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Bacterial Endophytes: Potential Role in Plant Growth Promotion

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Abstract

Endophytic bacteria belong to the group of microorganisms that complete their life cycle partly or entirely within a host plant without causing any apparent disease symptoms in the host. They are ubiquitously associated, either obligately or facultatively, with almost all plant parts and plant species, and this could be either beneficial or neutral effect on plants. In beneficial symbiotic associations, they enhance the plant growth under normal and stressed conditions through direct mechanisms such as production of phytohormones, improved bioavailability of nutrients and modulation of plant ethylene level or through indirect mechanisms by protecting host plant from the attack of pests and phytopathogens. Moreover, phytoremediation efficiency of bacterial endophytes contributes towards adaptation and enhanced growth of plants in sites heavily contaminated with organic pollutants. Therefore, application of endophytic bacteria with beneficial characteristics could be developed as a promising tool for gaining our goals of safe and sustainable agriculture system.

Introduction

Plants, with a complex micro-ecosystem, support a large and complex microbial community where a wide variety of habitats are effectively exploited by a number of different bacteria. Therefore, bacteria are considered be to the dominant microbial inhabitants of plants. Plant-bacteria relations have been subjected to extensive study for a past few decades. However, understanding the exact mechanisms underlying plant-bacterial interactions had remained rather elusive or fragmentary and this makes it difficult to explore the full advantage or benefit of these complex relationships. The micro-ecosystems associated with plants are not only represented by plant external surfaces such as leaf, stem or root surfaces where most of the epiphytic bacteria are found to predominate but also by internal tissues where many microbes can invade and survive successfully. Bacteria which are capable of colonizing the internal tissue of the host plant without any apparent sign of infection or negative effect on their host are known as endophytic bacteria (Schulz and Boyle, 2005).

Generally, the term “endophyte” is used to describe fungi; however there are plethora of research evidences pertaining to the endophytic colonization and survival of bacteria, with either beneficial or neutral effect on plants. Endophytic bacteria have been reported to present in a variety of tissues within various plant species without causing apparent disease symptoms which suggests the ubiquitous existence in almost all higher plants. Plants can be colonized simultaneously by distinct endophytic microbial communities including both Gram-positive and Gram-negative bacteria and their entry into the host plant occurs mainly through root and aerial plant parts with the involvement of complex communication process. A large variety of endophytic bacteria have been found within various plant parts such as leaves roots, stem, flowers, fruits and seeds which indicates colonization capacity of endophytic bacterial strains in various internal compartments of plants.

Every plant species that exists on earth is host to one or more types of endophytes. Mostly, they possess biphasic life cycle that alternates between host plant and their soil environments. Endophytic bacterial relationship with its host plants can be either obligate or facultative. Former association is strictly dependent on the host plant for their growth and survival whereas latter will have a part of their life cycle outside the host plants.

Plant Growth-Promoting Endophytic Bacteria

Endophytic bacterial colonization in plants is considered as a sign of a healthy plant system since this interaction brings numerous benefits to both the partners involved in it. Several research findings have revealed their growth promoting potential in many cultivated plants, such as tomato, amaranthus, lettuce, potato, brinjal, chilli, wheat, paddy, cucumber, cabbage, grape, black pepper and corn. Bacterial endophytes possess vital ability to enhance plant growth by multitude of mechanisms; including production of indole 3-acetic acid (IAA), cytokinin, gibberellic acid, siderophore, nitrogen fixation, ACC (1-aminocyclopropane-1- carboxylate) deaminase and phosphorous solubilization. Recognizing the importance of endophytic bacteria in plant growth promotion, increased interest has emerged towards the exploitation of their potentials in sustainable agriculture.

Bacillus species with the ability to form resistant structures known as endospores as a survival strategy under stressed environmental conditions forms one of the predominant bacterial endophytes in plants. This property of forming extremely resistant endospore can be exploited in bio-inoculation technologies, as it ensures survival of organisms for long period in bioformulation before its application. Endospore-forming endorhizosphere *Bacillus* spp. isolates from disease resistant amaranthus has been found improving the plant growth and suppressing the leaf blight disease caused by *Rhizoctonia solani* in the susceptible red amaranthus (Yashaswini *et al*., 2021) (Figure 1 & 2).

Bacterial Endophytes as Potential Biocontrol Agents

There are reported evidences on endophytic bacteria contributing towards the management of various devastating plant diseases through various biocontrol mechanisms *viz*. competition against pathogens for ecological niche or substrate, antibiosis, production of lytic enzymes and induction of systemic resistance. Bacterial endophyte mediated biocontrol activity is largely dependent upon many factors such as host specificity, population dynamics and pattern of host colonization, movement within host tissues, and the ability to induce systemic resistance, and all these factors are involved in determining the indirect promotion of plant growth. A list of endophytic bacterial biocontrol agents is given in Table 1.

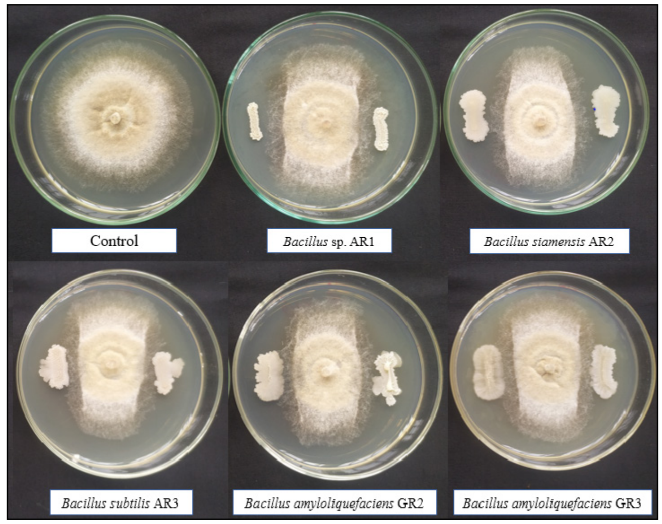

Figure 1: Dual culture plate assay showing direct antagonism of endospore forming endophytic bacterial isolates against *Rhizoctonia solani*

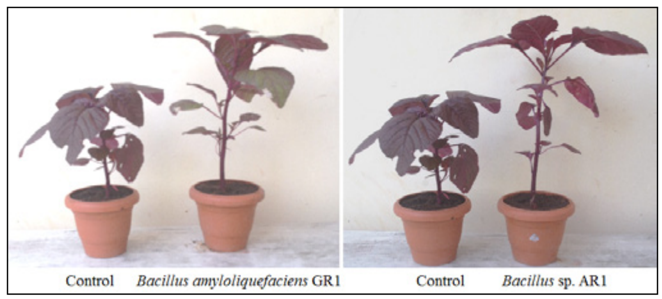

Figure 2: Effect of endospore forming endophytic bacteria on growth of amaranthus

Several endophytic bacteria isolated from various sources have been found to exhibit strong antifungal activity. For instance, endophytic bacteria obtained from seeds of rice have been shown to inhibit the growth of *Rhizoctonia solani, Pythium myriotylum, Gaeumannomyces graminis,* and *Heterobasidium annosum* (Mukhopadhyay *et al*., 1996). An endophyte isolated from corn, *Enterobacter cloacae*, seems to be supressing *Fusarium moniliforme* through antibiosis. In addition, endophytic bacteria also found to possess biocontrol against plant-parasitic nematodes and insects. These evidences pave possibilities of exploiting them as a pest control tool.

Table 1: Endophytic bacterial biocontrol agents		
Biocontrol agent	Source	Target pathogen
Serratia nematodiphila, Paenibacillus polymyxa, Brevundimonas olei, Bacillus megaterium	Root of *Eucalyptus pellita*	*Ralstonia solanacearum*
Bacillus subtilis	*Prunus cerasifera tissue*	*Verticillium dahliae*
Bacillus velezensis	Tomato stem	*Botrytis cinerea*
Bacillus axarquiensis-ESR 7, *Bacillus subtilis*-ESR 24, Bacillus licheniformis-ESR 26	Sugarcane	*Colletotrichum falcatum*
Bacillus sp. WR1	*Amaranthus viridis*	*Rhizoctonia solani* Kuhn
Enterobacter and *Bacillus* strains	Flower, fruit, leaf, petiole, root and stem of healthy tomato plants	*Meloidogyne incognita*
Bacillus subtilis (KJ-2)	The seed endosphere of a bacterial wilt tolerant chilli	*Ralstonia solanacearum*

Bacterial Endophyte-Mediated Phytoremediation and Plant Growth Promotion

Generally, plants growing in contaminated soil may possess several survival strategies, either genetical or physiological to tolerate the high-level concentrations of various pollutants. Of various strategies, use or recruitment of native endophytic microbes can be considered as the most effective phytoremediation strategy. Hence it can be adopted as an economically and socially acceptable technique for remediating sites contaminated with organic xenobiotics. Bacterial endophytes with combined action of the capacity to remediate high concentrations of pollutants and plant growth-promoting traits could be most useful in terms of simultaneous phytoremediation and plant growth promotion (Table 2).

Table 2: Endophytic bacteria with phytoremediation potential and plant growth promoting traits		
Plant used	Associated endophytic bacteria	phytoremediation activity and plant growth promoting traits
Wheat (*Triticum* sp.) and maize *(Zea mays)*	*Enterobacter* sp. 12J1	Pyrene degradation, indole acetic acid (IAA) and siderophore production.
Alfalfa (*Medicago sativa* var. Harpe)	*Enterobacter ludwigii* strains	Hydrocarbon degradation and ACC deaminase activities.
Lotus corniculatus L. and *Oenothera biennis* L	*Rhizobium, Pseudomonas, Stenotrophomonas,* and *Rhodococcus*	Hydrocarbon-degradation, IAA production, siderophore production and ACC deaminase activity.
Ryegrass (*Lolium perenne* L.)	*Pseudomonas* sp.	Hydrocarbon degradation, IAA production, phosphate solubilization, siderophore production and ACC deaminase activity.

Conclusion

Endophytic bacteria are known to improve plant growth in multitude of ways such as indole 3-acetic acid (IAA), cytokinin, gibberellic acid, siderophore, nitrogen fixation, ACC (1-aminocyclopropane-1-carboxylate) deaminase, phosphorous solubilization, biological control of various phytopathogens and phytoremediation. All these characteristics make them promising candidates in sustainable crop production. Owing to their capacity to promote plant growth either through direct or indirect mechanisms, they are receiving much attention as bioinoculants for use in agriculture. However, the exact mechanism of plant growth enhancement by bacterial endophytes has not been completely elucidated. A comprehensive understanding of their ecology and molecular interaction would certainly help us to find new possible applications of in agriculture.

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