant “hexalure” begins with mating disruption. In 1973, researches were conducted on pink bollworm whose first formulation was successfully revealed in 1978 [27]. In Germany and Switzerland, wine was produce more than 20% by the grape growers with uses of pheromones without using insecticides. In United States, most of the insect pests such as codling moth, pink bollworm, navel orange worm was reduced effectively by mating disruption. In western U.S, a fruit tree acre was treated with mating disruptions and more than 40% population of caterpillar was controlled.

## CONCLUSION

In developing countries, the demand of consumers and government on food was increasing with time. Many new strategies as well as techniques were adopted by the farmers to protect crops from pests. Biopesticides clearly proved beneficial more rationally approach alternative to synthetic chemical pesticides to protect crops from damaging. In spite of having many published reports on pesticides and human health, there always remains a deep argument regarding to the protection of crops. Biopesticides have potential scope to be used in future Integrated Pest Management whereas chemical pesticides short term profits will not compete with its fate.

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