Utilization of Plant Growth-Promoting Bacteria for Plant Diseases Bio-control

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Abstract--- *In sustainable agriculture, the management of plant disease has become a dispute for plant pathologists. Plant growth promoting rhizobacteria (PGPR) is a major group of microbes that plays a key role in plant pathogens biocontrol. PGPR can greatly enhance germination of seed, root development and water absorption. The most widely studied class of PGPB is the colonization of root surfaces by plant growth-promoting rhizobacteria (PGPR). Recent progress has been made in our understanding of their colonizing capacity, diversity, formulation, and action mechanism, and applications that promote their development as dependable agents of bio-control against plant pathogens. Pathogenic microorganisms that affect plant health are a significant and persistent threat to food production and the stability of the world's ecosystems. The rising cost of pesticides, especially in the less prosperous regions around the world, and demand of consumer for pesticide-free food has led to a quest for alternatives for these products. There are also a variety of particular diseases for which chemical solutions are less, non-existent or ineffective. Therefore, biological control is regarded as an alternative or additional way to minimize the use of chemicals in agriculture. This study reviews the principles and action mechanisms of plant growth-promoting bacteria and their use or potential use for plant disease biological control.*

Index Terms--- *Biocontrol, rhizobacteria, pathogenic microorganism, pesticide.*

I. INTRODUCTION

Free-living endophytic bacteria and rhizobacteria, despite their unique ecological niches, uses some of the same mechanisms to control phytopathogens and promote plant growth. The broadly recognized biocontrol mechanisms mediated by PGPB are competition for substrate or an ecological niche, induction of systemic resistance (ISR) in host plants to a wide spectrum of pathogens, abiotic stresses and production of inhibitory allelo-chemicals [1]. In conjunction with plant roots, soil microorganisms exist and interact with plant quality and microbial community structure. It is estimated that bacteria engage 7% to 15% of the total root surface area. Some bacteria have a positive effect on plants and are known as the plant growth-promoting rhizobacteria (PGPR)[2].

PGPR affect growth of plant in two different ways, directly or indirectly. By PGPR, the direct promotion of plant growth implies either providing the plant with a bacterium-synthesized compound, such as phytohormones, or facilitating the environmental uptake of certain nutrients [3]. Indirect promotion of the plant growth arises when PGPR

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reduces or prevents one or more phytopathogenic species from having deleterious effects.

This can occur through the development of antagonistic compounds or the induction of pathogen resistance. By using one or more of these mechanisms, a specific PGPR can affect plant growth and development [3], [4]. Plant growth promoting rhizobacteria (PGPR) plays a vital role in plant disease management among the wide range of beneficial microbes. PGPR are bacteria that are free-living and can have beneficial effects on plants. Plant disease biocontrol is particularly complex since diseases occur mostly in the dynamic environment at the plant root edge as well as in the aerial parts of plants [5]. PGPR promotes the development of seedlings, colonizes roots and increases the overall growth of plants and these may also suppress plant diseases [6].

Increasing awareness and health hazards related with pesticide applications have given rise to the interest in alternative plant defense methods. Rhizosphere microorganisms can provide a front-line defense contrary to pathogen attack from various organisms used for biocontrol, and are suitable for use as bio-control agents [5]. Bio-control involves harnessing microorganisms that suppress disease to improve the health of plants. Depending on their effects on plant growth, plant-associated bacteria can be categorized as deleterious, beneficial or neutral classes [7]. PGPRs colonize the rhizosphere, the rhizo-plane (root surface), regardless of the mechanisms of promoting vegetable growth. Only 1 to 2 percent of bacteria are well established to promote plant growth in the rhizosphere [8], [9]. Bacteria of different genera, including Pseudomonas and Bacillus spp., have been recognized as PGPR. PGPR and its plant interactions are commercially exploited and hold great promise for sustainable farming. Applications of these associations have been examined in wheat, maize, oat, peas, barley, canola, potatoes, soy, tomatoes, radicchio, lentils and cucumber [1], [6].

I.I. PGPR Interaction with Plants:

Inoculation with PGPR offers immunity to a range of pathogens including viruses, bacteria and fungi in different plant species. And besides causing certain morphological variations in the plant itself, it also induces phenolic accumulation and raises certain enzyme levels [10].

I.I.I. Genetic Variations in the Host:

The ability of plants to help and respond to beneficial microorganisms varies. The ability to support those biocontrol agents differs between cultivar and plant species. Many plants seem to attract and aid agents of biocontrol that are antagonistic to pathogens [11]. The response of legumes varies in response to Bacillus and P. polymyxa isolates from wheat roots increased wheat growth in a cultivar-specific manner [12]. Plant species are likely to vary in their ability to induce genes in biosynthesis of P. fluorescencs for pyoluteorin due to variation in root exudate composition among species. P. fluorescens strains that overproduce 2, 4-diacetyl-phloroglucinol and pyoluteorin, in some host-pathogen combinations and not others, provide superior disease suppression as compared to the parent strain, and effect correlates with the host, not pathogenic, in addition to antibiotic resistance[3][5].

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I.I.II. Root Colonization:

Colonization of the rhizosphere is critically important not only as the first step in the pathogenesis of soil-borne microorganisms, but is also essential for the use of microorganisms for beneficial purposes. PGPR typically promotes plant growth by colonizing the root system and preventing harmful rhizosphere microorganisms from being formed or suppressed. PGPR must be able to contest with the indigenous microbes and colonize the plant rhizosphere to be protected effectively. Colonization is broadly considered essential for biocontrol, and the root surface should be grown and colonized by a biocontrol agent. The biocontrol agent's colonization or even initial population size was strongly associated with the suppression of disease. Characteristics of the cell surface affect bacteria's attachment to roots, which may be important for colonization. Some mutants who cause secondary metabolite accumulation also affect root colonization in the field [5], [7]. A variety of bacterial characteristics and unique genes contribute to colonization, but few have been described. These include seed chemotaxis, motility and use of specific root exudate components, production of fimbriae or pili, production of components of specific cell surface, quorum sensing and protein secretion capacity[2], [12].Bio-control agent’s rhizosphere competence includes effective root colonization combined with the capability to survive and proliferate in the presence of indigenous microflora along growing plant roots over a considerable period of time. Given the importance of rhizosphere competence as a requirement for effective biological control, understanding the root-microbe communication in temporal and spatial contexts as affected by environmental and genetic determinants will contribute significantly to enhance the effectiveness of these biocontrol agents.

I.II. Indirect Plant Growth Promotion through Induced Systemic Resistance:

It has been shown that non-pathogenic rhizobacteria suppress disease by inducing a resistance mechanism called "Induced Systemic Resistance" in the plant. Induced resistance is the state of enhanced plant-developed defensive ability when properly stimulated. The inducing pathogens and rhizobacteria were inoculated and remained limited and separated on the same plant, thus avoiding microbial antagonism.

It was shown that the use of selected PGPR strains induced a plant-mediated resistance in parts of the plant above ground. This form of resistance is called as ISR and has been shown in many species of plants including carnation, bean, tomato, cucumber, tobacco, radish and Arabidopsis thaliana. Rhizobacteria-mediated ISR is phenotypically similar to the classic pathogen-induced resistance in which non-infected parts of a previously pathogen-infected plant become more resistant to additional infection. This resistance mechanism is called as systemic acquired resistance (SAR). ISR mediated by Rhizobacteria resembles pathogen-induced systemic acquired resistance (SAR), in that both forms of induced resistance make uninfected plant parts extra resistant to plant pathogens, including bacterial, fungal and viral pathogens as well as insects and nematodes. In the same plant, the same strain induces resistance to numerous pathogens. Bacillus and Pseudomonas spp in particular are the most studied rhizo-bacteria that trigger ISR.The difference between SAR and ISR is that SAR is induced systemically following inoculation with necrotic pathogens whereas; ISR is induced by non-pathogenic rhizobacteria. In addition, ISR is independent of the salicyclic acid, but involves signals of jasmonic acid and ethylene, while SAR requires salicyclic acid in plants as a signaling molecule.

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Protection against various pathogens was expressed in reducing symptoms of disease as well as inhibiting the growth of pathogens. Due to the spatial separation of rhizobacteria from pathogens, the mode of suppression of disease in plants is through the ISR. The ability to develop ISR seems to rely on the combination of host / rhizobacterium and indicates that specific identification is necessary for the induction of ISR between the plant and the ISR-inducing rhizobacterium. Biocontrol and its accuracy in the field are usually not enough to cope with traditional disease control methods.

The combined use of antagonistic microorganisms with diverse action mechanisms can improve the effectiveness and constancy of biocontrol agents. In addition, the combination of ISR and SAR resulting in an increased level of protection against definite bacterial pathogens offers great potential for integrating both forms of induced resistance into farming practices. Induced resistance seems to be more effective in controlling plant viral diseases where other management strategies are usually ineffective (Fig.1).

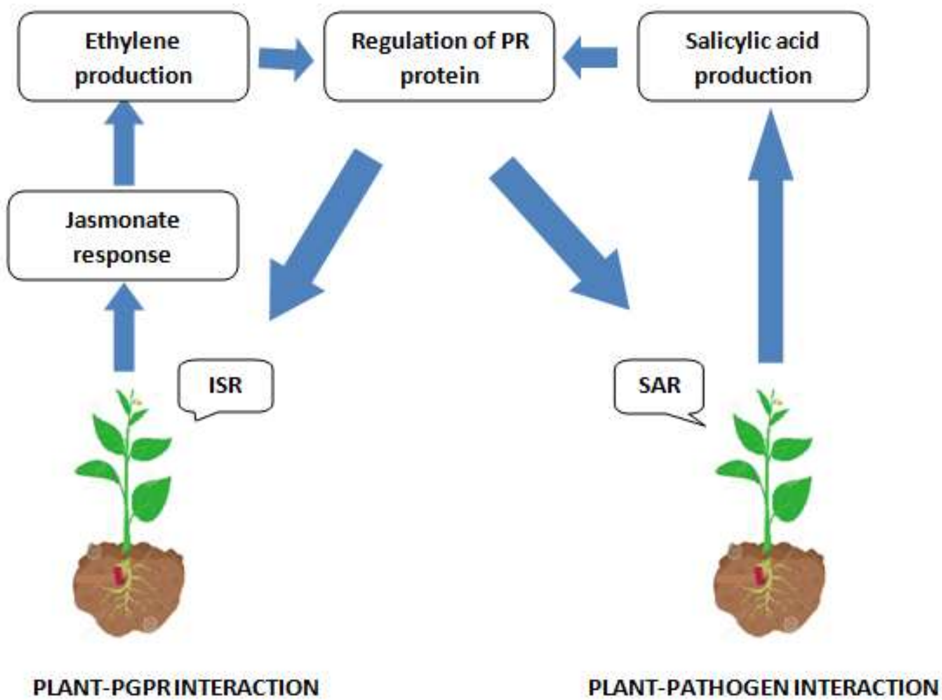

Fig. 1: - Signaling mechanisms in plants responsible for resistance to disease.

I.III.I. Determinants of ISR:

For both bacterial endophytes and rhizobacteria, the ability to act as bioprotectants by ISR has been well established, and important progress has been made in clarifying the mechanisms of plant-PGPB-pathogen interaction. Many bacterial characteristics (i.e., flagellation and development of lipopolysaccharidesand siderophores) were suggested to cause ISR, but there is no convincing evidence for a total ISR signal formed by the bacteria. Recently, volatile organic compounds have been documented to play a significant role in this process. For example, *B. amyloquefaciens* IN937a and *B. subtilis* GBO3 secreted volatiles were able to stimulate ISR pathway in *Arabidopsis* seedlings tested with soft rot pathogen *Erwinia carotovora*.

A significant difference often drawn between ISR and SAR is the latter's dependence on salicylic acid (SA) accumulation. However, most ISR-activating PGPBs appear to do so through a SA-independent pathway involving

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signals of jasmonate and ethylene. ISR is allied with arise in sensitivity to these hormones rather than an increase in their production, which could result in a partially diverse set of defense genes being activated.

II. CONCLUSION

Research by PGPB on to the plant growth promotion mechanisms has provided a better understanding of the numerous aspects of disease repression by these biological control agents. Revelations regarding PGPB action mechanisms open new doors to develop methods to improve the effectiveness of bio-control agents. Numerous studies have shown that PGPR has great potential in plant pathogens bio-control, but most studies have been carried out in pots and in sterilized soil. PGPR root colonization is also significant in order to raise their capacity as bio-control agents. Furthermore, it is advisable to use a mixture of effective PGPR strains compared with the use of a single strain. It is recommended that organic modifications be introduced to active PGPR strains as organic materials promote the growth of organisms that interact with or kill pathogens. PGPR can also be used for greater beneficial effects with fungal biocontrol agents and arbuscular mycorrhizal fungi. Also, a major obstacle to progress is the lack of commercial interest by PGPR in the biological control of plant pathogens. Continued research with endophytic bacteria also has the potential to develop biocontrol agents that can be self-perpetuating by colonization of hosts and passed to progeny, as is the case with associative nitrogen-fixing PGPB on sugarcane.

REFERENCES:

[1] A. Beneduzi, A. Ambrosini, and L. M. P. Passaglia, “Plant growth-promoting rhizobacteria (PGPR): Their potential as antagonists and biocontrol agents,” Genetics and Molecular Biology. 2012.

[2] B. R. Glick, “Plant Growth-Promoting Bacteria: Mechanisms and Applications,” Scientifica (Cairo)., 2012.

[3] M. Ahemad and M. Kibret, “Mechanisms and applications of plant growth promoting rhizobacteria: Current perspective,” Journal of King Saud University - Science. 2014.

[4] S. Compant, C. Clément, and A. Sessitsch, “Plant growth-promoting bacteria in the rhizo- and endosphere of plants: Their role, colonization, mechanisms involved and prospects for utilization,” Soil Biology and Biochemistry. 2010.

[5] P. N. Bhattacharyya and D. K. Jha, “Plant growth-promoting rhizobacteria (PGPR): Emergence in agriculture,” World Journal of Microbiology and Biotechnology. 2012.

[6] R. de Souza, A. Ambrosini, and L. M. P. Passaglia, “Plant growth-promoting bacteria as inoculants in agricultural soils,” Genetics and Molecular Biology. 2015.

[7] B. Bouizgarne, “Bacteria for plant growth promotion and disease management,” in Bacteria in Agrobiology: Disease Management, 2013.

[8] M. del C. Orozco-Mosqueda, M. del C. Rocha-Granados, B. R. Glick, and G. Santoyo, “Microbiome engineering to improve biocontrol and plant growth-promoting mechanisms,” Microbiological Research. 2018.

[9] S. A. Palaniyandi, S. H. Yang, L. Zhang, and J. W. Suh, “Effects of actinobacteria on plant disease suppression and growth promotion,” Applied Microbiology and Biotechnology. 2013.

[10] M. Ruzzi and R. Aroca, “Plant growth-promoting rhizobacteria act as biostimulants in horticulture,” Scientia Horticulturae. 2015.

[11] E. Gamalero and B. R. Glick, “Mechanisms Used by Plant Growth-Promoting Bacteria,” in Bacteria in Agrobiology: Plant Nutrient Management, 2011.

[12] H. Antoun, “Plant-Growth-Promoting Rhizobacteria,” in Brenner’s Encyclopedia of Genetics: Second Edition, 2013.

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