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A Review on Biopesticides: An Eco-Friendly Technology for Crop Protection Against Insect Pests in Sustainable Agriculture

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ABSTRACT: An ecofriendly alternative to chemical pesticides is biopesticides, which encompasses a broad array of microbial pesticides, biochemicals derived from micro-organisms and other natural sources, and processes involving the genetic incorporation of DNA into agricultural commodities that confer protection against pest damage. Biopesticides fall into three major classes. The potential benefits to agriculture and public health programmes through the use of biopesticides are considerable. The interest in biopesticides is based on the disadvantages associated with chemical pesticides are discussed. The total world production of biopesticides is over 3,000 tons/yr, which is increasing at a rapid rate. India has a vast potential for biopesticides. However, its adoption by farmers in India needs education for maximizing gains. The market share of biopesticides is only 2.5% of the total pesticide market. The stress on organic farming and on residue free commodities would certainly warrant increased adoption of biopesticides by the farmers. Biopesticides being target pest specific are presumed to be relatively safe to non-target organism including humans. However, in India, the registration committee requires the data on chemistry, bioefficacy, toxicity and packaging and labeling, for registration. Pesticide Registration Committee has so far not approved any guidelines for the registration of GM biopesticides. In India, some of the biopesticides like Bt, NPV, neem based pesticides, etc. have already been registered and are being practiced

KEYWORDS: biopesticides, eco-friendly, crop protection, sustainable agriculture, insect pests, safety

I. INTRODUCTION

The application of conventional pesticides is underscored by many negative externalities including environmental degradation and pest resistance. Consequently, their use in commercial farming is attracting regulatory restrictions leading to 2% decline per year in synthetic pesticides use in favor of 10% increase of biopesticides as alternative agrochemicals (Damalas and Koutroubas, 2018). Microbial biopesticides, biochemical biopesticides, and plant-incorporated protectants (PIPs) are the well-known categories of biopesticides, and they command 5% share of the pesticide global market, [1,2]with microbial biopesticide taking the lead (Pathma et al., 2021). However, the complete adoption of biopesticides is hindered by the short supply of products to meet farmers' demands, high cost of refined products, and slow action that they mostly exhibit (Verma et al., 2021). Although, these drawbacks are balanced with the tolerable toxicity, if any, that is manifested by biopesticides. They are also biodegradable, specific in action (harmless to non-target organisms), and also possess the ability to counter pest resistance issues caused by synthetic pesticides (Mishra et al., 2020). In the meantime, as the world waits for research advances to address the drawbacks, presently, crude extracts of pesticidal plants can be relied on, especially for local farmers and developing countries. Biopesticide-driven sustainable agriculture enjoys social acceptability, promotes economic productivity, and engenders environmental stewardship.[3,4] These three dimensions represents the tripartite concept of sustainable development whose finest concept is currently contained in the United Nations 2030 agenda, popularly known to as the Sustainable Development Goals (SDGs).

The SDGs tend to address all-round development including hunger eradication, poverty reduction, and sustainable farming among others (Vetter et al., 2017). Sustainable agriculture serves as the most critical sector of the SDGs, and it integrates most aspect of the 17 SDGs, directly and indirectly. However, it is directly linked to eight of the 17 SDGs in which both the SDG2 (Zero Hunger) and SDG1 (No Poverty) exert the greatest influence, while SDG9 (innovative technology and infrastructure) and SDG7 (affordable energy) have the least influence based on the decreasing degree of reliance on agriculture. The goals of these eight SDGs are centered on sustainable production and utilization, reliance on biodegradable feedstock, and environmental protection, which are to some extent the goals of green chemistry (GC)



principles. As green agrochemicals, biopesticides have great influence in sustainable agriculture, because their characteristics satisfy the conditions of GC principles and the tripartite concept of sustainable development. Moreover, this interconnectedness of sustainable development and GC by biopesticide-driven commercial farming ensures environmental protection, quantitative and qualitative productivity, safe and effective technology, and judicious and effective use of resources.[5,6]

Biopesticides exert their inhibitory effects through multiple mode of actions such as growth regulators, gut disruptors, metabolic poison, neuromuscular toxins, and non-specific multi-site inhibitors (Sparks and Nauen, 2015; Dar et al., 2021). These multiple modes of action against targeted pests obliterate the chances of developing resistance as is common with chemical pesticides. The intensive use of conventional pesticides in industrial-scale farming over a long period, especially in the Green Revolution era, also created challenges such as pesticide-related pollution, post-harvest chemical consumption through bioaccumulation, biodiversity losses, and resurgence of secondary pests and elimination of natural/beneficial enemies. These negative consequences are not associated with the use of biopesticides. Thus, prohibitive restrictions are continually imposed on synthetic pesticides to reduce their numbers with time. For instance, there has been a reduction to 250 active ingredients of conventional pesticides in 2009 as opposed to more than 1,000 in 2001 while entrance of new conventional pesticides into the market reduced from 70 in 2000 to 28 in 2012 (McDougall, 2013). The direct result of the declining number of classical pesticides is the increased demand for biopesticides for some beneficial reasons. These benefits include, but are not exclusive to, altering the course of pest resistance, low toxicity properties, complementary input to synthetic pesticides, eco-friendliness, specificity (thus have little or no negative impact on non-target organisms and humans), biodegradability, and little or no problem of post-harvest contamination, stability against abiotic stress (Deravel et al., 2014; Kalpana and Anil, 2021), and compatibility in integrated pest management (IPM).[7,8]

II. DISCUSSION

he commercially used synthetic pesticides have been proven to be toxic not only to humans and other animals, but also to non-target plant, the surrounding organisms around the plant, and the environment. There are also increased concerns regarding the development of pest resistance towards these synthetic pesticides. As such, biopesticides, which are defined as the certain kinds of pesticides derived from natural sources such as plants, bacteria, fungi, animals and some minerals, are potential alternative pesticides and are gaining increasing attention. Biopesticides are safer and eco-friendly pesticides used for pest management. Among these, plant-based biopesticides constitute a small but important group of biopesticides. Plant based extracts and essential oils have been particularly used in the management of insects exhibiting a variety of anti-insecticidal mechanisms. [9,10] Their chemical compositions are very complex and as such acquiring resistance by the pest against such biopesticide is very difficult. As far as their mechanism of action is concerned, these can act as insect repellants, insect attractants, or anti-feedants. They can also inhibit respiration or they can obstruct the host plant identification. These insecticides can inhibit oviposition and decrease adult emergence by ovicidal and larvicidal effects. Some of the essential oil based insecticides have even been commercialized for use. However, there are some limitations that restrict the widespread use of such biopesticides. These limitations include cost, difficulties in production, gentle action, and dearth of appropriate biopesticide formulations. As far as their regulations are concerned, it is still a problem in many countries further halting biopesticide use. But one thing is clear that biopesticides do have a promising future due to their eco-friendly nature and unique chemical compositions and unique mode of action.[11,12]

Pesticides are used in agriculture, globally, to reduce yield losses and maintain produce pre/postharvest quality by eradicating unwanted insects and controlling disease and extend its shelf-life in order to keep pace with the growing demand for food. This extensive use of chemical pesticides has certainly provided protection to the crops. However, the practice has also raised concerns about pesticide residues in the food and environment.

In Kashmir valley, chemical pesticide use has reached a high. Human well-being and loss of productivity have, although, remained stagnant. Ignorance among less knowledgeable farmers has resulted in the indiscriminate application of pesticides. Studies have found that about 1/3rd of the pesticides used are spurious in nature. Chemical pesticides adversely affect beneficial organisms, leave harmful residues in food, feed, and fodder, and cause environmental pollution.

The Food and Agricultural Organization (FAO) of the United Nations forecasted the need to increase world food production by 70% in order to keep pace with the increasing demand for food. Maximizing food production is the primary objective of all nations, as the global population is expected to reach approximately 10 billion by 2050.



Thus, arose a need to produce more food from less per capita arable land and available water. But providing ample food was only the first part of the challenge. The second and more important challenge was to produce and protect them in a safe and sustainable manner. This is where intensive agriculture was deployed, using green revolution technology, characterized by the use of high-yielding varieties, chemical fertilizers, and pesticides.[13,14]

There are an estimated 67,000 agricultural pest species that damage crops. However, due to the issue of pest resistance and withdrawal of some products on either regulatory or commercial grounds, only a few chemical pesticides are available in the market. Out of the 215 pesticides registered for use in India, 39 have been banned for use or withdrawn from the market. Thus, the requirement for the manufacture of even more pesticides has built up.

While the progress in agricultural production has been very impressive, intensive agriculture has resulted in several undesirable effects on the environment, and the overall sustainability of farming systems.

There are rising concerns about the loss of biodiversity and endangered species, set against the requirement to increase agricultural production without excessive reliance on chemical pesticides. Hence, the need of the day is to produce maximum from the decreasing availability of natural resources, without adversely affecting the environment. [15,16]

III. RESULTS

Environmental safety and agricultural sustainability are equally important for survival on Earth. This is where biopesticides come into the picture. Biopesticides or biological pesticides refer to the use of living biological organisms or their metabolites for pests, pathogens, weeds, nematodes, rodents, etc. In accordance with the United Nations Food and Agriculture Organization standards, biopesticides are generally natural compounds or genetic modification agents, including biochemical pesticides (pheromones, hormones, plant regulators, insect growth regulators) and microbial pesticides (fungi, bacteria, or genetically modified microorganisms), which do not include antibiotic agricultural preparations. However, in the practical application of agricultural production, biopesticides generally refer to the large-scale industrial production of microbial pesticides. Biopesticides are made from naturally occurring substances that control pests by non-toxic mechanisms and in an eco-friendly manner. Hence, biopesticides pose less threat to the environment and human health. They are generally less toxic than chemical pesticides, often target specific, have little or no residual effects, and have acceptability for use in organic farming.[17,18]

Increasing demand for pesticide residue-free crop produce is one of the key drivers of the biopesticide market. Growing organic food market and easier registration than synthetic chemical pesticides are other important driving factors.

The development of biopesticides has largely followed a chemical pesticide model that does not fully exploit favorable biological properties of the biological agents. While there is commercial pressure from the manufacturing side to develop products, the environmentalists prefer narrow-spectrum products based on the strains from the area of use.

To reconcile these divergent demands, biopesticides in the market have been maintained at minimal negative impact, if any, on the environment. Increased public concerns about potential adverse environmental effects associated with the use of synthetic pesticides prompted the search for products based on natural resources.[19,20]

One such innovation is the Integrated Crop Management (ICM) program. It is a pragmatic approach to maintaining an intricate balance between environmental safety and agricultural productivity with sustainability being an important factor.

Objectives of ICM are:

Reducing external inputs, such as inorganic fertilizers, pesticides, and fuel by means of farm-produced substitutes.

As complete replacement of these inputs is not possible without significant loss of yields, partial substitution of the inputs can be achieved by the use of natural resources. [21,22]

IV. CONCLUSIONS

In recent decades, the focus on crop production has shifted from yield to quality and safety. Evidence suggests that biopesticide is an important component for promoting sustainable agriculture, hence it has gained a lot of interest, particularly in view of the growing demand for organic foods.



On this note, let's also know some downsides of biopesticides:

- Slower rate of control, often a lower efficacy, and shorter persistence compared to conventional pesticides
- Greater susceptibility to adverse environmental conditions
- Greater level of knowledge required by the grower to use them effectively

Globally, there are 175 registered biopesticide active ingredients and more than 700 products available in the market. The global biopesticide market has been valued at US \$2.3 billion. It was expected to reach US \$5.2 billion by 2020.

But there is still a lot to achieve in this regard, now of all times, when people are consciously leaning towards safety rather than yield.[22]

Identifying the ill effects of synthetic pesticides, most countries have amended their policies to ensure minimal use of chemical pesticides and promote the usage of biopesticides. However, biopesticides are still under the regulatory system originally developed for chemical pesticides. This creates a market entry barrier by imposing burdensome costs on the biopesticide industry.

Biopesticides represent only 1% of the global market for agrochemicals. So, policy measures need to be strengthened in order to minimize the use of chemical pesticides and promote the use of biopesticides.

There are certain technical difficulties in making biopesticides more effective and applicable. Generally, biopesticide application is not complicated, however, it may require training and knowledge about pests/pathogens against which they can be applied successfully.

The other challenging task is to develop a balance between the broadly defined costs and benefits of biopesticides compared with synthetic pesticides.

The new-found biopesticides may bring with them new regulatory and economic challenges that must be addressed jointly by the social and natural scientists, policymakers, and the industry.

One other major obstacle in promoting biopesticides is the lack of profile which again reflects the weakness of the policy network. The relative immaturity of the policy network, lack of trust between regulators and producers, and limited resources and capabilities are some of the serious issues that need to be addressed.


A better understanding of the mode of action of biopesticides, their effects, and regulatory issues that arise during their adoption may help to raise their profile among the public and policy-makers.

As environmental safety is a global issue, there is a need to create awareness among the common people to switch over to biopesticides for their pest management requirements. Biopesticides are expected to provide predictable performance. Deployed properly, biopesticides have tremendous potential in bringing sustainability to agriculture and ensure environmental safety.[23]

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