Importance of Bacteria in Agriculture

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Introduction

Soil microorganisms such as fungi and bacteria interact with plant root and soil constituents in the root - soil interface and facilitate directly or indirectly the availability of certain nutrients to the plants as well as produce plant hormones to promote plant growth and antimicrobial compounds to protect the plants from biotic stresses.

Chemical fertilizers and pesticides lead to substantial cost to agriculture around the world. As a result, using microorganisms as inoculants to the boost plant development, mobilize nutrients into the soil and to withstand biotic and abiotic challenges has been discovered to be a viable option for reducing environment pollution and to increase the crop productivity. Among the soil microorganisms, bacteria provide a variety of ecological services, including improving of soil structure and aggregation, soil nutrients recycling and water recycling. Soil bacteria bind soil particles together using their secretions to produce micro aggregates in the soil. These aggregates are the components that make up soil and contribute to its stability. Well aggregated soil has better soil health and ensures higher agronomic production, is less prone to soil erosion and can help with carbon sequestration. Importance of certain group of beneficial bacteria that are helpful in agriculture has been elaborated below.

1. Nitrogen fixing bacteria: Despite the fact that nitrogen is a necessary component of life, most organisms cannot absorb it from the environment. Nitrogen-fixing bacteria remove nitrogen from the environment and make it available to other organisms for ingestion. Nitrogen gas must be converted to nitrate, which can be absorbed by the plants through their roots. Nitrogen fixation is the process of converting nitrogen gas to nitrates, which is carried out by nitrogen fixing bacteria. In general, there are two types of nitrogen fixing bacteria. (i). Free living (non symbiotic) bacteria (*Azotobacter*, *Azospirillum*, *Cyanobacteria*, *Beijerinckia* and *Clostridium*) and (ii). mutualistic (symbiotic) bacterium (*Rhizobium*, *Frankia*) associated with leguminous plants. These bacteria produce unique nitrogenase enzyme responsible for nitrogen fixation, which converts atmospheric nitrogen into ammonia, which plants can easily absorb.

2. Phosphorus solubilizing bacteria: The primary function of phosphorus is to store and transfer energy produced by photosynthesis for use in the growth and reproduction processes of the plants. Root growth and winter hardiness in the plants are aided by adequate 'P' levels, which also encourage tillering and accelerate maturity of the plants. Despite its abundance in both inorganic and organic forms, phosphorus is the limiting element for plant development. Soluble phosphorus combines with ions like calcium, iron, and aluminium to form precipitation or fixation, which decreases the availability of these elements to the plants. Inorganic chemical phosphate fertilizers become immobilized in the soil, making them unavailable to crops. As a result, increasing the amount of nutrients available to plants requires the solubilization of phosphorus by soil microorganisms. Phosphorus solubilizing microorganisms compensate upto 40% of the soil bacterial population and they play a significant role in solubilizing and mineralizing poorly accessible phosphorus. Phosphorus solubilizing bacteria such as *Pseudomonas* spp., *Agrobacterium* spp., *Bacillus* spp., *Burkholderia*, *Micrococcus*, *Aerobacter, Azotobacter, Paenibacillus, Enterobacter, Rhodococcus, Serratia, Bradyrhizobium, Ralstonia, Rhizobium, Salmonella, Sinomonas* and *Thiobacillus* (Babalola and Click, 2012; Postma *et al.,* 2010; David *et al.,* 2014) play a major role in solubilizing Phosphorus. They solubilize insoluble inorganic (mineral) phosphorus and mineralize insoluble organic phosphorus and make their bioavailability to the plants (Sharma *et al.*, 2013). Plants benefit from phosphorus solubilizing bacteria since they improve the effectiveness of biological nitrogen fixation, synthesize phytohormones and increase the availability of trace metals like zinc and iron (Wani *et al.*, 2007).

3. Zinc solubilizing bacteria: Zinc deficiency in the soil is one of the most prevalent micronutrient deficiencies and it leads to lower crop yields. Majority of agricultural soils are zinc deficient or contain zinc in a fixed form that is inaccessible to the plants, indicating zinc inadequacy in plants and soils. Zinc solubilizing bacteria are a viable zinc supplementation alternative because they transform applied inorganic zinc to usable forms. Bacterial strains that have been reported to show zinc solubilization include *Pseudomonas aeruginosa* (Fasim *et al.,* 2002), *Gluconacetobacter diazotrophicus* (Saravanan *et al*., 2007), *Bacillus* spp., *Pseudomonas fluorescence*, *Pseudomonas striata*, *Burkholderia cenocepacia* and *Serratia* (Pawar *et al*., 2015). These bacteria solubilize the insoluble zinc sources such as ZnO, $ZnCO_3$ and $Zn_3(PO_4)_2$ and $ZnSo_4$ (Saravanan *et al*., 2007).

4. Potassium solubilizing bacteria: Potassium (K) is an essential nutrient and an important component of all living cells. Although soil contains more K than any other nutrient, majority of the K is unavailable for plants to absorb. Potassium solubilizing bacteria solubilize potassium bearing minerals and convert insoluble K into soluble forms that plants can absorb. The bacteria such as *Acidothiobacillus ferrooxidans, Paenibacillus* spp., *Bacillus mucilaginosus*, *B. edaphicus* and *B. circulans* solubilize K minerals (biotite, feldspar, illite, muscovite, orthoclase and mica). Through the production of organic and inorganic acids, acidolysis, polysaccharides, complexolysis, chelation and exchange processes, KSB dissolve silicate minerals to release K (Etesami *et al*., 2017) and it has been observed that inoculation with KSB had a favourable effect on plant growth (Ahmad *et al*., 2016; Bakhshandeh *et al*., 2017; Xiao *et al*., 2017).

5. Bacteria in alleviating biotic stresses: Plant defenses have been reported to be elicited by *Pseudomonas* and *Bacillus* strains. To prevent plant pathogens infection, these organisms produce antimicrobial compounds and secrete extracellular cell wall lytic enzymes. When plants are exposed to biotic stresses, these PGPR activate the expression of dormant defensive mechanisms by activating the synthesis of signaling molecules such as salicylic acid, jasmonic acid and ethylene (Nie *et al.,* 2017). They also decrease biotic stresses in plants by producing antimicrobial compounds such as pyrrolnitrin, pyoluteorin and 2,4-DAPG.

6. Bacteria in alleviating abiotic stresses: Abiotic stresses are the primary constraint to agricultural productivity. Crop plants use their innate systems to cope with the external demands imposed by the environment and edaphic conditions. Microbial interactions with plants are an important aspect of the living ecosystem because they influence local and systemic mechanisms in plants to provide protection from external environmental factors. *Pseudomonas*, *Bacillus*, *Rhizobium* and other rhizobacteria associated with roots elicit so called induced systemic tolerance to drought, salt, heat stress and chilling injury (Yang *et al.,* 2009).

7. Bacterial biofertilizers: In general, bacterial biofertilizers can improve plant growth through a variety of mechanisms, including the synthesis of plant nutrients or phytohormones that can be absorbed by plants. Mobilization of soil compounds can be used as nutrients by the plants which will aid in protecting the plants under stressful conditions, thereby mitigating the negative effects of both biotic and abiotic stresses. In agriculture, rhizosphere bacterial strains with various plant growth promoting properties can be used as biofertilizers to boost crop yields. For many years, several plant growths promoting rhizobacteria (PGPR) have been utilized as biofertilizers around the world, helping to increase crop yields and soil fertility and contributing to more sustainable agriculture. The technologies for producing and applying bacterial biofertilizers are constantly evolving in recent days and the market for bacterial based biofertilizers is expanding as well.

Conclusion

Microbial inoculants represent a novel approach to achieve a more sustainable and efficient agriculture that benefits both society and farmers. This is the technique that is in line with the concepts of sustainable agriculture and strives to address recent pesticide and fertilizer overuse. As a result, using bacteria as biofertilizers that can boost plant development is portrayed as a more viable option. The use of biofertilizers results in a healthier crop that is also more resistant to both biotic and abiotic stresses.

As a result, inoculating soil or crops with bacteria biofertilizers is a promising technique for improving plant growth through the absorption of necessary nutrients while reducing the usage of environmentally harmful chemical fertilizers (Alori *et al*., 2012) and bacterial fertilizers containing effective bacterial inoculum can be a viable alternative to chemical fertilizers in terms of crop production and pests and diseases management.

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