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Biological Control: Sustainable Application for Pathogen Management

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Plant growth-promoting rhizobacteria (PGPR) are effective against plant pathogens, including fungi, bacteria, viruses, and nematodes, responsible for various crop diseases. While biocontrol mechanisms such as competition and antagonism are used, the induction of systemic resistance in host plants by these rhizobacteria is the most extensively studied. Biological control is a sustainable and effective alternative or complement to conventional pesticides for managing fungal and bacterial plant diseases. Bacterial biocontrol agents (BCAs) utilize a wide range of mechanisms to protect plants from pathogens. BCAs can directly interact with pathogens by secreting antimicrobial compounds, interfering with pathogen virulence, and competing for nutrients and space. Many BCAs produce and release metabolites like lipopeptides, bacteriocins, antibiotics, biosurfactants, cell-wall-degrading enzymes, and microbial volatile compounds that have antimicrobial properties, inhibiting the growth or metabolic activity of pathogens. BCAs can also disrupt the quorum sensing (QS) system of pathogens by enzymatically degrading or inhibiting the synthesis of signal molecules required to initiate infections.

What is Biocontrol?

Biological control, often referred to as biocontrol, is a method of managing pests, diseases, and unwanted organisms in agriculture, forestry, and other settings using natural enemies or beneficial organisms.

The goal of biological control is to achieve disease suppression or management in an environmental friendly and sustainable manner, reducing the reliance on chemical pesticides and promoting ecological balance.

Why Biocontrol is necessary?

a. **Environmental Sustainability:** Chemical pesticides can have negative environmental impacts, including soil and water contamination, harm to non-target species, and disruption of ecosystem balance. Biocontrol methods offer more sustainable and environmental friendly alternatives.
b. **Reduced Chemical Dependency:** Overreliance on chemical pesticides can lead to the development of pesticide-resistant pests and diseases. Biocontrol reduces the need for chemical treatments, helping to slow down the development of resistance.
c. **Preservation of Natural Resources**: Sustainable agriculture aims to preserve natural resources like soil and water. Biocontrol methods align with this goal by minimizing the use of synthetic chemicals, which can harm soil health and contaminate water sources.
d. **Long-Term Effectiveness**: Biological control agents can establish themselves and provide long-term disease management solutions, whereas chemical pesticides may require repeated applications.

e. **Economic Benefits**: In the long run, biocontrol can be cost-effective by reducing the need for expensive chemical inputs and increasing crop yields through sustainable pest management.

Biological Control Agents (BCA)

Biocontrol agents (BCAs) are living organisms used to control diseases in agriculture, forestry, horticulture, and other ecosystems. They offer an environmentally friendly and sustainable method to reduce disease impact. BCAs inhibit soil-borne pathogens and help restore the rhizosphere microbial community.

(a) **Bacteria as biocontrol agents:** Beneficial bacteria enhance plant health by forming biofilms and producing secondary metabolites like surfactin, iturin, bacillomycin, and fengycin, which reduce pathogen populations through interactions in the rhizosphere (Ayaz et al., 2022). They inhibit pathogenic fungi (e.g., *Fusarium*, *Rhizoctonia*, *Alternaria*) by secreting antibiotics, enzymes, siderophores, and HCN, and boost plant immunity by upregulating defense genes. Biocontrol agents such as *Bacillus, Paenibacillus*, *Agrobacterium*, *Pseudomonas*, and *Streptomyces* control diseases in crops (Ayaz et al., 2021). These bacteria also improve soil health, enhance nutrient uptake, and increase stress tolerance in plants. Integrating beneficial bacteria into agriculture can reduce chemical pesticide use and promote ecological balance, offering sustainable disease management solutions.

(b) **Fungi as a biocontrol agent:** Fungi serve as potent biocontrol agents by naturally suppressing plant pathogens and pests, offering an environmentally friendly alternative to chemical pesticides and promoting sustainable agriculture. Fungi produce large quantities of bioactive compounds such as terpenoids, alkaloids, steroids, peptides, isocoumarins, benzopyranones, and quinones that can be utilized as agrochemicals for crop protection. The development of fungal strains as biocontrol agents (BCAs) for plant diseases has garnered significant attention due to their ability to inhibit various plant pathogens (Zubair et al., 2021). Popular fungal genera used as BCAs include *Trichoderma, Aspergillus, and Penicillium*, which are effective against both bacterial and fungal plant diseases. *Trichoderma*, renowned for its broad-spectrum antagonistic activities, has been extensively studied for its direct and indirect control potential against phytopathogens. Direct control involves parasitism and the synthesis of insecticidal compounds, repellent metabolites, and antifeedant chemicals, while indirect approaches include attracting natural enemies, stimulating plant systemic defense mechanisms, and parasitizing insect-symbiotic microbes (Molinari and Leonetti, 2019). *Trichoderma* has demonstrated strong antagonistic potential against more than 80% of plant pathogens, making it a highly effective agent in plant disease management (Degani and Dor, 2021). By reducing disease incidence, enhancing nutrient uptake, and improving overall plant resilience, fungal BCAs support sustainable farming practices by decreasing reliance on chemical inputs and fostering ecological balance.

Mechanism of biocontrol

BCA have biocontrol activity through various mechanisms, including competitive colonization, production of antimicrobials, and/or induction of host systemic defense, antibiosis etc. Rhizobacteria employ both direct and indirect mechanisms to control plant pathogens and promote plant health.

1. **Direct Mechanism** Direct mechanisms of biocontrol agents involve actions that directly target and inhibit pathogens. This includes the production of antimicrobial compounds, such as antibiotics or lytic enzymes, which can directly kill or inhibit the growth of pathogenic organisms. Another direct mechanism is competition for resources, where

biocontrol agents outcompete pathogens for essential nutrients or space, thereby reducing their ability to establish and proliferate.

(a) Antibiosis: Antibiosis refers to the inhibition or destruction of a microorganism by substances produced by another microorganism, including specific or nonspecific metabolites, lytic agents, or enzymes or by the production of specific toxins like antibiotics (Allison et al., 2024). Bacterial species from the *Pseudomonas* and *Bacillus* genera are the most extensively researched for antibiotic production, with a substantial amount of scientific literature available on the subject (Hossain et al., 2017). *Streptomyces, Burkholderia, Serratia, Pantoea, Lysobacter and Enterobacter*

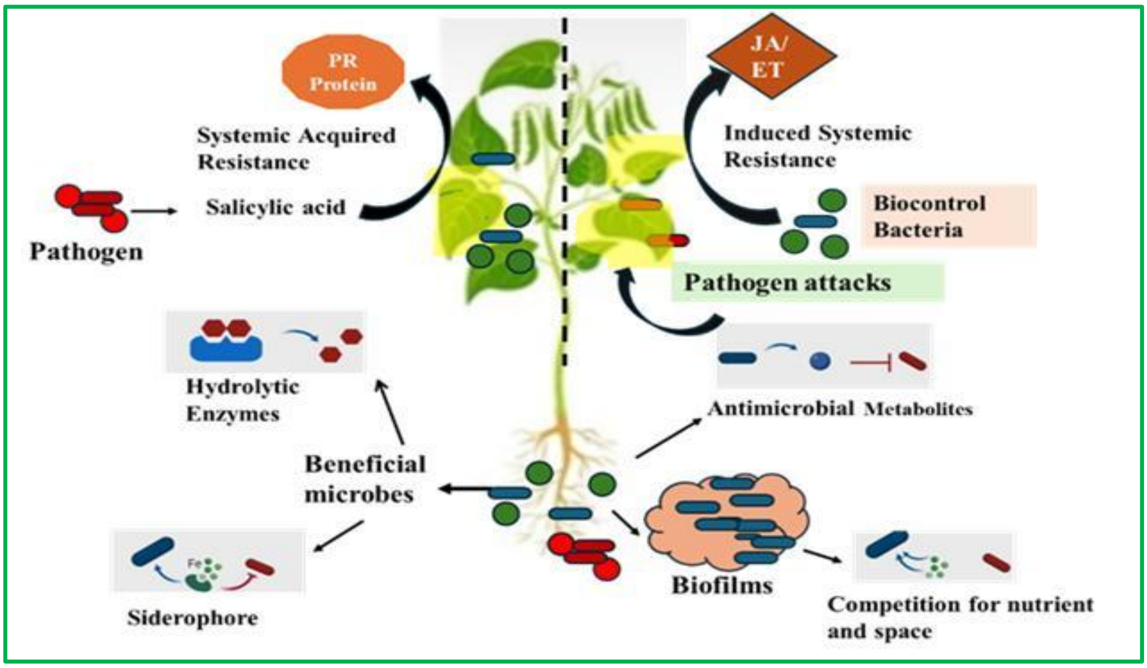

Figure 1. Mechanisms of action of biocontrol agents

(b) Production of Lytic Enzymes: Rhizobacteria produce lytic enzymes that are vital for their biocontrol mechanisms, inhibiting the growth and survival of plant pathogens. These enzymes are crucial for biocontrol activity, as they degrade the cell walls and proteins of plant pathogens, limiting their spread and promoting plant health. The presence of plant pathogens often induces or upregulates the production of lytic enzymes by rhizobacteria. When rhizobacteria detect pathogens or their cell wall components, they may enhance the production of these enzymes as a defense strategy (Lahlali et al., 2020).

Mode of Action:

Enzymatic degradation by rhizobacteria directly weakens and disrupts pathogens by breaking down their cell walls and proteins. Key enzymes involved include:

a. **Chitinases**: These enzymes target chitin in fungal cell walls, leading to the weakening and lysis of fungal cells, thus inhibiting their growth and spread.

b. **Proteases**: Also known as proteinases or peptidases, these enzymes break down proteins, disrupting the pathogen's physiology and reducing its virulence.

c. **Glucanases**: These enzymes degrade β-glucans in the cell walls of fungi and some bacteria, causing the weakening and lysis of fungal cells.

(c) Competition for Nutrients: Beneficial rhizobacteria compete directly with plant pathogens for essential nutrients in the rhizosphere, reducing resource availability for pathogens and limiting their growth. This competition is a key mechanism used by biocontrol agents to protect plants from pathogens.

Siderophore Production: Iron is an essential nutrient for many plant pathogens. The siderophores produced by bacteria bind iron more effectively than the siderophores of many pathogens. *Pseudomonas* spp, *Pseudomonas fluorescens*, *Bacillus subtilis*, *Bacillus methylotrophicus*.

(d) Biofilm Formation: Some biocontrol agents, particularly beneficial bacteria and fungi, use biofilm formation to enhance their effectiveness in protecting plants from pathogens. Biofilms are structured communities of microorganisms surrounded by a self-produced matrix of extracellular polymeric substances (EPS).

2. **Indirect mechanisms-** Biocontrol agents involve interactions with the plant itself to enhance its resistance or health, thereby reducing its susceptibility to diseases. One indirect mechanism is the induction of systemic resistance (ISR), where biocontrol agents trigger the plant's innate defense mechanisms. This can involve signaling pathways that activate defense-related genes, leading to a heightened immune response against pathogens. ISR triggers the plant's own defense mechanisms. ISR represents an eco-friendly and sustainable approach to disease management in agriculture, reducing the need for chemical interventions and promoting plant health. jasmonic acid (JA), and ethylene (ET), play crucial roles in this process. ISR relies on jasmonic acid and ethylene signaling (Yu et al., 2022). Induced systemic resistance (ISR) enhances a plant's defense against various pathogens, triggered locally by beneficial microbes at the roots. Initially observed in *Pseudomonas* species and other Gram-negative root-associated bacteria, ISR was later found to be elicited by *Bacillus* species, such as *B. subtilis* and *B. amyloliquefaciens*, in Arabidopsis, vegetables, tobacco, and tropical crops (Palmieri et al., 2022). SAR (Systemic Acquired Resistance) is mediated through salicylic acid (SA)-signaling pathways. Plant defense responses include thickening cell walls with lignin, depositing callose, accumulating antimicrobial phytoalexins, synthesizing proteins like pathogenesis-related (PR) enzymes such as chitinases and glucanase, and responding to bacterial and fungal elicitors such as lipopolysaccharides and siderophores. Biocontrol agents can also enhance plant health and fitness through mechanisms such as promoting nutrient uptake, improving soil structure, or producing growth-promoting substances like phytohormones. *Pseudomonas* spp., *Pseudomonas brassicacearum, Trichoderma, Sclerotinia sclerotiorum, Pseudomonas fluorescens* (Raymaekers et al., 2020)

References

1. Allison, D. G., & Lambert, P. A. (2024). Modes of action of antibacterial agents. In *Molecular medical microbiology* (pp. 597-614). Academic Press.
2. Ayaz, M., Ali, Q., Farzand, A., Khan, A. R., Ling, H., & Gao, X. (2021). Nematicidal volatiles from Bacillus atrophaeus GBSC56 promote growth and stimulate induced systemic resistance in tomato against Meloidogyne incognita. *International journal of molecular sciences*, *22*(9), 5049.
3. Ayaz, M., Ali, Q., Jiang, Q., Wang, R., Wang, Z., Mu, G., ... & Gu, Q. (2022). Salt tolerant Bacillus strains improve plant growth traits and regulation of phytohormones in wheat under salinity stress. *Plants*, *11*(20), 2769.
4. Degani, O., & Dor, S. (2021). Trichoderma biological control to protect sensitive maize hybrids against late wilt disease in the field. *Journal of Fungi*, *7*(4), 315.
5. Hossain, M. T., Khan, A., Chung, E. J., Rashid, M. H. O., & Chung, Y. R. (2016). Biological control of rice bakanae by an endophytic Bacillus oryzicola YC7007. *The Plant Pathology Journal*, *32*(3), 228.
6. Lahlali, R., Ezrari, S., Radouane, N., Kenfaoui, J., Esmaeel, Q., El Hamss, H., ... & Barka, E. A. (2022). Biological control of plant pathogens: A global perspective. *Microorganisms*, *10*(3), 596.

7. Molinari, S., & Leonetti, P. (2019). Bio-control agents activate plant immune response and prime susceptible tomato against root-knot nematodes. *PloS one*, *14*(12), e0213230.
8. Palmieri, D., Ianiri, G., Del Grosso, C., Barone, G., De Curtis, F., Castoria, R., & Lima, G. (2022). Advances and perspectives in the use of biocontrol agents against fungal plant diseases. *Horticulturae*, *8*(7), 577.
9. Raymaekers, K., Ponet, L., Holtappels, D., Berckmans, B., & Cammue, B. P. (2020). Screening for novel biocontrol agents applicable in plant disease management–a review. *Biological Control*, *144*, 104240.
10. Yu, Y., Gui, Y., Li, Z., Jiang, C., Guo, J. and Niu, D. 2022. Induced systemic resistance for improving plant immunity by beneficial microbes. *Plants*, 11(3): 386.
11. Zubair, M., Farzand, A., Mumtaz, F., Khan, A. R., Sheikh, T. M. M., Haider, M. S., ... & Wu, H. (2021). Novel genetic dysregulations and oxidative damage in Fusarium graminearum induced by plant defense eliciting psychrophilic Bacillus atrophaeus TS1. *International Journal of Molecular Sciences*, *22*(22), 12094.