

Rhizobacteria: Sustainable pathway

for legume production

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Pulses are crucial for global food security and sustainable agriculture. Enhancing their yield sustainably using multifunctional rhizobacteria offers an eco-friendly solution. These helpful microbes increase pulse/legume productivity in a number of ways, such as by fixing nitrogen, solubilizing phosphate, producing plant hormones, and controlling infections. They lessen reliance on chemical pesticides and fertilizers by enhancing soil health, increasing nutrient availability, and enhancing plant stress tolerance, thereby, promoting sustainable pulse production and global food and nutritional security through ecologically friendly production technology.

Keywords: Eco-friendly, Food security, Legume and productivity, Multifunctional rhizobacteria

PULSES are small, nutrient-dense foods with high protein levels, complex carbohydrates, micronutrients, and B-vitamins. They are essential for a balanced diet, low in fat, high in fiber, and beneficial for cholesterol management, digestive health, and energy levels. They are rich in folate, iron, calcium, magnesium, zinc, and potassium (FAO 2016). Pulses enhance soil fertility through biological nitrogen fixation, reducing synthetic fertilizer use. Nutrients in pulses improve seed yield, with nitrogen being crucial for legumes as it is the primary amino acid and protein component. Pulses, through symbiosis with soil rhizobia, can fix atmospheric nitrogen in their root nodule, enabling them to produce effectively in nitrogen-deficient soils. Seed inoculation with multifunctional rhizobacteria, viz. *Rhizobium*, *Bacillus*, *Pseudomonas* etc. could increase pulse production while lowering production costs with mineral fertilisation and protecting the environment.

Multifunctional rhizobacteria

Multifunctional rhizobacteria, commonly known as plant growth-promoting rhizobacteria (PGPR) are microorganisms capable of thriving independently in the rhizosphere, establishing symbiotic relationships with plants, and colonizing their internal tissues as endophytes in the soil in the absence of leguminous crops. Artificial seed inoculation is often needed to restore effective

strains and accelerate N-fixation. Bacteria are known to enhance plant growth by improving root system development, thereby providing greater access to nutrients and water. Rhizobacteria facilitate growth through biological nitrogen fixation, phosphate solubilization, siderophore production, and the synthesis of growth-promoting compounds like phytohormones.

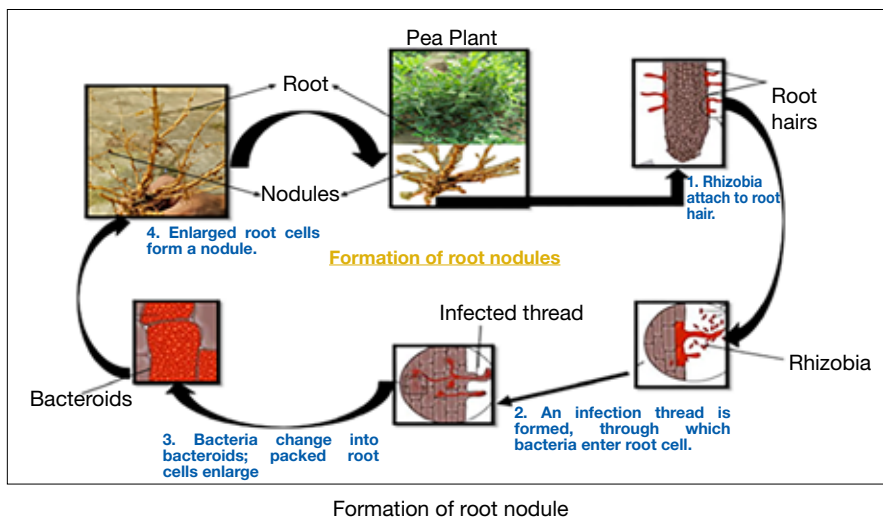


Table 1. Cross-inoculum group of rhizobia

Cross-inoculum group	Name of crops
<i>Bradyrhizobium japonicum</i>	Soyabean
<i>Rhizobium meliloti</i>	Alfa-alfa, Sweet clover, Fenugreek
<i>Rhizobium trifolii</i>	<i>Trifolium</i> spp.
<i>Rhizobium leguminosarum</i>	Pea, Faba-bean, Lentil
<i>Rhizobium phaseoli</i>	Beans
<i>Rhizobium lupini</i>	Lupine, Ornithopus

Role of multifunctional rhizobacteria

N fixation: Prokaryotes convert atmospheric nitrogen into ammonia, which is absorbed by plants to create nitrogen-containing biomolecules, a process known as biological nitrogen fixation (BNF). The prokaryotes involved in BNF include aquatic cyanobacteria, free-living soil bacteria like *Azotobacter*, plant-associated bacteria such as *Azospirillum*, and symbiotic bacteria like *Rhizobium* and *Bradyrhizobium*, which form partnerships with legumes and other plants. *Rhizobium* and *Bradyrhizobium* microorganisms enhance nitrogen fixation in legume seeds and soils, promoting plant growth, improved crop yields, and reduced nitrogen fertilizer usage, contributing to sustainable agriculture.

Phosphate solubilization: Phosphorus solubilization is a crucial mechanism by which multifunctional rhizobacteria promote plant growth and soil fertility. These bacteria, known as phosphate-solubilizing microorganisms (PSMs), convert insoluble phosphorus compounds into plant-absorbable forms like orthophosphate. They secrete organic acids like citric and gluconic acid, which chelate metal ions bound to phosphate or lower the pH of the rhizosphere, releasing phosphorus from its insoluble complexes.

Potassium solubilizing bacteria: Phosphate-solubilizing microorganisms (PSMs) convert

Table 2. Examples of plant nutrition substances secreted by PGPR that promote growth

PGPR strains	Plants	Growth substances
<i>Acinetobacter</i> spp.	Alfalfa (<i>Medicago sativa</i> L.)	IAA, phosphate solubilization, and siderophores
<i>Bradyrhizobium</i> spp.	Chickpea (<i>Cicer arietinum</i> L.)	HCN, IAA, ammonia, siderophores, and exo-polysaccharides
<i>Enterobacter</i> spp.	Pigeon pea (<i>Cajanus cajan</i>)	Phosphate solubilization and ACC deaminase, IAA, and siderophores
<i>Flavobacterium</i>	Common bean (<i>Phaseolus vulgaris</i> L.)	IAA and siderophores

insoluble potassium compounds into plant-absorbable forms. They secrete organic acids, produce enzymes, and release potassium from insoluble complexes.

Siderophore production: Siderophores, produced by rhizobacteria, are essential for microbial and plant growth, and aid bacteria in iron-deficient conditions and enhance plant health. They also serve as biocontrol agents, competing with soil-borne pathogens for iron, inhibiting harmful microbe growth, and protecting plant roots.

Synthesis of growth-promoting hormones: Rhizobacteria, multifunctional bacteria, significantly enhance plant growth by synthesizing essential phytohormones like auxins, cytokinins, and indole-3-acetic acid (IAA). These beneficial bacteria interact with plant roots, promoting

growth and development. Auxins, like IAA, regulate cell elongation, division, and differentiation, improves root architecture and nutrient uptake. Cytokines, like *Rhizobium* and *Azotobacter*, promote cell division, shoot initiation, and delay leaf senescence, boosting plant vitality. The phytohormone IAA enhances root system modification, lateral root formation, and root hair development, improving soil resource access, coping with abiotic stresses, and promoting sustainable agricultural practices by reducing chemical fertilizer dependence.

Impact of rhizobacteria on growth and yield of pulses

Rhizobacteria enhance pulse yields by fixing nitrogen, solubilizing nutrients, and producing growth hormones, improving plant nutrition and growth, resulting

Table 3. Examples of rhizobacteria that support plant growth and enhance productivity of pulses

PGPR strains	Plants	Role in plant growth and development
<i>Pseudomonas</i> spp.	Mung bean (<i>Vigna radiata</i>)	The plant dry weight, nodule count, total chlorophyll content, leghaemoglobin levels, nitrogen content in both roots and shoots, phosphorus in the roots and shoots, seed yield, and seed protein content were all considerably higher.
<i>Pseudomonas</i> spp.	Soybean (<i>Glycine max</i> L.)	There has been a significant increase in enzyme activity, soil productivity, and nitrogen absorption.
<i>Rhizobium phaseoli</i>	Mung bean (<i>Vigna radiata</i> L.)	Tryptophan assisted <i>Rhizobium</i> in reducing the harmful effects of salt, while also promoting increased plant height, nodule density, biomass, grain yield, and nitrogen content in the grain.
<i>Bacillus PSB10</i> spp.	Chickpea (<i>Cicer arietinum</i>)	There was a notable increase in seed yield, nodulation, chlorophyll content, leghemoglobin, and grain protein, along with a reduction in chromium absorption in the roots, shoots, and grains.



in 20–40% increase of pulses productivity. Rhizobacteria enhance pulse crop health by suppressing pathogens and improving soil structure. This promotes sustainable agricultural practices, reduces synthetic fertilizers and pesticides, and increases crop productivity, benefiting both the environment and human health.

SUMMARY

Native rhizobial populations might be unable to establish a successful symbiotic relationship in the field because of their small numbers and unfavourable soil conditions. In such scenario, native rhizobium bacteria and introduced multifunctional rhizobacteria often work in concert to promote faster plant growth, development, and


yield. Furthermore, co-inoculating pulses with multifunctional rhizobacteria and *Rhizobium* improves nodulation as well as growth, development and yield of pulses.

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Pages : i-xxxiv + 1-682 (Vol. 1)
i-xxiii + 683-1218 (Vol. 2)

Price : ₹ 2000/- (Vol.1 & 2) Postage ₹ 200/-

ISBN : 978-81-7164-187-1

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