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

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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 PGPR's 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 1that 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 compoumnd percepted by plant and promote the plant growth? And which kind signaling pathways were activated during these processes. Beside this, PGPRs also can modulate the polulation 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

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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 [*Solanumlycopersicum*], 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 oxysporumf* sp. Raphani [21,23]. Previous studies had shown that PGPRs induced systemic resistance by activing 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 percepte 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 known, 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 strians, 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 summaried 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

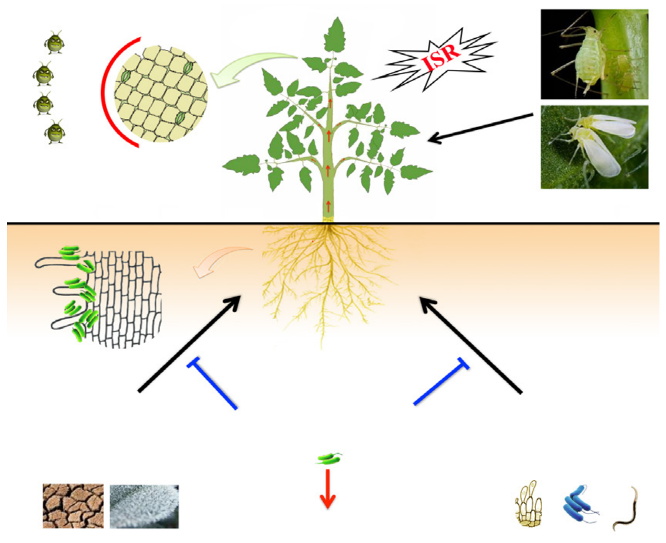

Figure 1: The Function of Rhizobacteria in regulation plant growth and fighting with the environment.

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.

References

1. Amar JD, Manoj K, Rajesh K (2013) Plant Growth Promoting Rhizobacteria (PGPR) An Alternative of Chemical Fertilizer for Sustainable Environment Friendly Agriculture. Res. J. Agriculture and Forestry Sci. 1: 21-23.
2. Kloepper JW, Schroth MN (1978) Plant growth-promoting rhizobacteria on radishes Proceedings of the 4th Internatational Conf. on Plant Pathogenic Bacteria Station de Pathologie Vegetable et Phytobacteriologie. INRA, Angers, France, 879-882.
3. Kloepper JW, Lifshitz R, Zablotowicz RM (1989) Free-living bacterial inoculation for enhancing crop productivity. Trends in Biotechnology 7 (2): 39-43.
4. Okon Y, Labandera Gonzalez CA, (1994) Agronomic applications of Azospirillum in Improving Plant Productivity with Rhizosphere Bacteria. Commonwealth Scientific and Industrial Research Organization, Adelaide, Australia. 274-278.
5. Glick BR (1995) The enhancement of plant growth by free living bacteria. Canadian Journal of Microbiology 41: 109-114.
6. Joseph B, Patra RR, Lawrence R (2007) Characterization of plant growth promoting Rhizobacteria associated with chickpea (Cicer arietinum L). International Journal of Plant Production 1: 141-152.
7. Saharan BS, Nehra V (2011) Plant Growth Promoting Rhizobacteria a critical Review. Life Sciences and Medicine Research: LSMR: 21.
8. Nautiyal CS, Bhadauria S, Kumar P, Lal H, Mondal R, et al. (2000) Stress induced phosphate solubilization in bacteria isolated from alkaline soils FEMS Microbiol. Lett 182: 291-296.
9. Graham DL, Steiner JL, Wiese AF (1998). Light absorption and competition in mix sorghum-pigweed communities. Agronomy Journal 80: 415-418.
10. De Salamone IEG, Hynes RK, Nelson LM (2006) Role of cytokinins in plant growth promotion by rhizosphere bacteria. In Siddiqui ZA (edn). Springer, Netherlands: 173-195.
11. Ryu, CM, Farag MA, Hu CH, Reddy MS, Wei HX, et al. (2003) Bacterial volatiles promote growth in Arabidopsis. PNAS 100: 4927-4932.
12. Crowley DE (2006) Microbial siderophores in the plant rhizospheric In Barton LL and Abadía J (eds) Iron Nutrition in Plants and Rhizospheric Microorganisms. Springer, Dordrecht: 169-198.
13. Sandy M, Butler A (2009) Microbial iron acquisition Marine and terrestrial siderophores. Chem Rev 109: 4580-4595.
14. Maksimov IV, Abizgil'dina RR, Pusenkova LI (2011) Plant growth promoting rhizobacteria as alternative to chemical crop protectors from pathogens.Appl Biochem Microbiol 47: 373-385.
15. Silo-Suh LA, Lethbridge BJ, Raffel SJ, He H, Clardy J, et al. (1994) Biological activities of two fungistatic antibiotics produced by Bacillus cereus UW85. Appl Environ Microbiol 60: 2023-2030.
16. He H, Silo-Suh LA, Handelsman J, Clardy J (1994) Zwittermicin A, an antifungal and plant protection agent from Bacillus cereus. Tetrahedron Lett 35: 2499-2502.
17. Riley M (1993) Molecular mechanisms of colicin evolution. Mol Biol Evol 10: 1380-1395.
18. Abriouel H, Franz CM, Ben Omar N, Gálvez A (2011) Diversity and applications of Bacillus bacteriocins. FEMS Microbiol Rev 35: 201-232.
19. Van Loon LC, Bakker PAHM, Pieterse CMJ (1998) Systemic resistance induced by rhizosphere bacteria. Annu Rev Phytopathol 36: 453-483.
20. Beneduzi A, Ambrosini A, Passaglia LMP (2012) Plant growth-promoting rhizobacteria (PGPR) Their potential as antagonists and biocontrol agents. Genet Mol Biol 35: 1044-1051.
21. Van der Ent S, Verhagen BW, Van Doorn R, Bakker D, Verlaan MG, Et al. (2008) MYB72 is required in early signaling steps of rhizobacteria-induced systemic resistance in Arabidopsis. Plant Physiol 146: 1293-1304.
22. Pieterse CMJ, Van Wees SCM, Ton J, Van Pelt JA, Van Loon LC (2002). Signaling in rhizobacteria-induced systemic resistance in Arabidopsis thaliana. Plant Biol 4: 535-544.
23. Pieterse CMJ, Van Wees SC, Hoffland E, van Pelt JA, van Loon LC (1996) Systemic resistance in Arabidopsis induced by biocontrol bacteria is independent of salicylic acid accumulation and pathogenesis-related gene expression. Plant Cell 8: 1225-1237.
24. Pieterse CMJ, Van Wees SC, van Pelt JA, Knoester M, Laan R, et al. (1998) a novel signaling pathway controlling induced systemic resistance in Arabidopsis. The Plant Cell 10: 1571-1580.
25. Niu DD, Liu HX, Jiang CH, Wang YP, Wang QY, et al. (2011) The plant growth-promoting rhizobacterium Bacillus cereus AR156 induces systemic resistance in Arabidopsis thaliana by simultaneously activating salicylate-and jasmonate/ethylene-dependent signaling pathways. Mol Plant-Microbe Interact 24: 533-542.
26. Yang JW, Kloepper JW, Ryu CM (2008) Rhizosphere bacteria help plants tolerate abiotic stress. Trends in Plant Science 14: 1-4.
27. Timmusk S, Wagner EGH (1999) the plant-growth-promoting rhizobacterium Paenibacillus polymyxa induces changes in Arabidopsis thaliana gene expression a possible connection between biotic and abiotic stress responses. Molecular Plant- Microbe Interactions 12: 951-959.
28. Mayak S, Tirosh T, Glick BR (2004) Plant growth-promoting bacteria that confer resistance to water stress in tomatoes and peppers. Plant Science 166: 525-530.
29. Marcia VBF, Burity HA, Mart ́ınez CR, Chanway CP (2008) Alleviation of drought stress in the common bean (Phaseolus vulgaris L.) by co-inoculation with Paenibacillus polymyxa and Rhizobium tropici. Applied soil ecology 40: 182-188.
30. Kohler J, Herna ́ndez JA, Caravaca F, Rolda ́NA (2008) Plant-growth-promoting rhizobacteria and arbuscular mycorrhizal fungi modify alleviation biochemical mechanisms in water-stressed plants. Functional Plant Biology 35: 141-151.
31. Wang CJ, Yang W, Wang C, Gu C, Niu DD, et al. (2012) Induction of Drought Tolerance in Cucumber Plants by a Consortium of Three Plant Growth-Promoting Rhizobacterium Strains. Plos one 7: e52565