Soil digestive system: functions and benefits of plant growth-promoting rhizobacteria©

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INTRODUCTION

Plant growth-promoting rhizobacteria (PGPR) are soil bacteria that live on or around the root surface. Through their growth and activities, PGPR are directly and indirectly responsible for plant growth, development, and productivity through improvement of nutrient acquisition and uptake, plant hormone modulation, and competitive inhibition which decreases the inhibitory impacts of plant pests and pathogens.

The plant growth promoting rhizobacteria (PGPR), are characterized by the following inherent distinctivenesses: (1) they must be proficient to colonize the root surface; (2) they must survive, multiply, and compete with other microbiota, at least for the time needed to express their plant growth promotion/protection activities; and (3) they must promote plant growth (Kloepper, 1994).

Somers et al. (2004) classified PGPR based on their functional activities as: (1) biofertilizers (increasing the availability of nutrients to plant), (2) phytostimulators (plant growth promotion, generally through phytohormones), (3) rhizoremediators (degrading organic pollutants), and (4) biopesticides (controlling diseases, mainly by the production of antibiotics and antifungal metabolites) (Antoun and Prévost, 2005).

A great deal of research has been, and continues to be, conducted in the field of PGPR, as well as other beneficial soil and rhizosphere organisms. This research, combined with years of tests, trials, and sales, has led to the utilization of PGPR to stimulate production, quality, and sustainability for the agricultural community.

NITROGEN

While approximately 78% of the Earth's atmosphere is comprised of nitrogen, the atmospheric form, N_2, is not directly available to plants. The atmospheric N_2 must first undergo a process known as biological nitrogen fixation (BNF). The BNF process converts N_2 into an ammoniacal form of nitrogen, which can then be utilized by plants.

BNF is carried out through two basic processes: symbiotic, such as rhizobia creating nodules in leguminous plants and Frankia with non-leguminous trees; and free-living BNF undertaken by a number of organisms outside of the plant in the rhizosphere or rhizoplane. According to research conducted by Rubio and Ludden (2008), collectively, symbiotic and free-living nitrogen fixation accounts for well over half of all nitrogen fixed globally.

PHOSPHORUS

Phosphorus is another essential nutrient required for plant growth that is generally present in the environment, but unavailable to the plant. Both the phosphorus that is naturally present in the soil and phosphorus that is applied through fertilization tend to quickly dissipate through leaching into water, become biologically bound in organic forms, or become unavailable by forming insoluble complexes which the plant cannot access.

In order to overcome shortages of phosphorus, many PGPR produce enzymes, organic acids, and other chemical complexes to solubilize the bound organic or insoluble phosphorus from the soil or environment. The PGPR with this ability are known as phosphate solubilizing bacteria (PSB). PSB are considered as promising biofertilizers since they can supply plants with P from sources otherwise poorly available (Ahemad and Kibret, 2014).

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IRON

Iron, like phosphorus, tends to become insoluble in the soil environment, and therefore unavailable to plants and other living organisms. In plants, iron is critical for a variety of enzymes, structures, and for photosynthesis itself. When iron levels become low in the plant, iron chlorosis occurs and leads to reduced production, health, and plant viability.

To access unavailable iron, PGPR produce iron-chelating molecules known as siderophores. These siderophores have the ability to effectively detach iron from insoluble sources and increase bioavailability.

HORMONES

Hormones are signaling molecules utilized by organisms to control and regulate physiological, behavioral, and biochemical reactions. From cell division to control of flowering, hormones play a significant role in almost every aspect of plant growth.

Utilizing these signaling molecules and pathways, PGPR can affect many aspects of plant health and growth, for example, bacterial IAA increases root surface area and length, and thereby provides the plant greater access to soil nutrients (Ahemad and Kibret, 2014). It is reported that 80% of microorganisms isolated from the rhizosphere of various crops possess the ability to synthesize and release auxins as secondary metabolites (Patten and Glick, 1996), which helps highlight how closely the PGPR function in synchrony with the plant's growth systems.

ABIOTIC STRESS REDUCTION

Ethylene's utility as a signaling molecule is widespread throughout plants. It performs as a plant growth regulator and functions as a stress hormone. In general, when biotic and abiotic conditions for growth become less favorable for the plant, ethylene levels will increase and act as an "aging" signal, forcing the plant to mature more quickly for survival.

PGPR can help the plant through stressful times by helping alleviate the stress response and thus lowering the ethylene levels. Plant growth promoting rhizobacteria which possess the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase facilitate plant growth and development by decreasing ethylene levels, inducing salt tolerance, and reducing drought stress in plants (Nadeem et al., 2007; Zahir et al., 2008). Several forms of stress are relieved by ACC deaminase producers, such as effects of phytopathogenic microorganisms (viruses, bacteria, and fungi), and resistance to stress from polyaromatic hydrocarbons, heavy metals, radiation, wounding, insect predation, high salt concentration, draft, extremes of temperature, high light intensity, and flooding (Glick, 2012; Lugtenberg and Kamilova, 2009). As a result, the major noticeable effects of seed/root inoculation with ACC deaminase-producing rhizobacteria are plant root elongation, promotion of shoot growth, and enhancement in rhizobial nodulation and N, P, and K uptake, as well as mycorrhizal colonization in various crops (Nadeem et al., 2007; Shaharoona et al., 2008; Nadeem et al., 2009; Glick, 2012).

While barely scratching the surface, these benefits help to illuminate some of the many ways in which PGPR can help nourish, enhance growth, and alleviate stress for a wide variety of plants with agricultural, horticultural, silvicultural, and ornamental applications, as well as provide other benefits to both people and the environment.

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