



## Biological Control of Plant Parasitic-Nematodes by Plant Growth Promoting-Rhizobacteria

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### Abstract

Plant growth promoting-rhizobacteria (PGPR) contributes a significant part in crop health improvement including pest management. It also protects plants from parasitic nematodes damage by exhibiting biocontrol activity besides improving the growth of plants by supplying nutrients, producing phytohormones and inducing modification of plants metabolisms. PGPR decreases or inhibits the hatching of nematode juveniles and suppresses the nematodes development and reproduction by exhibiting various mechanisms such as hyperparasitism, antibiotic synthesis or antibiosis, substrate competition, synthesis of lytic enzymes and induction of resistance in plants. Hence, PGPR could be an efficient biological protective agent that protects agricultural and horticultural crop plants from the infestation of parasitic nematodes.

**Keywords:** Biocontrol, PGPR, Plant health, Plant parasitic-nematodes

### Introduction

More than 4000 species of plant parasitic-nematodes (PPNs) have been reported worldwide, which are polyphagous to cause extensive damage in agricultural and horticultural important crops such as tomato, maize, potato, etc. Some of the PPN species include *Meloidogyne* sp., *Bursaphelenchus* sp., *Heterodera* sp., *Aphelenchoides* sp., *Globodera* sp., *Radopholus* sp. and *Pratylenchus* sp., which can cause a severe economic loss of yield of crops. One of the best effective methods to control PPNs by chemical means using nematicides, which led to environmental pollution and cause health complications in humans.

The soil-inhabiting bacteria are attracted towards the rhizosphere region by chemotaxis and colonize on the roots of plant under the influence of rhizodeposition. This rhizosphere colonizing bacteria involved in improving growth and fitness of plants termed as plant growth promoting-rhizobacteria (PGPR). Therefore, the utilization of PGPRs in crop production system is the best substitute for eliminating the deleterious effects created by improper practice of

synthetic fertilizers, chemicals and pesticides.

The diverse and well-established benefits of PGPR on plants are widely recognized. PGPR play a pivotal role in regulating plant development and enhancing yield through multifaceted mechanisms. These include the synthesis of essential plant chemicals, such as growth hormones, facilitating plant resistance against pathogens and improving the uptake of minerals from the soil. Furthermore, PGPR contributing to the enhancement of plant health through their ability to counteract disease-causing microbes and exhibition of antibiotic-producing properties, thus earning the designation of health-promoting rhizobacteria. The rhizosphere's bacterial community structure is altered by inoculating our targeted bio-inoculants to the rhizosphere onto seed treatment or soil application and helps them thrive. Some of these predominant rhizobacteria includes *Rhizobium*, *Bradyrhizobium*, *Bacillus*, *Frankia*, *Paenibacillus*, *Pseudomonas*, *Brevibacillus*, *Flavobacterium*, *Serratia*, *Azospirillum*, *Streptomyces* and *Burkholderia* are found to exhibits biocontrol activity against PPNs (Xiang *et al.*, 2017).

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## Mechanisms of PPNs Control

### Direct Mechanisms

#### Nitrogen Fixation

PGP nitrogen-fixing rhizobacteria (both symbiotic and free-living nitrogen-fixing bacteria) supplies nitrogen to plants by fixing atmospheric N<sub>2</sub> to ammonia, which is crucial for protein and nucleic acid synthesis as well as the photosynthesis of plants. Also, nitrogen-fixing rhizobacteria exhibiting nematicidal activity (Gowda *et al.*, 2022).

#### Phytohormones Formation

Moreover, PGPR contribute to improved plant growth, development and metabolism, moreover to induction of systemic resistance in plants to various stresses. They achieve this by producing a wide range of plant growth-stimulating chemicals, including phytohormones of auxins, abscisic acid, gibberellic acid, ethylene, brassinosteroids, polyamines, jasmonates, strigolactones and salicylic acid. These substances play crucial roles in promoting processes such as elongation, cell division, tissue expansion and facilitating plant-bacterial interactions. Overall, the occurrence of PGPR can have the insightful impact on plant physiology and enhance their ability to cope with environmental challenges.

#### Phosphate and Potassium Solubilization

Knowingly, PGPR solubilizes insoluble inorganic phosphate available in the soil and makes it accessible to the plants by producing iron chelating agents (*e.g.*, siderophores) and organic acids that increase plant growth by prompting cell division, tissue growth, nucleic acid formation, complex energy conversion, protein synthesis, *etc.* Additionally, PGPR increases the bio-availability of required phosphate to the plants by mineralization. Potassium solubilizing PGPR solubilizes insoluble form of potassium and makes them accessible to plants by using chelation of irons, organic acid production, reduction, hydrolysis and iron exchange properties (Gowda *et al.*, 2022).

#### Siderophores/ Ammonia Production

Siderophores, iron chelating agent is a low molecular weight compound released by PGPR that binds the insoluble

form of iron available in the soil and is transported into the cells of plants. Iron plays a significant role in electron transport, photosynthesis, respiration and cofactor of numerous enzymes. Additionally, ammonifying PGPR reduces nematode population with generating ammonia by decomposing nitrogenous related organic compounds.

### Indirect Mechanisms

#### Hyperparasitism

It is one of the prime mechanisms of antagonism against nematode by PGPR, which grows on, attacks and disintegrates the cell wall or cell membrane of targeted organisms through enzyme action.

#### Antibiotic Synthesis/ Antibiosis

Several PGPR produces low molecular weight chemical compounds such as secondary metabolites, metabolic by-products, enzymes and toxins of hydrogen cyanide and 2,4-di-acetyl-phloroglucinol that inhibits nematode juveniles hatching, suppresses the development, reproduction and survival, as well as kills the nematodes (Table 1). Moreover, PGPR produces 3,3-di-methyl octane and 2,4-di-tert-butylphenol, which inhibits nematode development (Gowda *et al.*, 2022).

#### Substrate Competition

Health-promoting plant rhizobacteria inhibits PPNs by creating competition and parasitism in the rhizosphere region.

#### Lytic Enzyme Production

Enzymes like  $\beta$ -glucanase, lipase, chitinase, chitosanase, gelatinase and protease, produced by PGPR could decrease nematode incidence by inhibiting the hatching of nematode juveniles. Moreover, it enhances the growth of plants by procuring phenylalanine ammonia lyase, dehydrogenase, peroxidase and phosphatases (Subedi *et al.*, 2020).

#### Induction of Plant Resistance

PGPR effectively decreases the population of PPNs by augmenting the plant's induced systemic resistance (ISR) through the activation of multiple defense enzymes associated with systemic resistance. These enzymes include

Table 1: Beneficial mechanisms of PGPR on PPNs bio-control

Nematode	PGPR	Beneficial Effects of PGPR
<i>Meloidogyne sp.</i> , <i>Xiphinema sp.</i> , <i>Bursaphelenchus sp.</i>	<i>Bacillus sp.</i>	ISR, production of lipases, protease, chitinase, Bt crystal protein (toxin), hydrolytic enzymes, antibiotics, secondary metabolites, siderophores.
<i>Meloidogyne sp.</i>	<i>Pasteuria sp.</i>	Predation.
<i>Meloidogyne sp.</i> , <i>Globodera sp.</i>	<i>Pseudomonas sp.</i>	Antibiotic production, chitinase, protease, sphingosine, hydrogen cyanide, siderophores, 2,4-di-acetylphloroglucinol (DAPG) production, ISR and SAR (systemic acquired resistance).
<i>Meloidogyne sp.</i>	<i>Serratia sp.</i>	ISR and chitinase, protease sphingosine, antibiotic production.
<i>Meloidogyne sp.</i>	<i>Rhizobium sp.</i>	ISR.
<i>Bursaphelenchus sp.</i>	<i>Brevibacillus sp.</i>	Proteases activity.
<i>Aphelenchoides sp.</i>	<i>Photorhabdus sp.</i>	Toxin A & B and antibiotics production.

superoxide dismutase, polyphenol oxidase, peroxidase, catalase, lipoxygenase, chitinase, phenylalanine ammonia-lyase,  $\beta$ -1,3-glucanase, ascorbate peroxidase and proteinase. The existence of these enzymes initiates the process of inducing resistance by producing phenolic chemicals and phytoalexins, which contribute to the plant's ability to defend itself against nematode infestations (Aioub *et al.*, 2022).

### Conclusion

PGPR safeguards plants against parasitic-nematodes while simultaneously augmenting plant growth, health and nutrition through a range of mechanisms. These include nitrogen fixation, the synthesis of phytohormones, phosphate and potassium solubilization, siderophores and ammonia production, hyperparasitism, antibiosis, lytic enzyme production and the induction of resistance in plant system. Consequently, the utilization of PGPR in agriculture offerings a favourable method to effectively control PPNs and serves as an integral component of an integrated pest management system.

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