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Role of Bacterial Biofertilizers in Agriculture for Prevention of Plant Disease

Patil L. P.[1], Navasare M. G.[1], Kambale O. S.[1], Jagtap G. P.[2]
[1]M.Sc., Department of Plant Pathology, College of Agriculture, Badnapur, (M.S.)
[2]Associate Professor, Plant Pathology, NARP, Aurangabad, (M.S.)

SUMMARY

Many rhizospheric bacterial strains possess plant growth-promoting mechanisms. These bacteria can be applied as biofertilizers in agriculture, enhancing crop yields. Bacterial biofertilizers can improve plant growth through several different mechanisms: the synthesis of plant nutrients or phytohormones, which can be absorbed by plants, the mobilization of soil compounds, making them available for the plant to be used as nutrients, the protection of plants under stressful conditions, thereby counteracting the negative impacts of stress, or defense against plant pathogens, reducing plant diseases or death. Several plant growth-promoting rhizobacteria (PGPR) have been used worldwide for many years as biofertilizers, contributing to increasing crop yields and soil fertility and hence having the potential to contribute to more sustainable agriculture. This article summarizes the main bacterial mechanisms for improving crop yields and prevention of plant diseases.

INTRODUCTION

Plant growth-promoting rhizobacteria (PGPR) are naturally-occurring soil bacteria able to benefit plants by improving their productivity and immunity. These bacteria are associated with the rhizosphere, the part of soil under the influence of plant roots and their exudates. According to their interactions with plants, PGPR can be divided into symbiotic bacteria, which live inside plants and exchange metabolites with them directly, and free-living rhizobacteria, which live outside plant cells. Most symbiotic bacteria live in the intercellular spaces of the host plant, but there are some bacteria able to form truly mutualistic interactions with their hosts and penetrate plant cells. Moreover, some of them are able to integrate their physiology with the plant, resulting in the formation of specialized structures. The best known mutualistic symbiotic bacteria are the rhizobia, which establish symbiotic associations with leguminous crop plants, fixing atmospheric nitrogen for the plant in certain root structures known as nodules. Other examples of mutualistic bacteria associated with plants are *Frankia,* which induces the formation of nodules in actinorrhizic plants, such as *Alnus*trees, where bacterial nitrogen fixation takes place. Several PGPR have been used worldwide as biofertilizers, contributing to increasing crop yields and soil fertility and hence with the potential to contribute to more sustainable agriculture. This article summarizes the main mechanisms of the bacteria able to improve crops yields concerning the role of bacterial biofertilizers in agriculture.

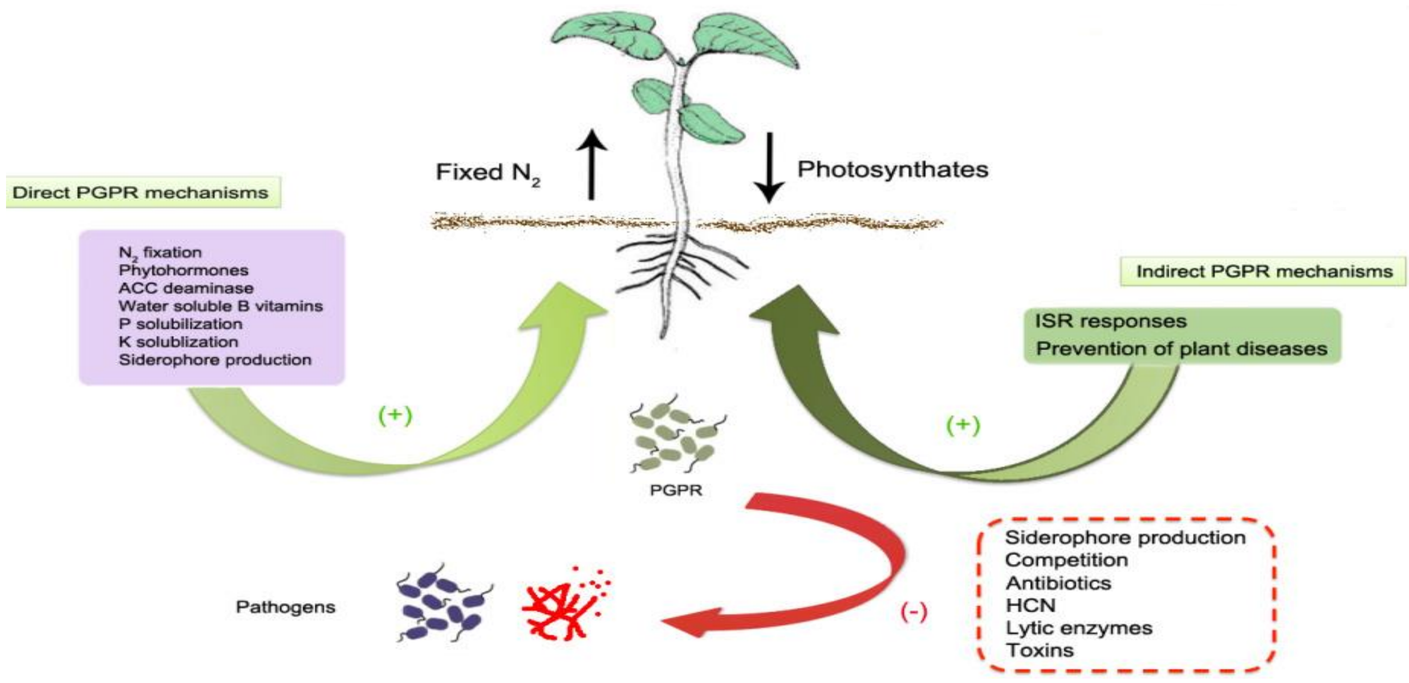

Fig.1. Mechanisms of Plant Growth-Promoting Rhizobacteria (Source: Paula *et al*. 2015)

Mechanisms of Plant Growth-Promoting Rhizobacteria

Rhizobacteria can promote plant growth through a broad variety of mechanisms (Table 1), which can be grouped according to their mode of action in:

- The synthesis of substances that can be assimilated directly by plants,
- The mobilization of nutrients,
- The induction of plant stress resistance.
- The prevention of plant diseases

Table 1. Plant-Growth Promotion Mechanisms by Rhizo Bacteria

PGPR	PGPR Mechanisms	Crops
Azobacter	Cytokinin synthesis	Cucumber
Azospirillum	Nitrogen fixation	Cereals, rice, sugar cane
Azotobacter	Nitrogen fixation	Wheat, barley, oats, rice, sunflowers, maize, line, beetroot, tobacco, tea, coffee and coconuts
Bacillus	Induction of plant stress resistance	Maize, peanuts
Bacillus	Siderophore production	Maize, pepper
Beijerinckia	Nitrogen fixation	Sugar cane
Mycobacterium	Induction of plant stress resistance	Maize
Pseudomonas	Induction of plant stress resistance	Cotton, Maize
Pseudomonas	Chitinase and β-glucanases production	Pigeon pea
Rhizobium	Nitrogen fixation	Rice

Prevention of Plant Diseases

The mechanisms of bacterial plant disease prevention may be direct, if pathogens are inhibited as a result from PGPR metabolism, or indirect, when the bacteria compete with the pathogens, reducing their ability to induce disease. Some PGPR synthesize antibiotic substances, that inhibit the growth of some plants pathogens. For instance, *Pseudomonas* sp. produces antibiotics that inhibit *Gaeumannomycesgraminis* var. tritici, the causal agent of of wheat. Most *Bacillus* spp. produce antibiotics that are active against Gram-positive and Gram-negative bacteria, as well as many pathogenic fungi. *B. cereus* UW85 contributes to the biocontrol of alfalfa damping-off. Cyanogenic compounds are nitrogen-containing compounds that have been shown to repel leaf-chewing herbivores. Rhizobia-legume symbioses have been demonstrated to enhance the resistance of plants to herbivore attack. Presumably, an additional nitrogen provided by the bacterium allows the plant to synthesize cyanogenic defense compounds. Since chitin and β-glucan are the major fungal cell wall components, bacteria producing chitinases and β-glucanases inhibit fungal growth. Finally, the presence of PGPR in the rhizosphere and rhizoplane might prevent plant diseases by competing for available nutrients, reducing the contact surface between the pathogen and the plant root or by interfering with the mechanisms leading to plant disease.

CONCLUSIONS

As long as the human population continues to increase the world will have to deal with an escalating demand for food. Seventy years ago, the Green Revolution increased agricultural production worldwide, saving about one billion people from starvation and under nourishment, and was founded on the development of chemical fertilizers, along with other advances. The synthesis of chemical biofertilizers consumes enormous amounts of energy, around 1% of the total energy consumption of the world, contributing heavily to climate change. However, their application in the field has an efficiency of just 60–70% and it has been shown that they produce negative effects on human health and the environment. Therefore, the development of a more efficient and sustainable agriculture, guaranteeing food supply for an expanding world population and minimizing damage to the environment, is one of the greatest challenges for humankind today. Promotion of the use of PGPR is one possible way to achieve the goal. Most soils are well inoculated with the organisms involved in the general decomposition processes taking place there. However, the inoculation of soils with special-purpose microorganisms can increase plant growth. The studies showing that bacteria can improve crop yields in agriculture, through many and diverse mechanisms. PGPR bacteria promote plant growth not only by supplying nutrients to the plant, but also by producing phytohormones, inducing stress resistance, or preventing pathogen-induced plant diseases. Thus, the development of the biofertilizer market and the promotion of bacterial inoculations in the field is an environmentally friendly way to meet the worldwide need to raise crops yields. Consumers demand more and more organic food, and most countries have developing policies to reduce the use of chemical fertilizers. As a result, the commercialization and application of bacterial biofertilizers on agricultural fields are increasing year by year. Nevertheless, their use is still far from that of chemical fertilizers. Demand from farmers is one of the most critical steps required for the promotion of biofertilizers. Farmers may be undecided as to whether they should adopt new technologies or trust biofertilizer efficiency. Therefore, governmental and international policies promoting this type of farming are needed urgently. Also, coordinated work by bacteriologists, chemists, geneticists, agronomists and farmers could allow the adaptation of bacterium-based biofertilizers to the different agricultural systems by making them more efficient in the field. Consortia of various organisms with different benefits for crops can be integrated to combine different microbial capabilities into one product with several yield-promoting effects. Research into the mechanisms of plant growth promotion by PGPB have provided a greater understanding of the multiple facets of disease suppression by these biocontrol agents. Still, most of the focus has been on free-living rhizobacterial strains, especially to *Pseudomonas* and *Bacillus*.

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