Indian Journal of Advances in Chemical Science

Review Article

Biopesticides: An Eco-friendly Alternative to Chemical Pesticides for Sustainable Agriculture

Vishakha Pandey, Divyanshi Mishra, Farheen Fatima, Neerja Masih*

Department of Biotechnology, Isabella Thoburn College, Lucknow University, Lucknow, Uttar Pradesh, India

ABSTRACT

Although conventional pesticides have been proved efficient in controlling pests and disease vectors and their use has greatly increased the agricultural productivity, they are still toxic chemicals which are dangerous not only to pests but humans and other animals also. They have instant as well as long-term impacts such as cancer. Thus, there is a need for a convenient alternative of chemical pesticides which can be used for pest management. This is where biopesticides comes in the picture. Biopesticides are natural components which are obtained from living organisms, they are less harmful than the conventional pesticides and in present time biopesticides can have a great significance in controlling pesticide pollution without compromising the productivity of crops. This article deals with harmful effects of chemical pesticides and biopesticides as an eco-friendly alternative of chemical pesticides, types of biopesticides, biopesticides as a sustainable tool of integrated pest management, and current status of biopesticides.

Key words: Pesticides, Bio-pesticides, Sustainable, Eco-friendly, Integrated PEST management.

1. INTRODUCTION

Over the past few decades, the protection of crops against pathogens has mainly depended on the chemical pesticides. Pathogens such as virus, bacteria, fungi, and nematodes cause drastic loss in the productivity due to which farmers are left with no choice other than relying on chemical pesticides to protect their crop. Pesticides are the leading cause of poisoning in India, with two in every three cases of poisoning happening because of pesticide consumption. However, with the help of biopesticides, it is possible to counter pests without causing harm to nature. Biopesticides are eco-friendly natural products and are derived from a wide range of living organisms including plants, microorganisms, insects, and nematodes. [1].

The bioactive compounds present in plants such as steroids, phenols, alkaloids, quinones, terpenes, and alcohols make them a major source of biopesticides. Antimicrobial substances such as α- and β-phillandrene, limonene, camphor, linalool, β-caryophyellene, and linalylacetate are found in different plant families which can be used in making natural pesticides [2]. Similarly microorganisms such as *Pseudomonas*, *Cynobacteria*, *Bacillus*, and *Xanthomonas* and Fungi such as *Trichoderma* and *Verticillium* can be used to develop biopesticides [3]. Different types of biopesticides work on specific pests and have different mode of action which include competition, predation, and parasitism [4]. Plant growth promoting bacteria colonize the environment around the roots of plant and perform nitrogen fixation and increases phosphate solubilization which leads to the increased yield [5].

This review sums up; disadvantages of conventional pesticides, major types of biopesticides, Biopesticides in integrated pest management (IPM) and present status of biopesticides.

2. HARMFUL EFFECTS OF CHEMICAL PESTICIDES

The chemical pesticides may cause many potential damages to our health as well as to the environment. Along with killing insects, they are also dangerous for humans, birds fish, and non-target plants.

Some common synthetic or chemical pesticides are: glyphosate, Acephate, Deet, Propoxur, Metaldehyde, Boric Acid, Diazinon, Dursban, DDT, Malathion, etc. There are major categories of chemical pesticides that may affect the human body parts. They can cause Chronic (long-term), Acute (short-term), and allergic effect on living organisms. Carbamates such as Carbofuran, aldicarb, and Carbaryl affect the Central Nervous System. Organophosphates such as Diazinon, Glycophosphate, and Malathion also damage central nervous system. Side effects of Pyrethroids such as Fenpropanthrin, Deltamethrin, and Cypermethrinare poorly understood. Organochlorines such as DDT, Toxaphene, Dieldrin, and Aldrin may damage the reproductive organs, nervous system, endocrine, and immune system [6].

Dursban, one of the common pesticides, which is used in hospitals, schools, houses as well as in agriculture it caused an inferior health risk, mainly to children. Due to this unacceptable health risk, it was banned in 2000 by the USEPA.

DDT was also banned by the United States because it causes behavioral anomalies and eggshell thinning of Bald Eagles. The use of DDT also caused preterm births and has a harmful impact on environment also [7].

2.1. Ramification on Environment by the Use of Chemical Pesticides

Chemical pesticides are well known pollutants which pollute the environment. When the pesticides are sprayed on the crops, the

***Corresponding author:**
E-mail: neerjamasih@yahoo.com

ISSN NO: 2320-0898 (p); 2320-0928 (e)
DOI: 10.22607/IJACS.2021.904028

Received: 08th October 2021;
Revised: 14th October 2021;
Accepted: 21st October 2021

particles of pesticides suspended in the air as particles are carried by wind to other areas, potentially pollute them [8] Applied pesticides can evaporate and carried out by wind into nearby areas, that may affect the wild life. Pesticides that are used to fumigate soil are known as Volatile organic compounds. It may react with other chemical and produce a pollutant, known as "Ground Level Ozone" [9]

Some common chemical pesticides such as fungicides, herbicides, and insecticides are as follows [10].

3. BIOPESTICIDES

Biological pesticides are the naturally occurring products consisting of plants. Nematodes mineral and microbes such as bacteria, fungi, and that prevent the increasing population of pests. Biopesticides are more sustainable and safe than chemical pesticide because it has more specific pests target so it can only affect or attack on specific pests which reduces the danger for rest of the animals such as mammals and birds and they are biodegradable.

3.1. There are four Major Categories of Biopesticide or Biological Pesticide

3.1.1. Microbial pesticides

Microbial pesticides are microorganisms that occur naturally such as bacteria, virus, and fungi or their product that can kill the pest insects. These organisms feed on pests and prevent their growth. *Bacillus thuringiensis* (BT) is a popular biopesticides which is used to resist the number of pest insect. Each strain of this pesticide develops separate mix of proteins. These mixes of proteins are in inactive form and are called inactive protein. BT is often uses to resist pests on Potato, Cabbage, and other crops [11].

3.1.2. Plant incorporated protectants (PIPS)

These are also called "PIPS." PIPS are genetically modified plants in which specific genes are inserted to produce a pesticide inside the plants. These pesticides develop inside the tissues of the plant. When the genetic modification takes place in a plant to produce pesticides, the modified plant is regulated as pesticide by the Environmental Protection Agency (EPA) [12].

3.1.3. Semiochemicals

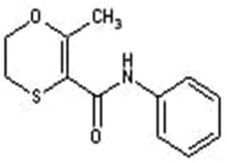
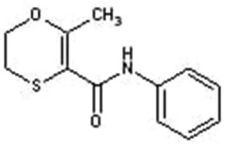
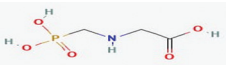
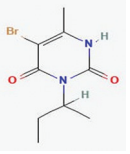
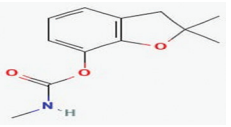
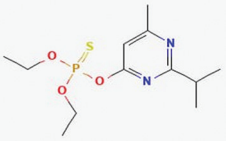
The word semiochemicals originate from the Greek Word "semeon" which means "Signals." These are also known as sign chemicals or messenger chemicals that covey or transfer information between living organisms. Semiochemicals are organic substances which are used by insects to transfer a particular chemical signal or message that can alter the behavior or physiology. Certain semiochemicals helps in pest control by interrupting their mating process, mass trapping, and repellency techniques. The molecular weight of semiochemicals depends on their carbon chains [13].

3.1.4. Biochemical pesticides

Biochemical pesticides are also called herbal pesticides which occur naturally in environment. These pesticides reduce or destroy the pests by non- toxic mechanism. Biochemical pesticides can be divided into functional categories such as pheromones, plant extract, and insect growth regulators [14].

4. BIOPESTICIDES AS A TOOL OF IPM

IPM is an approach which takes advantage of all appropriate pest management methods such as mechanical, physical, cultural, chemical, and biological methods rather than being limited to the use of pesticides only.

Pesticides	IUPAC names	Harmful Effects	Structure
Carboxin	5,6-dihydro-2-methyl-1,4-oxathiine-3-carboxanilide	vomiting and headache.	
Chlorothalonil	Tetrachloroisophthalonitrile	Irritation in nose, throat and lungs causing cough, phlegm	
Glyphosate	N-(phosphonomethyl) glycine3	eye or skin irritation	
Bromacil	5-bromo-3-sec-butyl-6-methyluracil	body weight decreases, cellular thyroid changes	
Carbofuran	2,2-Dimethyl-2,3-dihydro-1-benzofuran-7-yl methylcarbamate	weakness, sweating, nausea and vomiting, abdominal pain	
Diazinon	O, O-Diethyl O-[4-methyl-6-(propan-2-yl) pyrimidin-2-yl] phosphorothioate	watery eyes, runny nose, drooling, loss of appetite, coughing, urination, diarrhea, stomach pain, and vomiting.	

Biopesticides have become the main part of IPM and bio intensive pest management. They are easy to use and eco-friendly unlike chemical pesticides that directly kills or inactivates pests [15]. They specifically affect only the targeted pest and they do not harms humans and non-targeted organisms. On the other hand, chemical pesticides are known to affect the beneficial organisms including parasites, predators, and also humans. Using biopesticides as a tool of IPM program, we can reduce the use of chemical pesticides by fulfilling almost same level of crop yield without harming non target organisms [16].

IPM uses various natural and chemical approaches to control pests, which decreases dependency on chemical means. For example, as insecticides neem and BT (biopesticides) have shown great potential in Thailand, when used in an IPM strategy, to control *Maruca vitrata* [17]. Invasive species such as Guatemala potato tuber moth, *Tecia solanivora* (Povolny) (Lep. Gelechiidae) from Mesoamerica have spread widely in recent decades. Guatemala potato tuber moth species is the primary potato pest in Venezuela, Colombia, and Ecuador. There are no effective control methods being used by farmers. To deal with this problem, biopesticides have been expanded and used in an IPM program by identifying entomopathogenic viruses by extensive bioprospecting in 12 countries over the world and by mixing a dry carrier, biopesticide dust formulation was tested for example -$CaCO_3$ with distinct adjuvants ($MgCl_2$ or an optical brightener or soy lecithin) and distinct specific quantities of virus (JLZ9f) [18]. For the protection of crop alternative, instruments are being evaluated and are providing relief [19].

For example, *Pseudomonas fluorescens* (Pf-CL145A) is sold as a *Dreissenid* (i.e., any member of the Dreissenidae), control agents used in IPM in infested water pipes to decrease the use of a more broad-spectrum chemical [20].

Since the approach of IPM is to combine Prevention, Cultural, Physical, chemical and biological means to control pests these biological pesticides have been proved a sustainable tool in IPM.

5. PRESENT STATUS OF BIOPESTICIDES

The execution of biopesticides is still restricted as compared with synthetic chemical pesticides or conventional pesticides due to the expensive production methods, poor storage stability, susceptibility to environmental conditions, efficacy problems, and others. By some improvements and formulation, we can deal with these problems which can result in increased and sustained biopesticides activity [21]. According to current information, there are about 175 registered biopesticides globally while India have only 12 biopesticides registered (six bacterial, two viral, two fungal, and two plant products). To protect plants, *Metarrhizium*, *Beauveria bassiana*, nuclear polyhedrosis virus BT, *Trichoderma viride*, and neem are currently used [22]. To protect crops, the most suitable alternatives for chemical pesticides come from vegetable oil [23]. To cure injuries, as anti-inflammatory agents, as an antiemetic and as dry powder or coarse extract for the protection of crops, as a medicines Senecio species have been commonly used [24].

By-products required following mechanical extraction from seeds are oil seed cakes.

It can be divided into two types: Edible type in which it can be used as animal feed because it have high nutritional value whereas non edible oil seed cake *Azadirachta indica* (neem), *Jatropha curcas* (jatropha), *Madhuca indica* (mahua), and *Pongamia pinnata* (karanja) contains toxic substances so they cannot use as animal feed. Non edible oil type contains toxic substance which makes them effective biopesticides against termites [25]. The exploitation of higher plant products as chemotherapeutics seeks the attention of several parts of world. Globally, botanical biopesticides are now used. Botanical products are made from Pyrethroids and neem products. As antimicrobial, several essential oils from higher plant are used [26]. As many challenges are faced by the implementation of biopesticides, still they are better alternatives for chemical pesticides due to less toxicity and less harm to beneficial organisms.

The main limitation of biopesticide is that they have slower rate of kill compared with chemical pesticides and susceptibility to unfavorable environmental conditions. However, they only affect the targeted organisms and are less toxic to non-targeted organisms, so they can contribute meaningfully to gradual improvements in pest control [27].

6. BIOPESTICIDES REGISTERED IN INDIA [28]

S.no.	Name of biopesticides	Use for
1.	*Bacillus thuringiensis* var. israelensis	Diamondback moths
2.	*Bacillus thuringiensis var.* kurstaki	Diamondback moths
3.	*Bacillus thuringiensis* var. galleriae	*Helicoverpa armigera*
4.	*Bacillus sphaericus*	Diamondback moths
5.	*Trichoderma viride*	Root rots and wilts
6.	*Trichoderma harzianum*	Root rots and wilts
7.	*Pseudomonas fluorescens*	Bacterial and fungal pathogen
8.	*Beauveria bassiana*	Mango hoppers and mealy bugs and coffee pod borer
9.	NPV of *Helicoverpa armigera*	*Helicoverpa* on chickpea
10.	NPV of *Spodoptera litura*	*Spodoptera litura*
11.	Neem based biopesticides	Insect white fly
12.	Cymbopogon	Insect

7. CONCLUSION

Biopesticides are potential weapon to fight against pest and to reduce pesticide pollution. Different type of biopesticides have different properties and more research should be conducted to completely replace chemical pesticide with bio pesticides and more attention should be played on the commercialization of these natural alternatives so that it is easily accessible to the farmers. Data on toxicity levels, chemistry, active compounds and their compatibility with other methods of pests and disease management are needed to aid in formulation and commercialization. In India a Proper action plan should be developed for the for development and commercialization of biopesticides and awareness program should be organized in which farmers and common people should be educated about the side effects of chemical pesticides and how biopesticides can be a really good alternatives. Proper funding for development and marketing of biopesticides should be ensured by the government.

8. REFERENCES

1. S. Gašić, B. Tanović, (2013) Biopesticide formulations, possibility of application and future trends, ***Journal Pesticides and Phytomedicine (Belgrade)***, **2:** 97-102.
2. E. S. Mizubuti, V. L. Júnior, G. A. Forbes, (2007) Management of late blight with alternative products, ***Pest Technology***, **1(2)**: 106-116.
3. D. Kachhawa, (2017) Microorganisms as a biopesticides, ***Journal of Entomology and Zoology Studies***, **5(3)**: 468-473.

4. F. Vinale, K. Sivasithamparam, E. L. Ghisalberti, R. Marra, S. L. Woo, M. Lorito, (2008) *Trichoderma*–plant–pathogen interactions, ***Soil Biology and Biochemistry***, **40(1)**: 1-10.
5. S. Compant, C. Clément, A. Sessitsch, (2010) Plant growth-promoting bacteria in the rhizo- and endosphere of plants: Their role, colonization, mechanisms involved and prospects for utilization, ***Soil Biology and Biochemistry***, **42(5)**: 669-678.
6. Havahart. Available from: https://www.havahart.com/whyorganic-harmful-effects-of-chemical-pesticides. [Last accessed on 2021 Oct 01].
7. Synthetic Pesticides. Available from: http://www.bt.ucsd.edu/synthetic_pesticide.html.
8. Pesticide Education Safety Program. Available from: https://www.psep.cce.cornell.edu. [Last accessed on 2021 Oct 01].
9. University of California Agriculture and Natural Resources. Available from: http://www.ipm.ucdavis.edu. [Last accessed on 2021 Oct 01].
10. Frontiers in Public Health. Available from: https://www.frontiersin.org/articles/10.3389/fpubh.2016.00148/full. [Last accessed on 2021 Oct 02].
11. O. Koul, (2011) Microbial biopesticides: Opportunities and challenges, ***CAB Reviews Perspectives in Agriculture Veterinary Science Nutrition and Natural Resources***, **6:** 1-26.
12. Agricultural-and-biological-sciences/plant-incorporated-protectants. Available from: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/plant-incorporated-protectants. [Last accessed on 2021 Oct 01].
13. H. A. F. El-Shafie, J. R. Faleiro, (2017) Semiochemicals and their potential use in pest management. In: ***Biological Control of Pest and Vector Insects***, London, UK: IntechOpen. p5772.
14. G. K. Pal, B. Kumar, S. K. Shahi, (2013) Antifungal activity of some common weed extracts against phytopathogenic fungi *Alternaria* spp, ***International Journal of Universal Pharmacy and Life Sciences***, **3(2)**: 6-14.
15. A. Shishir, A. A. Bhowmik, N. R. Akanda, A. Al Mamun, S. N. Khan, M. M. Hoq, (2015) Efficacy of indigenous *Bacillus thuringiensis* strains for controlling major vegetable pests in Bangladesh, ***Egyptian Journal of Biological Pest Control***, **25(3)**: 729-734.
16. Gauraha, Rashmi Gauraha and Dr. Deepak. Available from: https://www.krishisewa.com/articles/crop-protection/136-biopesticide.html. [Last accessed on 2021 Sep 29].
17. P. Kumar, L. Y. Z. Huang, R. Srinivasan, (2014) Effect of three commercial biopesticides of neem (*Azadirachta indica*) and *Bacillus thuringiensis* on legume pod borer (*Maruca vitrata*) (*Lepidoptera*: *Crambidae*) in Thailand, ***International Journal of Tropical Insect Science***, **34(2)**: 80-87.
18. C. Carpio, O. Dangles, S. Dupas, X. Léry, M. López-Ferber, K. Orbe, J. L. Zeddam, (2013) Development of a viral biopesticide for the control of the Guatemala potato tuber moth *Tecia solanivora*, ***Journal of Invertebrate Pathology***, **112(2)**: 184-191.
19. E. L. Scudeler, A. S. G. Garcia, P. F. F. Pinheiro, D. C. Dos Santos, (2017) Neem oil (*Azadirachta indica* A. Juss) affects the ultrastructure of the midgut muscle of *Ceraeochrysa claveri* (Navás, 1911) (*Neuroptera*: *Chrysopidae*), ***Acta Histochemica***, **119(1)**: 84-91.
20. D. P. Molloy, D. A. Mayer, M. J. Gaylo, J. T. Morse, K. T. Presti, P. M. Sawyko, B. H. Griffin, (2013) *Pseudomonas fluorescens* strain CL145A – A biopesticide for the control of zebra and quagga mussels (*Bivalvia*: *Dreissenidae*), ***Journal of Invertebrate Pathology***, **113(1)**: 104-114.
21. S. Gašić, B. Tanović, (2013) Biopesticide formulations, possibility of application and future trends, ***Pesticidi i Fitomedicina***, **28(2)**: 97-102.
22. G. V. Ranga Rao, O. P. Rupela, V. R. Rao, Y. V. R. Reddy, (2007) Role of biopesticides in crop protection: Present status and future prospects, ***Indian Journal of Plant Protection***, **35(1)**: 1-9.
23. D. Rongai, C. Cerato, L. Lazzeri, S. Palmieri, G. Patalano, (2008) Vegetable oil formulation as biopesticide to control California red scale (*Aonidiella aurantii* Maskell), ***Journal of Pest Science***, **81(4)**: 179-185.
24. A. G. Portero, A. González-Coloma, M. Reina, C. E. Díaz, (2012) Plant-defensive sesquiterpenoids from Senecio species with biopesticide potential, ***Phytochemistry Reviews***, **11(4)**: 391-403.
25. S. Sharma, M. Verma, A. Sharma, (2013) Utilization of non edible oil seed cakes as substrate for growth of *Paecilomyces lilacinus* and as biopesticide against termites, ***Waste and Biomass Valorization***, **4(2)**: 325-330.
26. N. K. Dubey, B. Srivastava, A. Kumar, (2008) Current status of plant products as botanical pesticides in storage pest management, ***Journal of Biopesticides***, **1(2)**: 182-186.
27. L. A. Lacey, D. I. Shapiro-Ilan, (2008) Microbial control of insect pests in temperate orchard systems: Potential for incorporation into IPM, ***Annual Review of Entomology***, **53:** 121-144.
28. Researchgate. Available from: https://www.researchgate.net/figure/Biopesticides-registered-in-India-Anonymous-2014_tbl1_322799518/amp. [Last accessed on 2021 Oct 02].

***Bibliographical Sketch**

Vishakha Pandey is a Master of science student in the department of biotechnology, Isabella Thoburn College, Lucknow.

Divyanshi Mishra is a Master of science student in the department of Biotechnology, Isabella Thoburn College, Lucknow.

Farheen Fatima is a Master of science student in the department of biotechnology, Isabella Thoburn College, Lucknow.

Dr (Maj) Neerja Masih, MSc, PhD (Biochemistry) is an Asst Prof of Biochemistry at Isabella Thoburn College and She is Incharge, PG Department of Biotechnology. She has 10 years of experience as Defense Food Analyst in Army Service Corps in Indian Army and took release as a Major.

She is passionate about Environment and has presented many papers at International and National levels. She has taught 'Women and Environment' at the Post Graduate Department of Women's Studies at Isabella Thoburn College for past 7 years.Under the Biotech Society of Isabella Thoburn College, she is involved in training and sensitizing the students regarding Management of green waste on campus by Vermicomposting and has organized sessions of Guest Speakers with the students to ignite the scientific temper in them. She has organised, attended and participated in many workshops related to Environment and gender issues. She has been teaching post graduate students of Biotechnology & Nutrition for last 15 years and guided more than 60 students for project dissertation. She has many publications in national & international journals, she has contributed chapters in books. She is reviewer for many journals.