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Potential Benefits of *Pseudomonas fluorescens* Based Products and Its Application in Agriculture

Samir Kumar Jena*, R. Arutselvan, Nishitha Komal Sahu, Priyanka Priyadarshini and Rashmi Rekha Ray

Regional Centre, ICAR-CTCRI, Bhubaneswar, Odisha (751 019), India

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Corresponding Author

Samir Kumar Jena

e-mail: samirkumarjena14@gmail.com

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E-mail: bioticapublications@gmail.com

Abstract

Pseudomonas fluorescens belongs to Plant Growth Promoting Rhizobacteria (PGPR), is a gram-negative, rod-shaped bacterium. It is the most favoured bioinoculant due to its significant properties in both plant growth and phytopathogen control during its synergistic association with the host plant. These properties include Phyto-hormone production, siderophore production, phosphate solubilization, phenazines production and antibiotics production. The association of *P. fluorescens* with crop plants procures several secretory and electron-based feedback mechanisms in order to regulate the plant growth and phytopathogen control activities through the secretion of several phytohormones (auxins, gibberellins, indole-3-acetic acid), secondary metabolites (flavonoids) and enzymes (aminocyclopropane-1-carboxylate, phenylalanine ammonia-lyase). Ecologically significant applications of *P. fluorescens* in biocontrol and bioaugmentation are crucial for maintaining food security.

Introduction

Pseudomonas fluorescens is a group of common, non-pathogenic saprophytic bacteria that found in soil, water and plant surface environments in colonize form. It is a common gram-negative, rod-shaped bacterium. It belongs to the Pseudomonas genus on the basis of 16s rRNA analysis. It secretes a soluble greenish fluorescent pigment called fluorescein, specifically at low iron availability. It has multiple flagella that's why it is motile. It is an obligate aerobe, but certain strains are capable of using nitrate as an electron acceptor in place of oxygen during cellular respiration. They are known to enhance plant growth promotion and reduce severity of many fungal diseases in the field of agriculture.

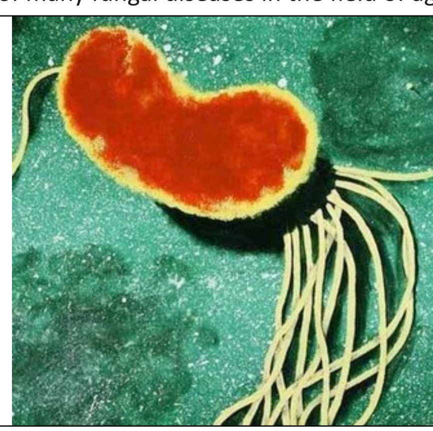

Figure 1: *Pseudomonas fluorescens* bacteria

Benefits

Pseudomonas fluorescens is mostly found in rhizosphere region. They help the plants in many different ways and also get certain nutrients and environmental protection from the plant. They protect the plants from infection by producing secondary metabolites like antibiotic and hydrogen cyanide. They degrade certain toxins and pollutants like styrene, polycyclic aromatic hydrocarbons and TNT. They act like a biopesticide. Not only in the field of agriculture but they are also very helpful to human beings. *P. fluorescens* produce antibiotic mupirocin, which is used in skin, ear, eye creams, ointment and sprays. They also used in certain food products, mostly in the production of yogurt. All around these are beneficial to plant and human (Sah *et al*., 2021).

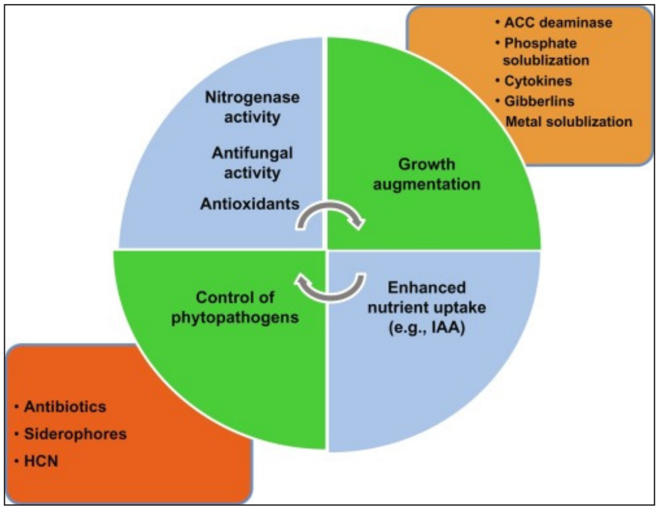

Figure 2: Mechanism of Plant Growth promotion by *Pseudomonas fluorescens*

Application in Agriculture

Phytohormone Production

The plant growth regulators (PGR) are hormones or chemotactic messengers, also known as phytohormones, are actively controlling the environmental stressors through positive (synergism) or negative (antagonistic) associations. This mechanism of communication is called cross-talk signalling. Phytohormone synthesis is linked with production of auxin similar to indole-3-acetic acid (IAA) which act as signalling molecules for regulating plant developmental growth, organogenesis stimulation, cell growth, division, and differentiation. *Pseudomonas fluorescens*, is the most distinguished and active strains which synthesize auxin. A high concentration of L-Trp-corresponds to high IAA production, which inhibits the effective parameters required for plant growth.

Siderophore Production

Siderophores are low molecular weight, water-soluble, organic ligands having affinity towards iron-binding compounds or iron carriers. Iron present as Fe (II) in the native form but, under aerobic conditions, Fe (II) oxidization occurs, leading to its conversion to Fe (III). This form of iron is insoluble, causing iron unavailable for metabolism in living organisms. Siderophores produced majorly by gram-negative bacteria, such as *Pseudomonas fluorescens* possess significant molecular and physiological indication for biocontrol of rhizospheric phytopathogens (Ganeshan *et al*., 2005). Higher production of heterologous siderophores in the rhizospheric *Pseudomonas* sp. through Fe (III) chelation indicates the blocking of other microorganisms with less iron affinity in the rhizosphere. Moreover, the binding of Ferric ion in phytopathogens reduces the competition in the rhizosphere. Pyoverdine is a fluorescent siderophore that symbolizes its function in stimulating plant growth.

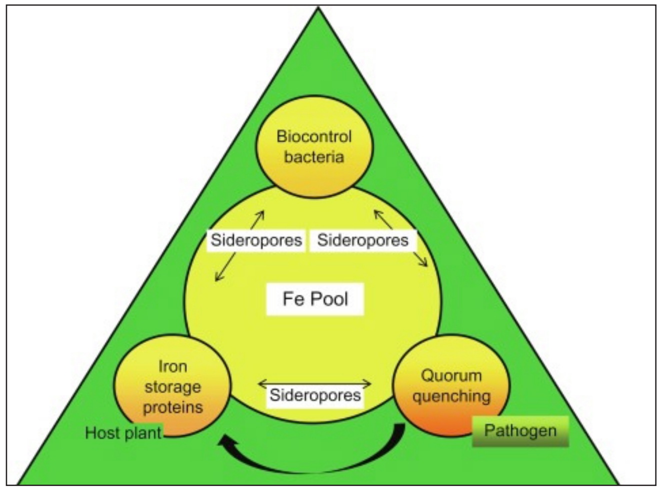

Figure 3: Siderophores production cycle

Phosphate Solubilization

Most of the soils on the Earth are phosphorous deficient and only 1-5% of phosphorous is available for plants. Availability of phosphorous serves as a limiting factor for the plant growth, certain microbes known as phosphate solubilizing bacteria (PSB), have capability to convert insoluble Phosphorous to soluble. *Pseudomonas fluorescens* can produce cyanide as secondary metabolites. This metabolite is crucial as it provides specific benefits to PSB through phytopathogen and disease management. *P. fluorescens* and PGPR mixture in an inoculum shows coupled activity and forms a mutualistic association aiming to increase plant growth (David *et al*., 2018). Therefore, can enhance crop yields by approximately 60-70%, enhancing phosphorus solubilization.

Nitrogen Fixation

Nitrogen fixing ability of member of genus *pseudomonas* is poorly understood. But it can classify the *Pseudomonas* spp. as nitrogen fixers based on their physiological properties, nitrogenase assays, phylogenetic studies and PCR amplification.

Phenazines Production

Phenazines infers as the N_2 bearing heterocyclic compounds with various antibiotic properties. Phenazines are biologically competent and ecologically active. *Pseudomonas fluorescens* are root colonizers actively producing phenazine molecules to suppress fungal disease in plants. The expression of the phz gene (phenazine) determines the root development and responds to the exogenous nutrients. The mechanism of action of phenazines in antifungal interactions is a due to genetic interactions and signalling mechanism for cell density-dependent regulation. The phzR encodes a transcriptional activator inducing the expression of phenazines in response to phzI production. Numerous *Pseudomonas* strains are sold commercially as biocontrol agents due to their self-regulation capabilities in the seed treatment to treat the seed-borne pathogens through phenazine production.

Antibiotics Production

Antibiosis through antibiotics and bacteriocins signifies the well-known biocontrol mechanism. *Pseudomonas fluorescens* inhibit various rhizobacterial microbes by producing various antibiotics on roots in the rhizosphere. The strain migula F113 of *Pseudomonas fluorescens* shows the control of soft rot disease in potato plants through DAPG production. A mutant with rifampicin resistance, *Pseudomonas fluorescens* strain NBRI1303R, observed to control phytopathogen through rapid root colonization. These types of mutations are found to be beneficial for the development of more effective biocontrol agents.

Conclusion

Environmental and consumer concerns have focused interest on the development of biological control agents as an alternative, environmentally-friendly strategy for the protection of agricultural crops against Phyto-pathogens. *Pseudomonas fluorescens* is one such proven biological control agent. Many success reports by several scientists around the world have described different Pseudomonas strains able to significantly control a number of fungal, bacterial and nematode diseases in cereals, horticultural crops, oil seeds and others. The efficacy of bacterial antagonism in controlling diseases was often better than with fungicides. However, the bacterial antagonism in combination with fungicides sometimes improved efficacy in controlling diseases. Besides disease control, treatments also improved seedling health and yields of crops. Polysaccharides enhanced the adhesion of *P. fluorescens S272* which promoted plant growth through increased antibiotic activity.

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