

## The Plant Healthy and Safety Guards Plant Growth Promoting Rhizo Bacteria (PGPR)

Jian Hua Guo\*, Chun Hao Jiang, Ping Xie, Zi Yang Huang and Zhi Hang Fa

Department of Plant Pathology, College of Plant Protection, Nanjing Agricultural University, Republic of China

### Abstract

Plant growth is influenced by a variety of abiotic and biotic factors. To survive a Complex and hostile environment, plants have evolved a series of inducible defense Mechanisms that enable them to activate appropriate defense responses upon Pathogen and abiotic stress factors attacking. Besides, rhizosphere bacteria also play a very important role in maintaining healthy plant growth process, such as PGPR strains. Bacteria that colonize plant roots and promote plant growth are referred to as plant growth-promoting rhizo bacteria (PGPR). As the name suggests, PGPR strains have a strong role in promoting the growth of plants in different ways. In addition, they also can help plants resist external environmental stress, such as pathogens, pest, and Abiotic stress. Their effects can occur via directly antagonism to pathogens or by induction of systemic resistance against pathogens, agricultural pest or abiotic stress throughout the entire plant. There have also been a number of studies in recent years aimed at understanding of how the PGPR strains promote the plant growth and help plant survive in the soil. In this article, we review the function and the mechanisms of PGPR in regulation plant growth and fighting with the environment.

**Keywords:** Plant growth-promoting rhizobacteria; Induced systemic resistance; Abiotic stress tolerance; Bio control

### Introduction

Plant growth promoting rhizobacteria (PGPR) are soil bacteria with some beneficial effects on soil properties, plant growth and the environment. PGPR term was coined for the first time by Kloepper and Schroth to describe this microbial population in the rhizosphere which is beneficial, colonize the roots of plants and shows plant growth promotion activity [1,2]. So far, serials of studies have shown that the PGPR strains not only can promote the plant growth, but also can help plants resist the harsh external environment. For example, various species of bacteria like

*Azotobacter*, *Klebsiella*, *Pseudomonas*, *Burkholderia*, *Bacillus*, *Serratia*, *Azospirillum*, *Enterobacter*, *Alcaligenes* and *Arthrobacter*, have been reported to enhance the plant growth and control some disease [3-7]. There have also been a number of studies in recent years aimed at understanding of how the PGPR strains promote the plant growth and help plant survive in the soil. The main aim of this review is to understand the role and mechanism of PGPR in crop protection.

### The plant growth promotion by PGPRs

Plant growth promoting rhizobacteria are beneficial soil bacteria that colonize plant roots and enhance plant growth promotion activity by different mechanisms in various ways [1]. For instance, PGPRs can solubilize insoluble inorganic phosphate for plant uptake. Nautiyal et al. [8] have reported the ability of different bacterial species to solubilize insoluble inorganic phosphate compounds such as dicalcium phosphate, tricalcium phosphate, rock phosphate and hydroxyapatite [8]. Some kinds of PGPRs also can fixate the nitrogen for plant using. Graham et al. [9] reported that *Azospirillum*, *Cyanobacteria*, *Azoarcus*, *Azotobacter*, *Acetobacter diazotrophicus* etc. are the examples of symbiotic nitrogen fixing forms [9]. Plant growth and development is also regulated by phytohormone. Phytohormones, such as auxins and cytokine production by PGPRs have been reported by many researchers. De Salamone et al. [10] reported that *Pseudomonas fluorescens* which was isolated from the rhizosphere of soybean can produce cytokinins [10]. Some studies mentioned that volatile organic compound (VOC) produced by PGPRs could promote the growth of plant. Two compounds, 3-hydroxy-2-butanone (acetoin) and 2,3-butanediol, isolated from *Bacillus subtilis* GB03 and *Bacillus*

*amyloliquefaciens* IN937a, shown significant growth promotion to *Arabidopsis* [11]. Meanwhile, serials of questions arised spontaneously, how the volatile organic compound perceived by plant and promote the plant growth? And which kind signaling pathways were activated during these processes. Beside this, PGPRs also can modulate the population of Rhizobacteria of around the root of plant. This is also one kind of main reason why the PGPR could promote the growth of plant.

### PGPR as a bio control agent

PGPR as a bio control agent to protect plant in two different ways, they are indirectly or directly respectively. For the directly, they can produce serials kinds of compounds which have the antagonistic activities, such as siderophores, bacteriocins, and antibiotics [1]. As we all known, siderophores, bacteriocins and antibiotics are three of the most effective and well-known mechanisms that an antagonist can employ to minimize or prevent phyto-pathogenic proliferation [1]. Hundreds of siderophores have been identified and reported for cultivable microorganisms, some of which are widely recognized and used by different microorganisms, while others are species-specific [12,13]. While, Antibiotics, such as polymyxin, circulin and colistin, produced by the majority of *Bacillus* ssp. Are active against Gram-positive and Gram-negative bacteria, as well as many pathogenic fungi [14]. The *B. cereus* UW85 strain, which suppresses *oomycete* pathogens and produces the antibiotics zwittermicin A (aminopolyol) and kanosamine (aminoglycoside), contributes to the bio- control of alfalfa damping off [15,16]. Other molecules used in microbial defense systems are bacteriocins. Almost all bacteria may make at least one bacteriocin, and sometimes they show broader spectra of inhibition [17,18]. But

**\*Corresponding author:** Jian Hua Guo, Department of Plant Pathology, College of Plant Protection, Nanjing Agricultural University, Engineering Center of Bio resource Pesticide in Jiangsu Province, Key Laboratory of Monitoring and Management of Crop Diseases and Pest Insects, Ministry of Agriculture, Nanjing 210095, People's Republic of China, Tel: 86 2584395366; E-mail: [jhguo@njau.edu.cn](mailto:jhguo@njau.edu.cn)

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right now, the urgent questions, which were needed to answer, would be how the synthetic pathway of these substances and regulatory genes function on the synthesis process. While, for the indirectly, PGPRs can induce systemic resistance to pathogens in plants.

### Induced systemic resistance (ISR)

Non-pathogenic rhizobacteria have been shown to suppress disease by inducing a resistance mechanism in the plant called “Induced Systemic Resistance” (ISR) [19,20]. ISR has been demonstrated in many plant species (e.g. bean [*Phaseolus vulgaris*], carnation [*Dianthus caryophyllus*], cucumber [*Cucumis sativus*], radish [*Raphanus sativus*], tobacco [*Nicotiana tabacum*], tomato [*Solanum lycopersicum*], and the model plant *Arabidopsis* [*Arabidopsis thaliana*]), and is effective against a broad spectrum of plant pathogens, including fungi, bacteria, viruses, and even insect herbivores [19,21]. The rhizobacterial strain *Pseudomonas fluorescens* WCS417r (WCS417r thereafter) has been shown to trigger ISR in several plant species [22]. In *Arabidopsis*, WCS417r elicits ISR against a variety of plant pathogens such as bacterial leaf pathogens *Xanthomonas campestris* pv *armoraciae* and *Pseudomonas syringae* pv *tomato* DC3000 (Pst DC3000), the fungal leaf pathogen *Alternaria brassicicola*, the oomycete leaf pathogen *Hyaloperonospora parasitica*, and the fungal root pathogen *Fusarium oxysporum* sp. *Raphani* [21,23]. Previous studies had shown that PGPRs induced systemic resistance by activating the signaling pathways in plants, such as SA, JA- or ET- signaling pathways. Different PGPR triggered ISR depended on different pathways Pieters et al. [24]. reported that WCS417r-triggered ISR was dependent on the JA/ET-signaling pathway and NPR1 in *Arabidopsis* [24]. Nevertheless, it has also been documented that some rhizobacteria induced systemic resistances by simultaneously activating SA- and JA/ET-dependent signaling pathways [25]. For example, Niu et al. [25] found that the ISR triggered by rhizobacterium *B. cereus* AR156 involved the SA- and JA/ET-signaling pathways as well as NPR1. But till now, this research area has many unclear issues to be resolved. For example, a lot of articles reported that PGPRs could induce systemic resistance to pathogen, but how the plant recognized the rhizobacteria and triggered ISR to the leaf pathogens, and If the plant can perceive the localization and produce some resistance signaling, the how signaling transfer to up ground. And how long can the duration of the induced resistance last, whether it is a lifelong memory. In order to resolve this, all the researchers in the world who work on biocontrol mechanism explanation, have to work harder.

### Induced tolerance to abiotic stress

The PGPR strains induce physical and chemical changes in plants, resulting in enhanced plant tolerance to abiotic stresses termed as induced systemic tolerance (IST) [26,27]. In addition to single strains of PGPR, its combination with either mycorrhizal fungi or Rhizobium also has also been demonstrated to elicit plant drought tolerance. For instance, co- inoculation of the common bean (*Phaseolus vulgaris* L.) with *Rhizobium tropici* (CIAT 899) and the two *Paenibacillus* strains *Paenibacillus polymyxa* (DSM 36) and *Paenibacillus polymyxa* Loutit (L) more effectively alleviated the deleterious effects of drought stress on plant growth, nitrogen content, and nodulation than inoculation with *R. tropici* (CIAT 899) alone [28]. Moreover, co20 inoculation of lettuce with the PGPR strain *Pseudomonas mendocina* Palleroni and an arbuscular mycorrhizal (AM) fungus (either *Glomus intraradices* or *Glomus mosseae*) significantly enhanced the root phosphatase activity; and the proline accumulation and the activities of nitrate reductase, Peroxidase (POD), and Catalase (CAT) in the leaves under moderate and severe drought stress [29]. It is also known that PGPR confers IST

to drought stress in plants by a variety of mechanisms. For instance, the PGPR strain *Paenibacillus polymyxa* has been demonstrated to enhance the drought tolerance of *Arabidopsis thaliana* by stimulating the transcription of a drought-response gene, Early Responsive to Dehydration 15 (ERD15), and of an ABA-responsive gene, RAB18 [27]. However, as we all know, it has been well established that PGPR strains that contain 1-aminocyclopropane-1-carboxylate (ACC) deaminase confer IST to drought stress in a number of plants via the action of ACC deaminase to lower plant ethylene levels. For example, the ACC deaminase-containing PGPR strain *Achromobacter piechaudii* ARV8 has been demonstrated to significantly increase the fresh and dry weights of both drought-treated tomato and pepper seedlings, and reduce ethylene production in tomato seedlings exposed to transient water deficit stress [30]. While, Wang et al. [31]. demonstrated that a consortium of three plant growth-promoting rhizobacterium (PGPR) strains (*Bacillus cereus* AR156, *Bacillus subtilis* SM21, and *Serratia* sp. XY21), could induced systemic tolerance to drought stress in cucumber plants, by protecting plant cells, maintaining photosynthetic efficiency and root vigor and increasing some of antioxidase activities, without involving the action of ACC deaminase to lower plant ethylene levels [31]. The induced tolerance to abiotic stress, by PGPR strains, such as drought, cold and salt etc., is a very significant discovery. They provide a new choice for the survival of plant adversity. But now, the mechanisms of this part were still unclear, the unclear issues will be how the PGPR strains induce tolerance to such abiotic stress and which kind of genes, proteins and signaling pathways take part in the whole process. Some paper mentioned that ABA signaling pathways and some gene were involved in the process. But these results are far from enough for a clear interpretation of this part of the content.

### Conclusion

The plant growth-promotion rhizobacteria (PGPR) played an important role in regulating the plant growth and fighting with the environment. In the process of guaranteeing the healthy growth of plants, the PGPR strains had made a significant contribution in different ways. As shown in the Figure 1. We summarized the function of the plant growth-promotion rhizobacteria (PGPR) to plants when they localized on the surface of plant roots, as you see, Firstly the PGPR strains can promote the growth of plant and enhance the crop

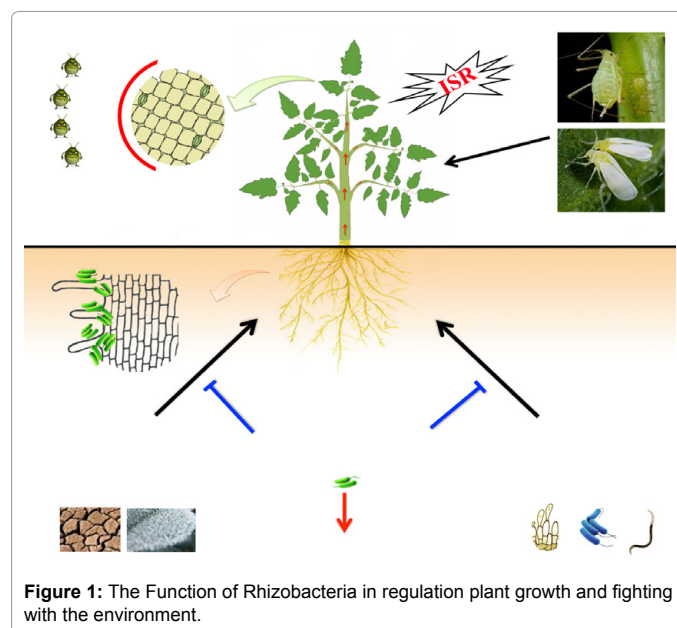


Figure 1: The Function of Rhizobacteria in regulation plant growth and fighting with the environment.

production. In addition, the PGPR strain also can protect plant from the stressing of abiotic or biotic stress. For the soilborn disease, the PGPR strains can directly inhibit the pathogen by their antagonistic properties, while for the plant shoot disease, the PGPR strains can induce systemic resistance to the plant leaf pathogens and they trigger ISR through JA/ETH and/or SA two signaling pathways. Besides, the PGPR strains also can induce the plant raise the tolerance to some abiotic stress, such as cold stress, drought stress and salt stress, as shown in the Figure 1. For the function of the PGPR strains, some research articles also mentioned that they could be used to control the agricultural insects. The application of some PGPR strains can induced systemic resistance to some agricultural insects, and the process mainly occurred by activating JA signaling pathways. In conclusion, the Plant 6growth-Promotion Rhizobacteria (PGPR) plays a very important role in helping plants to adapt to the environment.

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