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REVIEW ARTICLE

Biodiversity of Plant Growth Promoting Rhizobacteria (Pgpr) In Mangrove Ecosystem: A Review

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ABSTRACT

Mangroves provide a unique ecological niche to different a microbe which plays various roles in nutrient recycling as well as various environmental activities. Much study has been conducted in various mangroves in India and the literature is scettered. To conserve arid tropical mangrove ecosystems, maintenance and restoration of the microbial communities is required. The present review, the biodiversity of PGPR isolates in mangrove ecosystem was discussed. There is sufficient published evidence to propose a close microbe-nutrient plant relationship that functions as a major mechanism for recycling and conserving essential nutrients in the mangrove ecosystem. Plant growth-promoting rhizobacteria (PGPR) are naturally occurring soil bacteria that aggressively colonize plant roots and benefit plants by providing growth promotion. There has been much research interest in PGPR and there is now an increasing number of PGPR being commercialized for various crops. This review assesses the following topics: PGPR in marine ecosystem, Nitrogen fixation in mangrove ecosystem, Phosphate solubilizing bacteria, Photosynthetic anoxygenic bacteria and PGPR as biocontrol agents. Several reviews have discussed specific aspects of growth promotion by PGPR.

Key words: Mangrove ecosystem, Biodiversity, PGPR, Nitrogen fixation and Biocontrol.

1. INTRODUCTION

Mangrove ecosystem has long been a natural resource of importance to mankind by virtue of its utility and aesthetic value. These ecosystems is one of the most productive ecosystem of tropical and sub-tropical regions of the world and serve as nursery, feeding and spawning grounds for commercial living organisms. Mangroves have attained great importance both in terms of economical and ecological aspects, therefore, various conservation programmes have been taken to protect the ecosystem all over the world. In India, mangroves are found in West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra, Gujarat, and Andaman and Nicobar Islands [1].

Plant growth in agricultural soils is influenced by many abiotic and biotic factors. There is a thin layer of soil immediately surrounding plant roots that is an extremely important and active area for root activity and metabolism which is known as rhizosphere. The rhizosphere concept was first introduced by Hiltner to describe the narrow zone of soil surrounding the roots, where microbe populations are stimulated by root activities. The original concept has now been extended to include the soil surrounding a root in which physical, chemical and biological properties have been changed by root growth and activity A large number of microorganisms such as bacteria, fungi, protozoa and algae coexist in the rhizosphere. Bacteria are the most abundant among them. Plants select those bacteria contributing most to their fitness by releasing organic compounds through exudates creating a very selective environment where diversity is low [2]. Since bacteria are the most abundant microorganisms in the rhizosphere, it is highly probable that they influence the plants physiology to a greater extent, especially considering their competitiveness in root colonization [3].

The use of PGPR offers an attractive way to replace chemical fertilizer, pesticides, and supplements; most of the isolates result in a significant increase in plant height, root length, and dry matter production of shoot and root of plants. PGPR help in the disease control in plants.

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Some PGPR especially if they are inoculated on the seed before planting, are able to establish themselves on the crop roots. PGPR as a component in integrated management systems in which reduced rates of agrochemicals and cultural control practices are used as biocontrol agents. Such an integrated system could be used for transplanted vegetables to produce more vigorous transplants that would be tolerant to nematodes and other diseases for at least a few weeks after transplanting to the field [4]. Selected strains of beneficial PGPR trigger a plant mediated induced systemic resistance (ISR) response that is effective against a broad spectrum of plant pathogens. ISR is a plant-mediated mechanism it resembles classic pathogen-induced resistance, in which non-infected parts of previously pathogen-infected plants become more resistant to further infection [5]. The present review was focused on the biodiversity of PGPR isolates in mangrove ecosystem.

2.PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR) IN MANGROVE ECOSYSTEM

Mangrove ecosystems are rich in organic matter; however, in general, they are nutrient-deficient ecosystems, especially of nitrogen and phosphorus [6], which are indispensable for plant growth. In spite of this, on a global scale, mangroves are among the most productive ecosystems. This paradox can be explained by a very efficient recycling that keeps the scarce nutrients within the system. Microbial activity (bacteria and fungi) is responsible for major nutrient transformations within a mangrove ecosystem [7]. In tropical Australian mangroves, bacteria and fungi constitute 91% of the total microbial biomass, whereas algae and protozoa represent only 7% and 2%, respectively [8].

Plant growth-promoting bacteria (PGPB), studied mainly in association with crops, can be of various types: nitrogen fixers, phosphate solubilizers, phytohormone producers, siderophore synthesizers, mineral uptake enhancers, root development enhancers, proton extrusion enhancers, and biocontrol of phytopathogens [9]. They belong to various genera and each species might be used singly or together with other strains to inoculate the plants and enhance their growth. The study of PGPB in mangroves ecosystems is in its infancy; however, several studies demonstrate the potential for using rhizosphere bacteria isolated from mangrove roots as PGPB.

3. NITROGEN FIXATION IN MANGROVE ECOSYSTEM

Nitrogen (N_2) fixation is common in mangroves. High rates of nitrogen fixation were detected in association with dead and decomposing leaves, pneumatophores (aerial roots), the rhizosphere, tree bark, cyanobacterial mats covering the surface of sediments, and in the sediments themselves [10]. Nitrogen-fixing bacteria identified as members of the genera *Azospirillum, Azotobacter, Rhizobium, Clostridium,* and *Klebsiella* were isolated from the sediments, rhizosphere, and root surfaces of various mangrove species. In an arid mangrove in Mexico, several strains of diazotrophic bacteria were isolated from the rhizosphere of the mangroves *Rhizophora mangle, Avicennia germinans,* and *Laguncularia racemosa.* Some of these strains were identified as *Vibrio campbelli, Listonella anguillarum, Vibrio aestuarianus,* and *Phyllobacterium* spp. The amount of nitrogen contributed by these free nitrogen-fixing bacteria in this ecosystem is unknown, although we know that the capacity of these bacteria to fix nitrogen is similar to that for diazotrophic bacteria from the terrestrial environment, such as *Azospirillum* spp. [11].

Nitrogen-fixing and non-nitrogen-fixing cyanobacteria, diatoms, green microalgae, bacteria, and fungi were found colonizing the surface of pneumatophores (aerial roots) in black mangroves [12]. Year-round in situ measurements of nitrogen fixation associated with the aerial roots of *Azospirillum germinans* in a Mexican mangrove showed rates up to ten times higher during the summer than during autumn and winter. The main factors influencing nitrogen fixation were light intensity and water temperature. Similar results were obtained with aerial roots of *Azospirillum marina* in South Africa [13].

4.PHOSPHATE SOLUBILIZING BACTERIA

In marine sediments, phosphates usually precipitate because of the abundance of cations in the interstitial water, making phosphorus largely unavailable to plants. Phosphate- solubilizing bacteria (PSB), as potential sup - pliers of soluble forms of phosphorus, would provide a great advantage to mangrove plants. Almost no research has been focused on this group of bacteria found in coastal environments, either in temperate or tropical regions and even less in mangrove ecosystems. In an arid mangrove ecosystem in Mexico, 12 strains of phosphate-solubilizing bacteria were isolated from mangrove roots. The phosphate-solubilizing activity of one strain, *Bacillus amyloliquefaciens,* had an average solubilization capacity of 400 mg of phosphate per liter of bacterial suspension (10^8 cfu/ml). This amount could theoretically supply a small terrestrial plant with its daily requirement of phosphate. The mechanism involved in phosphate solubilization was probably the production of organic acids [14].

5.PHOTOSYNTHETIC ANOXYGENIC BACTERIA

Members of this group of bacteria include purple sulfur bacteria and green and purple non-sulfur bacteria. Sulfur rich mangrove ecosystems, which have mainly anaerobic soil environments, would provide favorable conditions for the proliferation of these bacteria. Only a few papers have reported the presence of anoxygenic photosynthetic bacteria in mangrove environments. Nevertheless, representatives of the families Chromatiaceae (purple sulfur bacteria) and Rhodospirillaceae (purple non-sulfur bacteria) were found in sediments of a mangrove community in India [15]. The predominant bacteria in the mangrove ecosystem of Cochin (India) were members of the genera *Chloronema, Chromatium, Beggiatoa, Thiopedia*, and *Leucothiobacteria*. Between 4% and 20% of the total anaerobes isolated were phototrophic sulfur bacteria. Large populations of *Chromatium* grew in enrichment cultures containing sediments from a mangrove community in Florida. This bacterial species was seen with the naked eye as a coating on submerged leaves in mangrove pools.

Two morphological types of purple sulfur bacteria were isolated from the submerged part of the pneumatophores of *Azospirillum germinans* in a semiarid mangrove in Baja California Sur, Mexico. Initial characterization of the two strains of purple sulfur bacteria showed typical profiles of the pigments bacteriochlorophylls *a* and *b* (Holguin G, unpublished data). In another arid mangrove on the coast of the Red Sea in Egypt, 225 isolates of purple non-sulfur bacteria belonging to ten species, representing four different genera, were identified. The strains were isolated from water, mud, and roots of *Azospirillum marina* specimens. Nine of the ten species of purple non-sulfur bacteria inhabited the rhizosphere and the root surface of the trees. The most common genera were *Rhodobacter* and *Rhodopseudomonas*, detected in 73% and 80% of the samples [16]. Although there is yet no published evidence, one can hypothesize those photosynthetic anoxygenic bacteria, the predominant photosynthetic bacteria in mangrove communities, in addition to cyanobacteria, may contribute to the productivity of the mangrove through carbon fixation.

6. PGPR AS BIOCONTROL AGENTS

PGPR are indigenous to soil and the plant rhizosphere and play a major role in the biocontrol of plant pathogens. They can suppress a broad spectrum of bacterial, fungal and nematode diseases. PGPR can also provide protection against viral diseases. The use of PGPR has become a common practice in many regions of the world. Although significant control of plant pathogens has been demonstrated by PGPR in laboratory and greenhouse studies, results in the field have been inconsistent. Recent progress in our understanding of their diversity, colonizing ability, and mechanism of action, formulation and application should facilitate their development as reliable biocontrol agents against plant pathogens. Some of these rhizobacteria may also be used in integrated pest management programmes. Greater application of PGPR is possible in agriculture for biocontrol of plant pathogens and biofertilization [17].

A major group of rhizobacteria with potential for biological control is the *Pseudomonas*. *Pseudomonas* sp. is ubiquitous bacteria in agricultural soils. Tremendous progress has been made in characterizing the process of root colonization by *Pseudomonas*, the biotic and abiotic factors affecting colonization, bacterial traits and genes contributing to rhizosphere competence, and the mechanisms of pathogen suppression [18]. *Pseudomonas* possess many traits that make them well suited as biocontrol and growth-promoting agents. In addition, *Pseudomonas* is responsible for the natural suppressiveness of some soils to soil borne pathogens [19]. The major weakness of *Pseudomonas* as biocontrol agents is their inability to produce resting spores (as do many *Bacillus* spp.), which complicates formulation of the bacteria for commercial use. Fluorescent *Pseudomonas* has been studied for decades for their plant growth-promoting effects through effective suppression of soil borne plant diseases.

Among various biocontrol agents, Fluorescent *Pseudomonas*, equipped with multiple mechanisms for biocontrol of phytopathogens and plant growth promotion, are being used widely as they produce a wide variety of antibiotics, chitinolytic enzymes, growth promoting hormones, siderophores, HCN and catalase, and can solubilize phosphorous. *Pseudomonas fluorescens* MSP-393, a plant growth-promoting rhizobacterium is an efficient biocontrol agent in rice grown in saline soils of coastal ecosystems [20].

Bacillus subtilis is also used as a biocontrol agent. This prevalent inhabitant of soil is widely recognized as a powerful biocontrol agent. In addition, due to its broad host range, its ability to form endospores and produce different biologically active compounds with a broad spectrum of activity, *Bacillus subtilis* as well as other *Bacilli* are potentially useful as biocontrol agents [21]. *Bacillus megaterium* from tea rhizosphere is able to solubilize phosphate, produce IAA, siderophore and antifungal metabolite and thus it helps in the plant growth promotion and reduction of disease intensity. Two strains [*Bacillus thuringiensis (kurstaki)* and *Bacillus sphaericus*] have the ability to solublize inorganic phosphates and help in the control of the lepidopteron pests [22].

Azospirillum spp. is not considered a classic biocontrol agent of soil-borne plant pathogens. However, *Azospirillum brasilense* have moderate capabilities of biocontrolling crown gall-producing *Agrobacterium*; bacterial leaf blight of mulberry [23]; and bacterial leaf and/or vascular tomato diseases. In addition, the proliferation of other non-pathogenic rhizosphere bacteria can be restricted by *Azospirillum brasilense* [24]. These *Azospirillum* antibacterial activities could be related to its already known ability to produce bacteriocins and siderophores. In addition, *Azospirillum brasilense* was recently reported to synthesize phenylacetic acid (PAA), an auxin-like molecule with antimicrobial activity. Recently, actinobacteria residing in plants called endophytic actinomycetes, have been reported as new sources for bioactive compounds and had beneficial effects to the host plant by protecting plant from pathogens [25].

7. CONCLUSION

Worldwide, mangrove ecosystems are an important natural resource that should be protected. The vitality of mangroves is dependent on diverse, and largely unexplored, microbial and faunal activities that transform and recycle nutrients in the ecosystem. Some of the bacteria found in mangrove roots can be used as PGPR to improve the establishment and enhance the growth of mangrove seedlings in arid coastal areas. Plant growth promoting rhizobacteria (PGPR) are a heterogeneous group of bacteria that can be found in the rhizosphere, at root surfaces and in association with roots, which can improve the extent or quality of plant growth directly or indirectly. In last few decades a large array of bacteria including species of *Pseudomonas, Azospirillum, Azotobacter, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Burkholderia, Bacillus, Rhizobium* and *Serratia* have reported to enhance plant growth. The direct promotion by PGPR entails either providing the plant with plant growth promoting substances that are synthesized by the bacterium or facilitating the uptake of certain plant nutrients from the environment.

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