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# HARNESSING MICROBES FOR BIOTIC STRESS MANAGEMENT IN CROPS

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**Abstract**

In agriculture, biotic stress is a major cause of pre- and post-harvest losses. Soil microorganisms play a vital role in plant growth productivity in a stressful environment. Microbial populations have functional roles within communities where interactions among distinct microorganisms will permit their survival. The mechanisms responsible for this biocontrol activity include competition for nutrients, niche exclusion, induced systemic resistance (ISR), and the production of anti-microbial metabolites. Using microbes to manage biotic stress in crops is a promising approach that aligns with sustainable agriculture practices.

## Understanding Biotic Stress in Crops : Types and Impacts

Agriculture, the backbone of global food security, faces numerous challenges, among which biotic stress stands out as a significant threat. Biotic stress refers to the damage caused to crops by living organisms such as bacteria, viruses, fungi, insects and weeds. These stress factors can lead to severe crop losses, compromising both the quantity and quality of agricultural products.

## Types of Biotic Stress

**Pathogens:** Pathogens are disease causing organisms that include bacteria, fungi, viruses, and nematodes. These organisms infect crops, leading to a range of diseases that can devastate entire fields if left unchecked. Bacteria such as *Xanthomonas*, *Pseudomonas*, and *Erwinia* are notorious for causing bacterial blights, wilts, and soft rots in crops. These diseases often result in wilting, leaf spots and decay, severely affecting plant's health. Fungi like *Fusarium, Phytophthora* and *Botrytis* are responsible for diseases such as wilt, blight, and mold. Viruses such as Tobacco Mosaic Virus (TMV) and Tomato Yellow Leaf Curl Virus (TYLCV), can stunt plant growth, cause leaf curling, discoloration, and ultimately reduce yields. Viruses are often spread by vectors, making their management particularly challenging. Root nematodes *(Meloidogyne* spp.) are microscopic worms that attack plant roots, causing galls that disrupt plant's ability to absorb water and nutrients. This leads to stunted growth and cause significant reduction in crop yield.

**Insects and pests:** Insects and pests cause direct damage to crops by feeding on various plant parts. Additionally, they act as vectors for diseases, further exacerbating the stress on crops. Aphids are the small insects that suck the sap from plants, weakening them and often transmitting viral diseases in process. Aphid infestation can lead to curled leaves, stunted growth and reduced crop productivity. The larvae of moth and butterflies, such as corn earworm, chew on leaves, stems and fruits, causing physical damage that can reduce the plant's ability to photosynthesize and grow properly. Beetles like Colorado potato beetle is known for their voracious appetite for leaves. Their feeding habits can defoliate plants, severely impacting their growth and yield potential.

**Weeds:** weeds compete with crops for essential resources such as light, water, and nutrients. They can also serve as host for pests and diseases, creating a dual threat to crops. Parasitic weeds like Striga (Witchweed) and Orobanche (broomtape) attach themselves to crop roots, siphoning off nutrients and water. This parasitic relationship severely stunts crop growth and can lead to significant yield loss. Non

parasitic weeds like Johnson grass or pigweed outcompete crops for resources, often leading to reduced crop vigor and productivity.

**Impact of Biotic stress on crop yield**

Biotic stress can have devastating effect on crop yield and quality. The impact of biotic stress manifests in several ways. Biotic stress can cause partial or complete crop failure. For instance, fungal diseases like rust can devastate wheat yields, potentially reducing yields by up to 50% in affected areas. It can lead to deformities in fruits, vegetables and grains, rendering them unmarketable. Viral infections often result in discolored or misshapen fruits, affecting both appearance and nutritional value of the produce. Farmers must invest more in pesticides, herbicides and other disease management strategies to combat this. This in turn increases the cost of production and can reduce overall farm profitability. Widespread biotic stress can lead to significant economic losses, especially for smallholder farmers. Moreover, it threatens food security by reducing the availability of crops in regions heavily dependent on agriculture.

Rice blast disease caused by the fungus *Magnaporthe oryzae*, rice blast is one of the destructive diseases affecting rice crops worldwide. It causes lesions on leaves, stems and panicles leading to significant yield losses. Potato late blight caused by *Phytophthora infestans*, was the primary cause of the Irish Potato famine and it results in rapid decay of potato plants, often leading to total crop loss. The larvae of *Helicoverpa armigera* are notorious for feeding on cotton bolls, leading to reduced fiber quality and quantity. Wheat stem rust caused by *Puccinia graminis*, is a highly destructive fungal disease that continues to be a significant threat in wheat growing regions, especially where resistant varieties are not available.

**Types of Microbes for Biotic Stress management in crops**

In the face of increasing agricultural challenges, particularly those posed by biotic stress factors such as pests, weeds, and pathogens, the need for sustainable and eco friendly management strategies is more pressing than ever. Among the various approaches available, the use of beneficial microbes has gained significant attention for its potential to protect crops against these biotic threats. Microbes, including bacteria, fungi and viruses are proving to be invaluable allies in enhancing plant resilience and reducing impact of biotic stress.

**Beneficial Bacteria:** Certain bacterial species can suppress plant pathogens, promote healthier plant growth, and even induce the plant's immune system to ward off attacks. *Bacillus spp*. are known for their ability to produce antibiotics, and it inhibit the growth of harmful plant pathogens. They also produce enzymes that break down the cell walls of damaging fungi, helping to control diseases such as root rot and blight. *Pseudomonas spp.* are effective biocontrol agents, producing metabolites that suppress soil–borne pathogens. In addition, Pseudomonas bacteria compete with harmful pathogens for essential resources, reducing the likelihood of disease outbreaks. *Rhizobium spp.* are well known for their symbiotic relationship with leguminous plants which can fix atmospheric nitrogen, enhancing plant growth and vigor. This strengthened growth helps crops better withstand the effects of biotic stress, such as those caused by pests and diseases.

**Beneficial fungi:** Fungi protects crops from biotic stress through various strategies, including competition, parasitism and the induction of plant defenses. Mycorrhizal fungi establish symbiotic relationship with plant roots, extending their hyphae into the soil to enhance nutrient uptake, particularly phosphorous. By bolstering overall plant health, mycorrhizal fungi help crops resist biotic stress factors, including pathogens and pests. *Trichoderma spp.* have biocontrol capabilities, especially against soil borne pathogens. They colonize plant roots and produce enzymes that degrade the cell walls of harmful fungi. Furthermore, *Trichoderma spp.* can induce systemic resistance in plants, fortifying them against a broad range of diseases.

**Viruses and other microbes:** While viruses are typically associated with plant diseases, certain viruses can be harnessed to control pest populations or serve as biological control agents. Entomopathogenic viruses specifically infect and kill insect pests, reducing their populations without harming the plants. Baculoviruses are used to control caterpillar pests in various crops offering a targeted and environmentally friendly pest management.

**Mechanism of Action : How microbes combat biotic stress**

Biocontrol agents: Microbes act as natural enemies to plant pathogens and pests , either by directly antagonizing them or by outcompeting them for resources. *Bacillus* species produce antibiotics that eliminate or inhibit harmful bacteria and fungi, while *Trichoderma* species parasitize pathogenic fungi, effectively curbing their spread.

1) Induced Systemic Resistance (ISR): Certain beneficial microbes can trigger a plant's immune system, making it more resilient to future attacks by pathogens or pests . This process, known as Induced systemic resistance (ISR), functions similarly to vaccinating the plant, providing broad spectrum protection against multiple threats. *Pseudomonas* and *Trichoderma* species are well known for their ability to induce ISR in crops, enhancing their overall defense

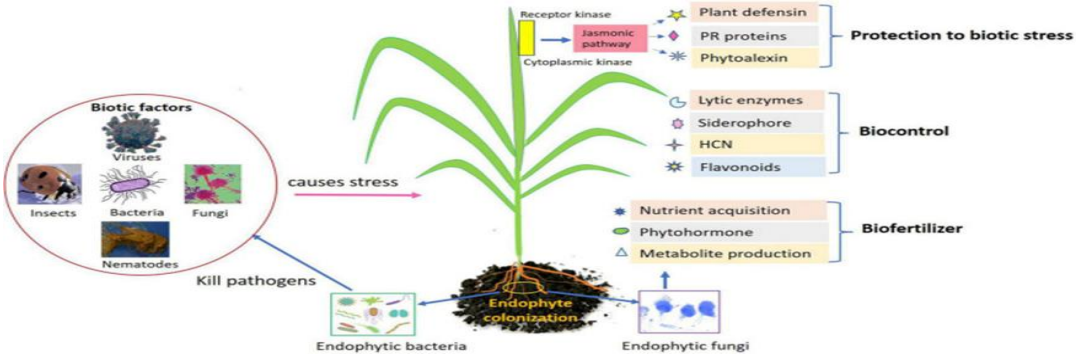
2) Competition and Antagonism: Beneficial microbes often outcompete harmful organisms for space and nutrients, reducing the chances of pathogen establishment. Additionally, some microbes produce compounds that are toxic to pests and pathogens, further bolstering the plant's defenses.

**3)** Enhanced nutrient uptake: By improving nutrient availability, particularly in nutrient poor soils, beneficial microbes can enhance plant health and vigor. Healthier plants are better equipped to withstand attacks from pests and diseases, making enhanced nutrient uptake a critical aspect of biotic stress management

**Practical applications: Microbes at work in agriculture**

*Trichoderma* species are widely used to control soil-borne diseases such as root rot, damping off and wilt in crops like tomatoes, cucumbers and peppers. By colonizing the rhizosphere, *Trichoderma* outcompetes pathogenic fungi, reducing diseases incidence and promoting healthier plant growth.

*Bacillus thuringiensis*, a bacterium known for producing insecticidal toxins, is widely used to control caterpillar pests in crops like corn, cotton, and vegetables. Bt- based biopesticides offer an environmentally friendly alternative to chemical insecticides, reducing the reliance on synthetic chemicals in pest management. Mycorrhizal fungi have been shown to improve resistance to pathogens in crops such as wheat, maize, and soybeans by enhancing nutrient uptake and overall plant health. These fungi also help plants tolerate drought and other abiotic stresses, further contributing to crop resilience.



**Limitations**

- Inconsistent Effectiveness: The effectiveness of naturally occurring microbes in managing biotic stress can be inconsistent. Microbial communities in the soil are highly variable, and their effectiveness can depend on factors like soil type, climate, and plant species. This means that the beneficial effects observed in one location or under certain conditions might not be replicable elsewhere.
- Competition with Other Microbes: In natural soil ecosystems, beneficial microbes have to compete with a wide variety of other microorganisms, some of which might be harmful to plants or inhibit the beneficial microbes. This competition can reduce the effectiveness of these naturally occurring microbes in managing biotic stress
- Environmental Sensitivity: Naturally occurring microbes are highly sensitive to environmental changes such as temperature, pH, moisture levels, and nutrient availability. Fluctuations in these factors can alter the microbial community structure and function, potentially reducing the efficacy of biotic stress management
- Specificity of Microbial Interactions: The interactions between microbes and plants are often highly specific. A microbe that benefits one plant species may not be effective, or could even be harmful, to another species. This specificity limits the broad applicability of any single microbe or microbial community for biotic stress management across different crops
- Complex Interactions with Plant Physiology: The interaction between plants and microbes is complex and can be influenced by the plant's own physiology, which can vary widely depending on the plant's genetic makeup, age, and health. This complexity makes it difficult to predict and control the outcomes of using natural soil microbes for biotic stress management

**Conclusion**

Microorganisms such as beneficial bacteria, fungi, and viruses can protect plants against pests and diseases through various mechanisms, including competition, antibiosis, and induced systemic resistance. Beneficial microbes can be used as biocontrol agents directly combat harmful pathogens and pests, effectively serving as natural pesticides. The primary strategy of microbial agents are summarized as antibiosis, competition for micronutrients such as iron, mycoparasitism, production of hydrolytic enzymes, and induction of ISR in host plants. In addition, the production of metabolites that are inhibitory to plant pathogenic rhizosphere microorganisms is considered one of the major biocontrol activities in many microbes. Continued research and development in this field are crucial for optimizing the use of microbes in diverse agricultural settings and ensuring their effectiveness in different crop species and environmental conditions.

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