Plant Growth Promotion: Role of Nanoparticles and Soil Microorganisms

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Abstract

Crops intended to support rapidly expanding populations often face numerous harsh environmental conditions. Despite the natural evolution of plants in response to changing environments and ongoing efforts to engineer resistant varieties using the latest research advancements, food scarcity remains a challenge. Cultivating rhizosphere microorganisms presents an alternative strategy for enhancing plant growth and development. Moreover, *engagements between flora and microbes influence both flora's well-being and soil productivity. Autonomous soil bacteria, PGPR, contribute significantly to enhancing plant growth and development. These microbes commonly inhabit plant roots and form nodules, known as nodule-forming bacteria or plant health-promoting bacteria (PHPR). They are commonly found in association with the rhizosphere, creating a microenvironment conducive to plant-microbe interactions. PGPR contributes to sustainable floral growth in three main ways: by aiding in the creation of specific compounds necessary for plant growth, facilitating nutrient uptake from the soil, and protecting plants against pathogens. This article explores various approaches through which microbes and noncompounds positively influence vegetative growth and development.*

Keywords: *Bacteria, nitrogen fixation, Nano compounds, Chemical mixtures, Biosorption.*

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Abbreviations: PGPR: Plant growth-promoting rhizobacteria
PHPR: Plant health-promoting bacteria
LCO: Lipo-cytooligosaccharide
IAA: Indole-3-Acetic Acid
AM fungi: Arbuscular Mycorrhizal Fungi

INTRODUCTION

Microbes have been utilized within farming practices for generations. These bacteria help [1] (1) in supplying nutrients to the plants; (2) in stimulation of phytohormone production (3) in regulating the plant pathogens; (4) in enhancing soil quality (5) in microbial washing out of inorganic compounds. Recently, microbes have also been employed for the bioremediation of polluted soils [2]. Interactions among microbial flora in the rhizosphere have a significant impact on the conversion, mobility, solubility, and other properties of organic and inorganic compounds, ultimately impacting the absorption by plants and positively affecting sustainable yields. Bacteria associated with the rhizosphere are referred to as PGPR, PHPR providing a crucial micro-ecosystem for plant-microbe interactions.

Many researchers have elaborated the potential of the PGPR in facilitating advances in the field of sustainable agricultural approaches. There are different mechanisms of action of PGPR, [3], by helping in the synthesis of certain compounds beneficial for plants by promoting nutrient absorption from the growth medium and by thwarting the plant diseases. To date the fundamental process of PGPR facilitated floral growth and improvement in productivity. It regulates and promotes the growth as well as the life cycle of the plants. Also increases tolerance to stressed conditions like drought [4] high salt concentrations, waterlogged soil [5] and an imbalance between the Reactive Oxygen Species generation and its detoxification and synthesis of vital vitamins micronutrients and phytochemicals substances. Figure 1 shows the diverse activities of floral development promoting bacteria in enhancing floral development.

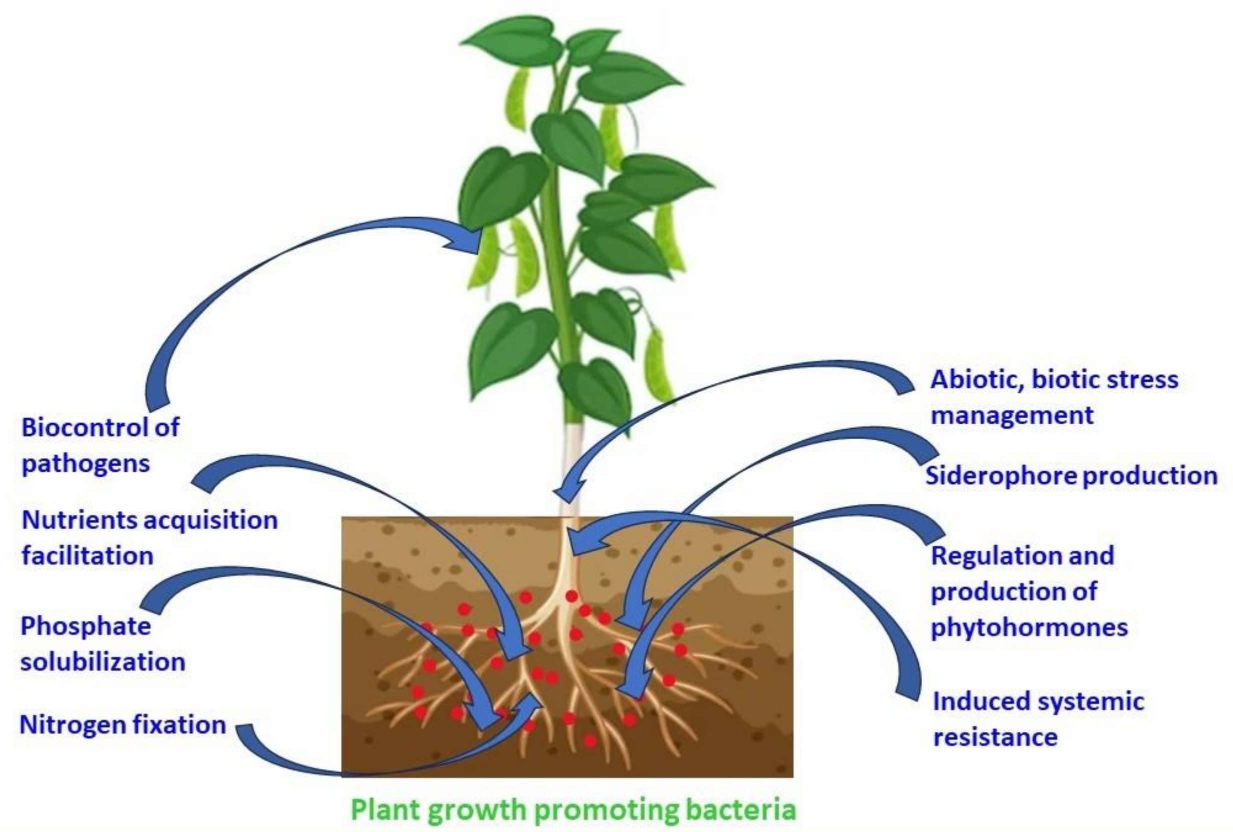

Figure 1. *Diverse Role of Plant Growth Promoting Bacteria (Red Dots) in Soil Region.*

NITROGEN TRANSFORMERS BACTERIA- SYMBIOTIC ASSOCIATION.

Nitrogen is crucial to produce different enzymes, different types of RNA and DNA many types of proteins which plays an indispensable role in floral growth and food/feed production.

The Legumes obtain nitrogen by fixing atmospheric nitrogen with symbiotic rhizobial bacteria.

65% of agricultural nitrogen demand is met through biological nitrogen fixation and will be useful for promoting sustainable agricultural practices. The collaborative linkage of N2-fixing microbes with legumes facilitates biochemical reactions that change nitrogen gas (N2) to NH3 [6]. Plant rhizobia species secrete chemotactically responsive flavonoids. This flavonoid induces the manifestation of the nodulation gene in rhizobia, leading to the lipo-cytooligosaccharide (LCO) signal, which in turn induces mitotic cell division, leading to nodulation. The interdependent symbiotic relationship between Rhizobium and legumes has been studied extensively. Atmospheric nitrogen fixation by rhizobium in green plants facilitates the nitrogen translocation to grown non-legume plants during transplantation. Legumes are important in grass forage systems because they fix N2, which is needed for nitrogen fixation and grass protein synthesis. This helps ensure the quality of feed in livestock production [7]. Rhizobium species such as Rhizobium and Bradyrhizobium promote nitrogen fixation as well as growth hormones and molecules (auxin, cytokinin, abscisic acid, lumichrome, riboflavin, lipochitooligosaccharides and vitamins) [7,8]. Inhabitation of plant roots by rhizobia bacteria contributes to plant growth and productivity. Rhizobia and Bradyrhizobia species have shown the ability to induce the release of plant hormones [9], siderophores, and phosphate solubilization. pathogen [10].

NON-SYMBIOTIC NITROGEN-FIXING BACTERIA

Plant expansion and output of C3 and C4 crops are significantly increased due to growth-promoting rhizobacteria (PGPR). Heterotrophic diazotrophs such as Azotobacter species (Azotobacter vinelandii and Azotobacter chroococcum) depend on a supply of reducing carbon compounds as an energy source [11]. The use of straw in rice cultivation can boost the growth and activity of Azotobacter species [12] in the degradation of cellulose into cellobiose and glucose. Azotobacter has shown potential to increase productivity in rice, cotton, wheat [13,14]. other crops [15]. With reference to other medicinal crops, Solanki et al [16] reported the application of *Azotobacter chrooccoccum* in arid region along with AM fungi in enhancing the nutrient uptake and yield of *Chlorophytum borivillianum.* They described the significant role of *Azotobacter chroococcum* in enhancing the yield and nutrients in *Plantago ovata*. The authors have studied the interaction of *A. chroococcum* along with AM fungi in arid region. The results showed that A. chroococcum bacteria also perform well under arid region. *Azosirillum* has demonstrated positive impacts on the productivity of wheat crop with respect to greenhouse and field conditions [17].

Azospirillum is an aerobic heterotroph inhabiting the rhizosphere of gramineous flora that fixes atmospheric nitrogen in low oxygen environments. The improvement in crop productivity of different host flora is majorly reliant on enhanced uptake of moisture and nutrients through developed roots rather than fixation of atmospheric nitrogen. *Azospirillum brasilense* exhibits both chemotaxis and chemokinesis as a reaction to various chemo effectors' time-based gradients, thus enhancing the likelihood of root-bacterial interactions.

PHOSPHORUS (PH)-SOLUBILIZING BACTERIA

Ph is one of the essentials nutrients for floral growth and reproduction. It is found in both forms (organic and inorganic) in the soil, ranging from 400 to 1200 milligrams per kilogram. PGPR facilitates the alteration of in-dissolvable phosphate into dissolvable complexes and increases its availability to plants. The density of dissolved phosphate in soil is generally low, usually less than 1 ppm [18]. Plants require various forms of phosphorus (P) to grow, and orthophosphate is the most absorbed. In addition, pH and soil type greatly affect phosphorus formation and precipitation. Numerous studies have shown that microbial phosphate excretion can occur from natural phosphate foundation [19]. Certain microbes have been found to have a remarkable skill to dissolve inorganic phosphate compounds. These include tricalcium phosphate, dioxyphosphate, hydroxyl apatite and phosphate rocks. Pseudomonas, Bacillus and Rhizobium species are more easily degraded by phosphate solvents and tricalcium phosphate and hydroxyl apatite than rock phosphate [20]. Bacteria Pseudomonas sp. and Burkholderia cepacia often use certain acids, especially gluconic acid, to dissolve phosphate minerals. 2-Ketogluconic acid, an organic acid, is present in phosphate-solubilizing strains such as Rhizobium leguminosarum, Rhizobium meliloti and Bacillus firma [21]. Rhizobium, including Rhizobium/Bradyrhizobium, show phosphate-solubilizing activity directly related to the synthesis of 2-ketogluconic acid. Furthermore, the ability of acid to dissolve phosphate is eliminated by the simple addition of NaOH, thus proving that the ability of organisms to lower the pH of the medium is the only cause of phosphate-dissolving activity. [22] Kumar and Narula [23] reported on phosphate solubilization by Azotobacter crococci mutants and its effect on wheat seed germination. A. chroococcus strains improved wheat seed germination and phosphate solubilization compared to control (non-isolated treatment). Nevertheless, comprehending the precise biochemical and molecular procedures responsible for phosphate dissolvelization by both free-living and symbiotic nodule bacteria is imperative.

ALTERNATIVE APPROACHES TO STIMULATE PLANT DEVELOPMENT.

Some mutualistic and non-mutualistic bacteria can stimulate floral growth by secreting floral hormones [24] and other flora growth-promoting mechanisms. Rhizobacteria that promote flora growth are accountable for the production and distribution of phytohormones called PGRs, PGRs can affect flora growth and development by influencing physiological processes, even in small amounts. It is widely known that there are five major groups of floral growth controllers, namely auxin, gibberellin, cytokinin, ethene and abscisic acid. The importance of the phytohormone auxin has attracted much attention. IAA can be said to be the most active plant hormone because it induces rapid cell extension and prolonged cell proliferation and specialization response in plants [25]. IAA is a well-known phytohormone that regulates flora development. It is important to note that about 80% of rhizosphere bacteria can produce IAA. Some bacteria like Paenibacillus polymyxa and Azospirillum could generate various compounds in the rhizosphere. These compounds can indirectly contribute to flora development. Recognition and certification of cytokinins, important phytohormones, is challenging due to their limited concentration in biological samples. (Frankenberger and Nieto, reported by running cytokine bioassays.[26]

The primary impact of cytokines on flora is increased cell proliferation; However, it affects root development and rhizoid emergence. [27] Flora and flora-related microbes contain more than 30 genera that produce compounds of the cytokine group. 90% of the microbes found in the rhizosphere were found to be able to release cytokinin when cultivated in vitro. Plants and related microbes have been shown to store more than 30 floral-promoting compounds from the cytokine group. In addition, 90% of microbes present in the rhizosphere can produce cytokinin's when cultured in vitro.

All or most bacteria are believed to be capable of synthesizing ethene. Ethene is a powerful flora development controller that significantly influences various features of floral development, development, and maturity. Furthermore, being a maturation hormone, ethene has a major role in the formation of roots and root hairs, initiation of germination, and prevention of seed drying [28]. High concentrations of ethene after germination inhibit root elongation and root symbiotic N2 fixation [29]. Many floras beneficial microbes have been proposed to do this by reducing ethene levels in plants. Ammonia and α-ketobutyrate, hydrolysis products, can be deployed by bacteria as a depository of nitrogen and carbon for growth. Bacteria serve as a depository for reducing ethene levels in flora and blocking the deleterious effects of high ethene concentrations [5,30].

CONCLUSION

Soil and floral health are highly dependent on the transformation of atmospheric nitrogen by ammonia bacteria. These bacteria are pivotal in the soil nutrient cycle. Soil is home to many bacteria that not only contribute significantly to the nutrient cycle, but also prevent plant diseases. PGPR bacteria stimulates botanical expansion through several indirect mechanisms. phytochemicals altering root modifiers, making them more suitable for nutrient absorption, siderophore production, defense against root pathogens, phosphorus mobilization, and nitrogen assimilation. Studies have yielded positive control reports; however, natural variability (weather and biological) makes it difficult to replicate the effects of PGPR real-world environments. PGPR should be cultivated to improve durability, stability and biological performance in agricultural contexts. In addition, it is recommended to reapply PGPR every year to maintain optimal bacterial growth in the soil.

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