Biological Control of Plant Pathogens: An Eco-Friendly Disease Management

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Due to the continuous use of pesticides and fungicides in large quantities to manage the plant diseases has seriously raised a concern about the contamination of the ecosystem because of the introduction of these potent dangerous chemicals in to the agriculture system over years. The existence of the chemicals in the ground leads to the contamination of air, water and degradation of land as these particles takes more time to degrade in the natural system. So, there is an high need of alternative management of plant diseases (Collinge *et al.,* 2022). An eco-friendly and sustainable alternative to chemical-based remedies for managing plant infections and pests is biological control.

Biological control

The use of living organisms to govern or restrict populations of plant pathogens, pests or invasive species is known as biological control, sometimes known as biocontrol. Beneficial insects, parasitoids, predatory nematodes, microorganisms such as bacteria and fungi and even other plants are examples of these organisms. The organisms which are used in the biocontrol management are called as biocontrol agents (BCA). Unlike chemical pesticides, biological control approaches rely on natural enemies of plant pathogens to maintain ecological equilibrium (Fira *et al.,* 2018).

Need for eco-friendly plant pathogen management

As stresses about the environmental impact of chemical pesticides mount, there is an compelling necessity to move to more sustainable and environmentally friendly agricultural practices. Non-target creatures can be harmed by chemical pesticides, which can contaminate soil and water and lead to the development of pesticide-resistant pathogens. Biological control tackles these concerns by providing a comprehensive and environmentally benign method that minimises ecosystem damage and supports long-term pathogen management.

Beneficial biocontrol agents

Microorganisms are critical components of biological control techniques that aim to manage plant diseases while minimising environmental effect. In this section, we will look at the importance of harnessing the power of helpful microbes and the different varieties used in plant pathogen control.

Harnessing the power of microbes

Microbes are widely recognised as having the potential to inhibit plant diseases. These microscopic creatures have the ability to colonise plant surfaces and interact with diseases, either directly antagonising them or boosting the plant's innate defence mechanisms. Utilising the potential of helpful microorganisms is a key component of environmentally responsible plant disease treatment.

Beneficial microorganisms utilized in plant pathogen control

To tackle plant infections, a varied array of helpful microbes has been mobilised in the search for sustainable agriculture. In this section, we will look at different types of microorganisms, each with their distinct way of action:

Antagonistic bacteria: Bacterial strains that produce antimicrobial chemicals and compete for resources with harmful microbes, limiting their growth are known as antagonistic bacteria.

Ex: *Bacillus* bacteria have inhibited soybean seed pathogenic fungi *in vitro*, *Rhizoctonia solani*, *Sclerotinia sclerotiorum* and *Phomopsis* sp (Widnyana and Javandira, 2016).

Pseudomonas fluorescens acts against *Fusarium* wilt and *Rhizoctonia* damping off in tomato and pepper (Domenech *et al.,* 2006).

Fungal Antagonist: Mycoparasitic fungi such as *Trichoderma* and *Ampelomyces* parasitize pathogenic fungi, interrupting their development and decreasing illness severity.

Ex: *Trichoderma asperellum* and *Metarhizium anisopliae* are used to control powdery mildew (*Leveillula taurica*)in pepper (Lopez *et al.*, 2019).

Endophytes: Endophytes are microorganisms that reside within plant tissues and can help the plant resist infections by secreting protective chemicals or generating systemic immune responses.

Beneficial Rhizobacteria: Rhizobacteria, such as nitrogen-fixing bacteria, can benefit plant health by improving nutrient uptake and in turn, indirectly reducing pathogen pressure.

Biopesticides

Biopesticides are gaining popularity as safe and sustainable pest and disease management solutions in agriculture. Biopesticides are natural disease management products derived from microorganisms, plants, animals and their byproducts. They are designed to control pests like insects, weeds and plant pathogens while minimizing harm to non-target organisms and the environment (Koul, 2023). Biopesticides are considered an eco-friendly and sustainable alternative to synthetic chemical pesticides because of their lower toxicity and fewer negative ecological impacts.

There are three types of biopesticides namely microbial biopesticides, plant-incorporated protectants (PIPs) and biochemical biopesticides (Fragkouli *et al.*, 2023). Microbial biopesticides contain living microorganisms that can infect or parasitize pests, such as *Bacillus thuringiensis* (Bt) and *Metarhizium anisopliae*. Plant-Incorporated Protectants (PIPs) are genetically modified crops that express proteins derived from naturally occurring microorganisms, such as Bt crops. Biochemical biopesticides are naturally occurring substances extracted from plants, animals or microorganisms, disrupting the physiology or behaviour of pests.

Biopesticides have many advantages, including being environmentally friendly, having reduced chemical residues, targeting specific pests and being less toxic to humans and animals. They are also a key component of integrated diseases management, promoting sustainable and holistic approaches to disease control. However, biopesticides face challenges such as limited persistence, specificity, regulatory hurdles and cost.

Biopesticides are utilized in various agricultural settings, including organic farming, conventional agriculture and integrated pest management programs, to manage a broad range of pests, including insects, weeds and plant diseases. As research and development in this field continue, biopesticides are expected to play an increasingly significant role in modern agriculture.

Safe and sustainable disease management

Biopesticides represent a significant departure from traditional chemical pesticides, providing a safer and more ecologically friendly approach to pest and pathogen management. Biopesticides, unlike their chemical equivalents, are obtained from natural sources such as beneficial bacteria, plant extracts or biochemicals. Because of this differentiation, they are less harmful to humans, non-target creatures and the environment.

The emphasis on safety and sustainability in biopesticide use is consistent with rising understanding of the negative impacts of chemical pesticides on ecosystems, beneficial organisms and the development of fungicide-resistant pathogens. Biopesticides not only alleviate these problems, but also contribute to agricultural ecosystems long-term health and resilience.

Development and use of biopesticides

Creating efficient biopesticides necessitates substantial study and development. This section will go over the various stages of biopesticide development, such as:

Isolation and screening: Identifying and isolating pest-controlling microbes or chemicals from nature.

Formulation: Creating formulations that improve the stability and effectiveness of biopesticides for use in the field.

Field Trials: Extensive testing in real-world agricultural settings to determine the efficacy and safety of biopesticides.

Regulation and Registration: Navigating regulatory processes to guarantee biopesticides meet commercial safety and efficacy standards.

Integrated Disease Management (IDM): The use of bioagents into comprehensive IDM programmes that combine multiple pathogen control approaches for maximum performance (Rong *et al.*, 2020).

Advantages of biological control

1. Reduced Chemical Dependency: It minimizes the need for synthetic chemical pesticides, reducing the chemical residues in the environment and preventing the development of pesticide-resistant pathogens.
2. Soil and Water Protection: By reducing chemical runoff and soil contamination, it helps to safeguard water quality and preserve soil fertility.
3. Reduced Resistance Development: Unlike chemical pesticides, biocontrol methods are less prone to the development of resistance in pathogens and pests.
4. Enhanced Precision: The specificity of biocontrol allows for precise pest and disease management, reducing the risk of overuse or unintended harm to beneficial species.
5. Lower Carbon Footprint: It typically has a lower environmental footprint compared to the production and application of synthetic chemicals.
6. Organic farming compatibility and certification: Biological control methods are compatible with organic farming practices and are widely accepted in organic certification standards.

Limitations of biological control

1. Specificity: Many biocontrol agents are highly specific to particular pathogens or pests. This means that they may not be effective against a wide range of pathogens.
2. Effectiveness: The effectiveness of biocontrol can vary depending on environmental conditions, such as temperature, humidity and soil type.
3. Slow Action: Biocontrol agents often take longer to show results compared to chemical pesticides.
4. Incompatibility with Certain Practices: Some agricultural practices, such as the use of certain chemical pesticides or soil fumigation, can harm or disrupt biocontrol agents, limiting their effectiveness.
5. Cost: While biocontrol can lead to long-term cost savings, the initial investment in research, development and implementation can be higher than conventional chemical pest management.
6. Knowledge and Training: Successful use of biocontrol often requires specialized knowledge and training. Farmers need to understand the life cycles and interactions of biological control agents and their target pathogens.
7. Availability: Availability of specific biocontrol agents can be limited in certain regions, making it difficult for farmers to access and implement these methods.

Conclusion

Biological control of plant diseases is a ray of hope in the field of environmentally friendly disease management in agriculture. This sustainable strategy has several positive aspects ranging from environmental stewardship and human safety to long-term efficacy and tailored disease management. We may reduce the ecological harm associated with chemical pesticides while improving the health and resilience of our agricultural ecosystems by utilising the power of beneficial bacteria, predatory insects, and natural antagonists. Yet it is crucial to realise the inherent constraints and difficulties that come with biological control, including regulatory barriers and issues with specificity and efficacy. Even if it is not a magic solution, it is a crucial part of Integrated Disease Management techniques that encourage peaceful cohabitation between agriculture and the

environment. In our drive for sustainable, wholesome and resilient crop systems, biological management is poised to become more and more important as research continues to reveal new technologies.

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