The Future of Pest Management: Expanding the Role of Microbial Bioagents

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ABSTRACT

With the global increase in human population, the challenge of meeting food demands intensifies. Despite geometric population growth, land degradation and stagnating crop yields hinder agricultural productivity. Insect pests, responsible for significant yield losses, prompt farmers to rely heavily on chemical pesticides. However, the overuse of these chemicals leads to environmental contamination, impacts on human health, harm to non-target organisms, and increased resistance in pests and diseases. To address these issues, there is a growing need for safer and more sustainable pest control alternatives. One of which is the use of microbial biocontrol agent-based formulations because of their high specificity, safety, and effectiveness against the target organisms. With ongoing research and development, particularly in high-potential strains, biopesticides are poised to play a crucial role in sustainable pest management and meet future agricultural needs.

INTRODUCTION

The world currently has 7.5 billion people, and by 2050, that number is expected to rise to 10 billion, according to the United Nations World Population Prospects. The population is growing geometrically, yet the land is deteriorating and, the yield hasn't increased that much to satisfy the growing population. One of the biggest barriers to raising yield and productivity is insect pests causing yield

losses. Therefore, farmers use a lot of chemical pesticides to keep the insect population below the economic damage level. However, the overuse of hazardous chemical pesticides contaminates the land, air, and water and is not sustainable. It also has a detrimental effect. It also negatively impacts humans and non-target organisms, including natural predators, while fostering resistance to insect pests and diseases. Therefore, a safer and more cost-effective alternative is needed to control harmful insects without damaging the environment. This sparked the idea of using living organisms for insect management, a concept known as biological control. Biological control usually includes both microbial and macrobial. In this article, we provide an overview of the various types of microbial biological control agents used to manage insect pests.

Microbial biopesticides

The microbial biopesticides were developed from various microbial agents such as algae, bacteria, fungi, protozoans, or viruses. These microorganisms directly or their toxins could be an active ingredient in the biopesticide formulation. The microbial agents potentially utilized in development of formulation are as follows:

1. **Entomopathogenic bacteria:** The bacteria intended for the use as biological control agents against insect pests were categorized into four groups depending on the spore formation. These are crystalliferous spore formers (*Bacillus thuringiensis*); obligate pathogens (*Bacillus popilliae*); potential pathogens (*Serratia marcesens*); and facultative pathogens (*Pseudomonas aeruginosa*). Spore formers have been the most widely exploited for commercial use due to their safety and effectiveness (Rajashekhar *et al*., 2021).

2. **Entomopathogenic viruses:** The entomopathogenic viruses belonging to various families that target harmful insect pests were identified. The viruses that belong to the family baculoviruses were largely exploited for biopesticide formulation development because of their high efficiency. It was reported that more than 700 insect species were known to be infected by entomopathogenic viruses with order Lepidoptera being the susceptible group (Raj *et al*., 2022).

3. **Entomopathogenic Fungi:** Entomopathogenic fungi were proven as effective biocontrol agents targeting large number of insect pests mainly because of greater host range, ease of production, and application in the field, high durability and greater virulence. *Trichoderma harzianum, Trichoderma viridae, Streptomyces griseoviridis, Verticillium chlamydosporium, Beauveria bassiana, Metarhizium anisopilae, Nomuraea rileyi, Paecilomyces farinosus* and *Verticillium lecanii*. Many have been commercialized globally (Seenivasagan *et al*., 2021).

4. **Entomopathogenic nematodes:** Entomopathogenic nematodes were described from 23 nematode families and a successful one from the family Heterorhabditidae and Steinernematidae received greater attention. Entomopathogenic nematodes proved effective against different insect orders. These fascinating organisms suppress insects in cryptic habitats such as soil-borne pests and stem borers (Van der Linden *et al*., 2022).

5. **Entomopathogenic protozoans:** Although protozoan pathogens naturally infect a broad spectrum of pests and cause chronic, debilitating effects that can reduce pest populations, their use as biopesticide agents has not been very successful. Protozoa are

classified into several phyla, some of which include species that target insects. Among these, microsporidian protozoans have been extensively studied as potential components of integrated pest management programs (Yadav *et al*., 2021).

Research and Development in Biopesticide-Based Pest Management

Among the various types of biopesticides currently in use, microbial biopesticides represent the largest group of broad-spectrum agents. These biopesticides are highly specific to pests, targeting only pest species while remaining environmentally safe. They are available in 30 countries affiliated with the Organization for Economic Co-operation and Development (OECD).

CONCLUSION

Various biopesticides have demonstrated effectiveness against different insect pests, offering host-specific solutions that are safe for the environment and non-target organisms. Growing health consciousness and the increasing interest in organic farming, especially among the youth, have driven up the demand for biopesticides. Their success in reducing pest populations in numerous cases further supports their potential. As the adoption of biopesticides continues to rise, the demand for these products is expected to increase significantly in the future. To support this expansion, governments should implement policies that encourage biopesticide production and provide subsidies to farmers, making high-quality biopesticides more accessible and affordable

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