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2. Biopesticides and Biological Control Methods: Natural Allies in Pest Management

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Abstract:

Crops are mostly associated with one or more insect pest. Plants can tolerate them up to a certain point, beyond which intervention of management methods is necessary. Management strategies could be many but as chemical methods proved to be the most promising one because of their quick action, also accounts for several undesirable side-effects along with it. In a developing country like India, where a vast diversity of crop is being grown has become a centre for insecticides residues problems.

The conventional chemicals account for about one third to one half of the total mean of the input costs required for growing various crops. After realizing this, as an alternative the bio-pesticides and the biological control methods were adopted which proved to be natural allies for pest management in an unconventional way with their multiple mode of actions.

Possessing huge positive characteristics and potential against exotic pests, have made these two methods more acceptable. In IPM integration of biopesticides along with bio-control agents has led a sustainable way for management of some major insect pest which has been discussed here.

Keywords:

Chemical methods, biopesticides, biological control methods, IPM.

2.1 Introduction:

In this era of ever-growing population, the uncurbed use of conventional pesticides has caused several ecological problems like development of resistance, pest resurgence, environmental pollution and increasing health problems of living organisms. In commercial farming their use is decreasing by 2% every year because of regulatory measures and an increase of the biopesticides use by 10% as their low-risk alternatives (Damalas and Koutroubas, 2018). In sustainable agriculture, enhancing the food production along with its safety should also aim at using biopesticides which are the chemical compound derived from the biological entity used for either to deter, sterilize or kill the unwanted harmful organisms (Fenibo *et al.,* 2021). They are broadly divided into microbial biopesticides, bio-chemical biopesticides and plant incorporated protectants (PIPs). In the global biopesticide share, it accounts for around 5% with microbial ones having the lead (Pathma et al., 2021). It has been recorded that around 3000 tonnes of biopesticides are produced annually throughout the globe which is expected to rise in the subsequent years in India. In the country's total pesticide contribution, biopesticides account for only 4.2%. This is because of different local-level hurdles faced in its implementation (Chakraborty *et al.,* 2023). In India's agricultural ministry, biopesticides accounts for only 2.89% of the 100,000 metric tons of pesticides sold worldwide, which is expected to increase approximately by 2.3% annually (Leng *et al.,* 2011).

Crop loss caused by the insect pest are very high in both developing as well as developed countries. An approx. of 70,000 pest species along with 9000 sporadic insect species recorded worldwide for damaging agricultural crops. Out of which 1000 species being major key pests with 200 of them having prominent damaging ability under Indian condition (Vendan, 2016). Sole use of chemical insecticides has affected human health very adversely. According to an estimation given by the World Health Organisation (WHO), each year around 25 million people are developing pesticide poisoning out of which 20,000 are dying worldwide (Chakraborty *et al*., 2023). The popularity of the biopesticides is due to its sustainable plant protection, eco-friendly nature, high species specificity (does not impact non-target organisms and humans), easy bio-degradability, proper integration in IPM systems and easy applicability. It also enhances the quality and productivity (Sharma *et al*., 2019) of the produce without leaving any residue (Swati and Singh, 2016) and counters the pesticide borne insect resistance. Bio-pesticides being the possessor of multiple modes of action they have a great potentiality in elimination of pest resistance development, alternative to synthetic pesticides, low-toxicity properties, reduced post-harvest contamination and stability against abiotic stress (Vendan, 2016; Kalpana and Anil, 2021). They are socially acceptable, economical, comes with wide options and are perfect for a sustainable step towards food security. Biopesticide is often mistaken for being able to control the insect pest rather it keeps the population below an economic injury level.

Along with the use of bio-pesticides, reuniting the natural enemies with their insect pest is the best alternative for a supplementary management. The biological control methods include release of the natural enemies into the places where they are not reported earlier and also manipulating the environment a bit for their easy multiplication, establishment and conservation. This method should be the corner stone of the Integrated pest management system (IPM).

The natural enemies could be predators, parasites, pathogens etc which work continuously in bringing down the population of the insect pest below ETL. It has been observed that using these beneficial agents have a huge successful past record and it is not bounded to any particular crop or pest. The predator-prey population dynamics works continuously and very efficiently.

2.2 Biopesticide Types:

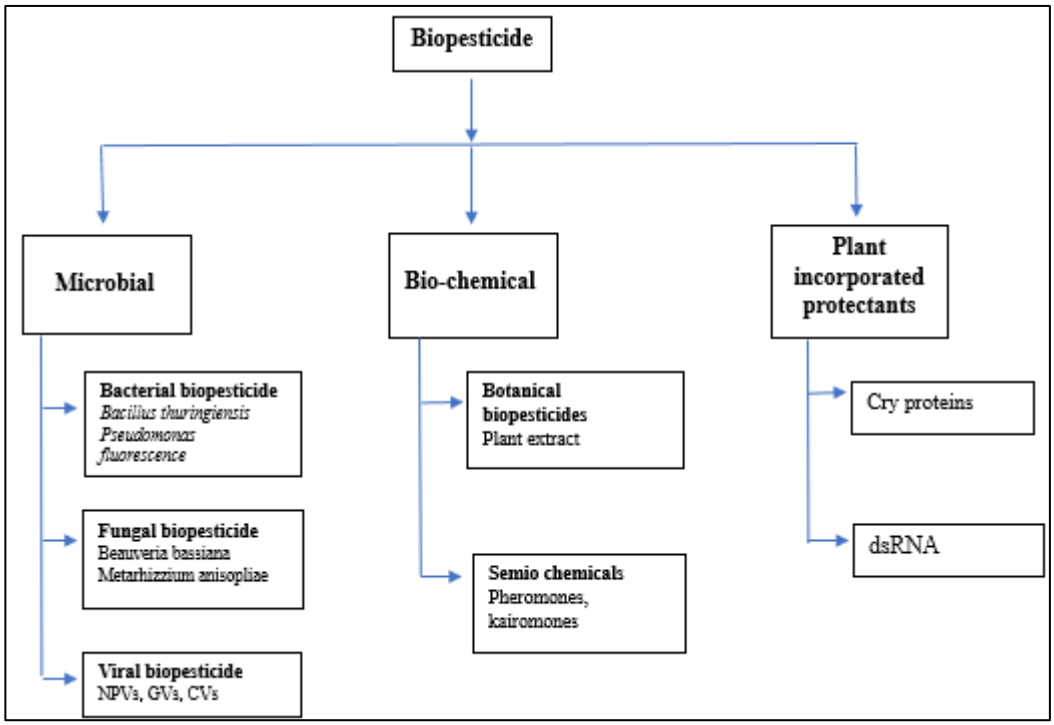

Figure 2.1: Types of Biopesticide

The Environmental Protection Agency (EPA) has classified the bio-pesticides mainly into three groups:

2.2.1 Microbial Biopesticides:

As the name suggests, it consists of original microbes or genetically modified microbes (bacteria, virus, fungus, protozoans) as its key components. They act either by producing harmful toxins against a particular pest as well as by preventing their establishment by competition or other ways (Dar *et al.*, 2021).

Their application includes live microbes, dead ones or their spores (Mishra *et al*., 2020). Their effectiveness is attributed to its ability of penetrating through skin or through stomach by feeding. The microbial toxin may vary in structure and toxicity but basically, they are peptide compounds (Suman and Dikshit, 2010).

Types of Microbial Biopesticides:

a. Bacterial biopesticides: - *Bacillus thuringiensis, Pseudomonas fluorescens*
b. Fungal biopesticides: - *Verticillium lecani, Metarhizium anisopliae*
c. Viral biopesticides: - Nuclear Polyhedrosis Virus, Granulosis Virus
d. Protozoans biopesticides: - *Nosema* sp.

Nematode biopesticides: - *Steinernema carpocapsae* (DD-136), *Heterorhabditis indica, S. abbasi, S. thermophilum, S. riobrave*

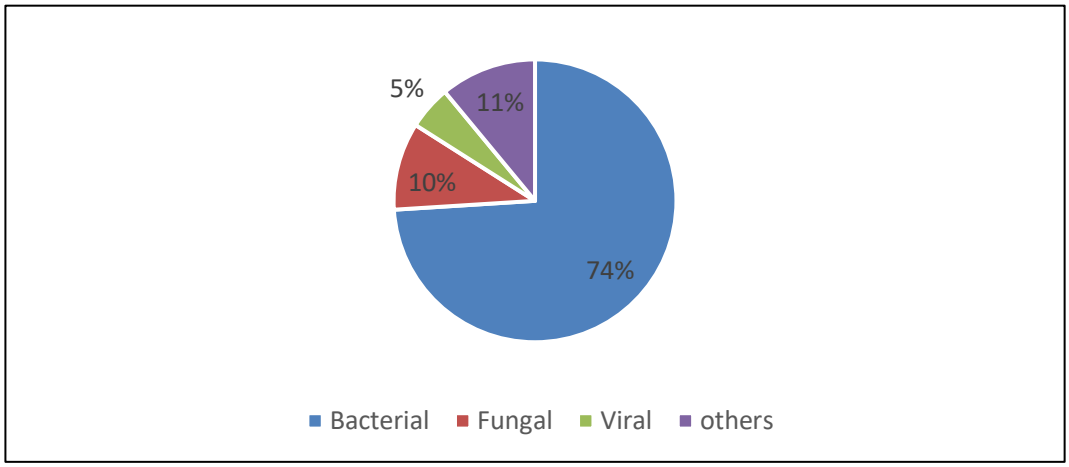

Figure 2.2: Microbial Pesticide Distribution (Thakore, 2006)

Table 2.1: List of *Bacillus* Species Used Against Different Insects

Sr No.	Bacteria used	Target pests
1	Bacillus popilliae	Japanese beetle grubs
2	B. sphaericus	Mosquito larvae
3	B. thuringiensis subsp. aizawai	Lepidopterans
4	B. thuringiensis subsp. israelensis	Mosquito, black flies and fungus gnats
5	B. thuringiensis subsp. kurstaki	Lepidopteran larvae
6	B. thuringiensis subsp. tenebrionis	Colorado potato beetle, stored pests, coleopteran adults and larvae
7	B. thuringiensis subsp. Galleriae	Lepidopteran larvae, bollworms, Diamond back moth

Source: Usta (2013

Table 2.2: List of *Bt* Subspecies Toxins Affecting Various Insect Orders

Sr No.	*Bt* subspecies	Toxin produced	Targeted insect order
1	*Bt* sub *sp.* Berliner	**Cry I**	Lepidoptera
2	*Bt* sub *sp.* Kurstaki	**Cry I**	Lepidoptera
3	*Bt* sub *sp.* Kurstaki	**Cry II**	Lepidoptera, Diptera
4	*Bt* sub *sp.* aizawai	CryI	Lepidoptera
5	*Bt* sub *sp.* tenebrionis	CryIII	Coleoptera
6	*Bt* sub *sp.* israelensis	CryIV	Diptera

2.2.2 Biochemical Bio-Pesticides:

These are organic compounds extracted from the living organisms (animal, plant or insects) to use against insect pest for its management in a non-toxic manner *i.e* either by modifying physiology and behaviour (Rishap and Singh 2019). They include semiochemicals, plant growth regulators and insect growth regulators which inhibits feeding, breeding, establishment and also facilitates attraction or repulsion of the pest from the crops. They are present in the plants in an inactive form which becomes active on insect attack. Insect pheromones, a component of semiochemicals are species specific and are used widely for monitoring as well as mating disruption among insects belonging to same species. Secondary metabolites like alkaloids, nitrogenous and non-nitrogenous compounds are released against it resulting in defensive properties. The plant extract and oils collected are a mixture of compounds. They can vary in their role from a herbicide to insecticide depending upon the active ingredient present in it. Botanicals can act like a synergist in different IPM modules (Srinivasan, 2012).

a. Botanical extract: - *Pyrethrin*, NSKE (Azadirachtin), Garlic extract, *Artemesia* green leaf extract, Walnut extract, Rotenin
b. Semiochemicals: - Pheromones (Sex lures, aggregation), kairomones (Cucurbitacin, Gossypol)
c. Insect Growth promoters: Juvenile hormone-based insecticide, Chitin Synthesis inhibitors
d. Plant Growth Promoters: Plant hormones

2.2.3 Plant Incorporated Protectants (PIPs):

These are the unconventional method of pest management (Abbey *et al.*, 2019). PIPs are the compounds produced by the genetically modified plants. Plant genetic material is altered according to the desired characteristics by incorporating a gene which are responsible for producing toxins or proteins which are specific to some insect group. These compounds are expressed directly in the tissue of the modified plant parts which is ingested by the insect (Chakraborty *et al.*, 2023). Bt *Cry* protein, Toxic complex (Tc) proteins from *Xenorhabdus* and *Photorhabdus*, α-amylase inhibitors, protease from Baculovirus, double-stranded ribonucleic acid (dsRNA), and Mir1-CP are some of the

known PIPs responsible for management of insect pests belonging to different groups (Ganapathy *et al*., 2021).

2.3 Biocontrol Methods an Ally for Pest Management:

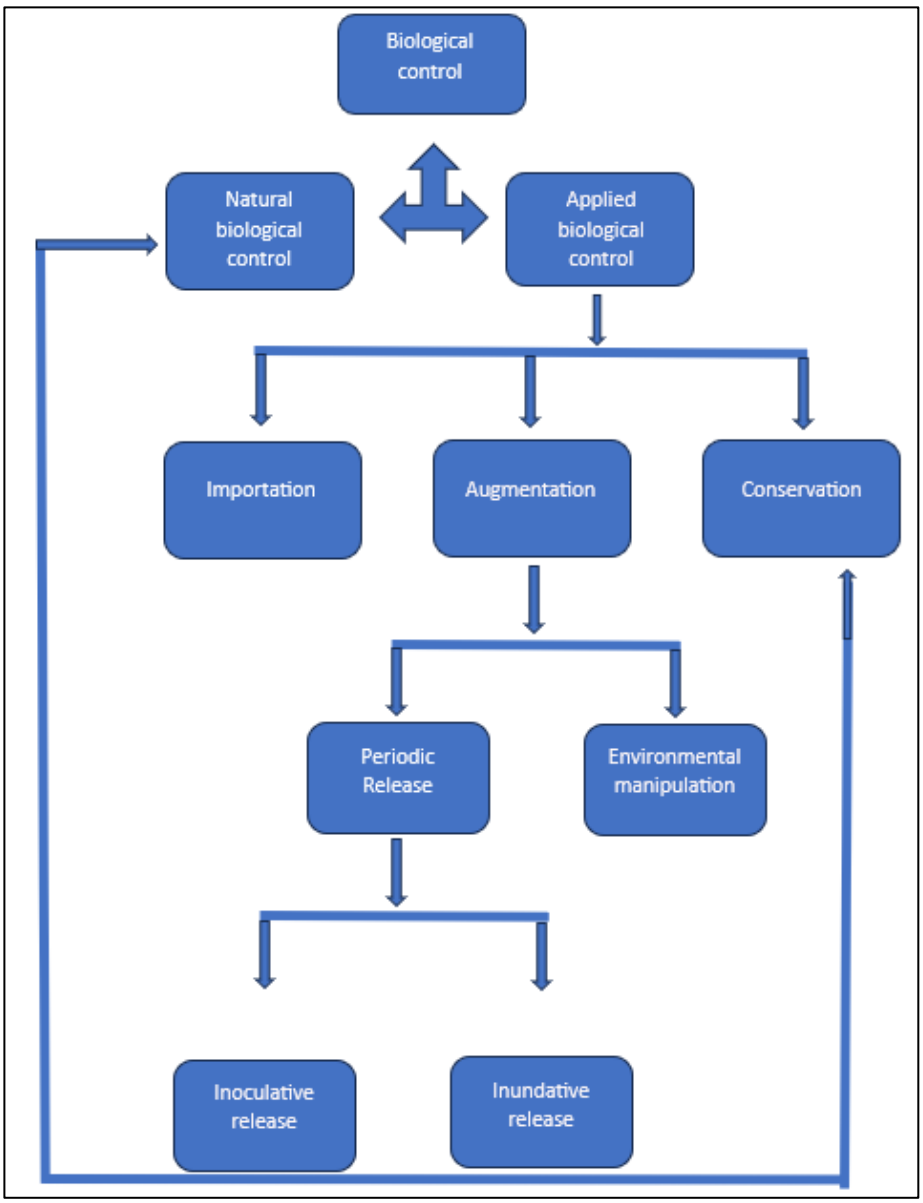

Figure 2.3: Biocontrol Methods an Ally for Pest Management

Bio-control methods are the ones which make use of natural enemies (Predators, parasitoids, parasites, virus, disease *etc*.) in keeping the pest population below the economic threshold level so that it could not reach the economic injury level to cause significant damage (Bellows and Fisher,1999).

It aims on bringing back the pest nearer to their natural enemies or manipulating the environment of the pests to affect their population dynamics as well as the enhancement of the natural enemy population (Robert *et al*., 2003).

Bio-control methods include: Importation of the exotic or natural enemies from the native place of the insect pest, augmentation and conservation of the natural enemy population. The conservation biological control methods involve the modifications in the environment where the factors reducing their population is lowered and the ones helping in increasing are supported. Conservation biological control methods and IPM shares similar goals of viewing the ecological processes driving the pest population dynamics (Huffaker, 1980). The IPM principles promote changes in practices *i.e* crop diversification, reduced pesticide application *etc*, which are similar to the changes in production practices of the natural enemies. Even after seeing the economic threshold level (ETL) and the framed forecast, basing on it release of the bio-control agents into any new areas is done. After importation, the augmentation biological control method deals with multiplication of the insects themselves using special rearing chambers called insectaries and periodic release thereafter. The release is through two approaches i.e. inoculative and inundative. In case of inoculative method the control is expected from the next generation but in inundative control is expected from the released organisms itself. To improve the survival and ability of these natural enemies, genetic modifications are also available (Whitten and Hoy, 1999). Manipulation of the environment is also looked after to improve the population of the already present natural enemy in the locality. It is done by providing a suitable/ alternate host to the prey, using semio-chemicals to enhance the activity of the natural enemies, providing nesting, food and breeding sites and managing practices affecting their population (Nordlund, 1996). Following the augmentation of the insect population, their conservation is necessary to keep a balance between the natural enemies and the pest. Biological control methods are systematic with step-by-step applications of improved technical knowledge during the importation of agents and contributions from the farmers during their conservation, proving to be highly effective when used along with bio-pesticides in bringing down the number of pest species.

Table 2.3: Bio-Control Agents Against Major Insect Pest

Crop	**Pest**	**Biocontrol agent**	**Stage of pest controlled**	**Control type**
Sugarcane	*Pyrilla perpusilla*	*Epiricania melanoleuca*	Nymph and adult	Parasitoid
		Ooencyrtus pyrillae	Eggs	Parasitoid
	Chilo sacchariphagus indicus	*Cotesia flavipes*	Larva	Parasitoid
		Rhaconotus scirpophagae		Fungal pathogen parasitoid
Cotton	*Earias insulana*	*Chelonus blackburni*	Egg	Parasitoid
		Trichogramma brasiliensis		
	Helicoverpa(Heliothis)	Nuclear		Viral pathogen

Crop	Pest	Biocontrol agent	Stage of pest controlled	Control type
	armigera	polyhedrosis virus (HaNPV)	Larva	Parasitoid
	Pectinophora gossypiella	*Apanteles angaleti*		
		Bracon bravicornis		
		Bracon hebetor		
Rice	*Scirpophaga incertules*	*Trichogramma chilonis*	Egg	Parasitoid
		Tetrastichus schoenobii		
	Cnaphalocrocis medinalis	Trichogramma japonicum	Egg	Parasitoid
	Nilaparvata lugens	*Cyrtorhinus lividipennis*		
	Orseolia oryzae	*Platygaster oryzae*		
Maize	*Rhopalosiphum maidis*	*Coccinella septempunctuata*	Nymph and adult	Predator
		Chrysoperla carnea		
		Menochilus sexmaculata		

2.4 Problems and Future Prospects of Using Biopesticides and Biocontrol Agents:

Identification and introduction of new bio-chemicals or bio-control agents should continue to facilitate the maximum utilisation of these natural resources in bringing down the insect pest population. Still complete adoption of these alternatives faces various difficulties like low supply to farmers, long-acting time (Verma *et al*., 2021), high cost of refined commercial products, inability to meet global market demand, differing standard method of preparations and guidelines, dose determination of active ingredients, the susceptibility of biopesticides to several environmental factors, ephemeral stability, and slow action among others (Fenibo *et al*., 2021).

Adoption of IPM method is based on the awareness, knowledge of the farmers their experience regarding the biocontrol methods for pest management. Mostly under the protected cultivation, success of this method is seen as pests in this condition develop resistance quickly. Bio-control tactics found to be very effective under greenhouse condition as it is labour intensive supplied with high quality technology and high knowledge (Chandler *et al*., 2011). Still, lots of studies are their which needs to be addressed and problems should be overcome in order to achieve a successful control of insect pest.

2.5 Conclusion:

In view of the ongoing environmental problems related to increased insecticide residues, pest resistance followed by resurgence, secondary pest outbreak, pollution, emerging health problems of living organisms because of the excessive use of chemical pesticides has demanded a non-toxic and sustainable way to counter these effects. Using of bio-pesticides along with the natural enemies or solo itself has led to overcome the negative effects of the conventional insect pest management methods i.e. use of chemical pesticides. More and more studies related to the possible bio-molecules and their efficacy should be evaluated. Studies related to their residual effect and complimentary integration with other management methods is also necessary to see the alternatives of the chemical molecules and hence reduce dependency on it. Importation, augmentation and conservation of the natural enemies work profusely with bio-pesticides as they are safer to them and affect only specific organisms. Both of the factors manage the pest population on their part by complementing each other.

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