Role of Bio-Fertilizers in Agriculture

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Abstract

Worldwide human population growth presents a major threat to each people's food security as the land for agriculture becomes scarce and even decreased over time. It is therefore important that agricultural production be enhanced significantly in the next few decades in order to meet the growing demand for food by the increasing population. Too much reliance on chemical fertilizers for more crop yields ultimately destroys with considerable severity both the natural ecosystem and human health. The use of microbes as bio-fertilizers in the agricultural sector is considered to some degree an alternative to chemical fertilizers owing to their significant capacity for increasing productivity and food safety. Some microorganisms, like plant growth stimulating fungi, bacteria, cyanobacteria, etc., have shown bio-fertilizer-like behaviour in the farming sector. Extensive work on bio fertilizers has shown their potential to provide necessary quantities of to the crop in sufficient nutrients that have led to increased crop yields. The present analysis clarifies different mechanisms that bio-fertilizers have practiced to foster plant growth and also offers protection to different pathogens of plant.

Key words: Agriculture, Bio-fertilizers, Crop Production, Eco-system, Food security, Human health

Introduction

There are reportedly about 6 billion people living in the world, and this amount is expected to rise to around 7 billion by 2020. With the projected increase of world population, as a consequence of rapid growth of urbanization and industrialization, damage to the environment is growing. Nevertheless, feeding the large population already represents a significant obstacle, which will gradually increase over time.However, the massive use of chemical fertilizers in cultivation makes the country self-dependent in supplying vast amounts of food supplies but at the same time massively damages the environment and has harmful effects on living beings. The indiscriminate use of chemical fertilizer by polluting air, water, and land shows great danger to the environment. Since the plants cannot take up these hazardous chemicals, they start accumulating in soil and some of these contaminants are also responsible for causing water bodies to eutrophise.

Such contaminants have an adverse effect on soil in terms of water carrying power loss, surface productivity, decreased salinity and soil nutrient difference. Taking into account all the adverse effects of excessive use of chemical fertilizers, organic farming has emerged as a promising alternative area in terms of growing demand for healthy food supply, long-term sustainability and environmental pollution issues. While the use of chemical fertilizers is unavoidable in order to meet the world's growing demand for food, there are opportunities where certain chosen crops and niches will thrive well through organic farming.

A bio-fertilizer is a material that includes live microorganisms that colonize the rhizosphere or the inside of the plants when added to plants, crops, soil, and encourage plant growth by growing nutrient supply to the host plant. Bio-fertilizers are commonly used to speed up microbial processes that maximize nutritional supply that plants can readily assimilate. Through fixing atmospheric nitrogen and solubilizing insoluble phosphates, they increase soil fertility, and generate plant growth-promoting compounds in soil.Such bio-fertilizers were encouraged to harvest the naturally accessible biological nutrient mobilization mechanism which increases fertility of soil enormously and ultimately crop yield. This study also highlights the potentialities of bio-fertilizers in various sectors like agriculture, biodiversity, and restoration which can create bio-fertilizer as a promising resource for sustainable development in agriculture.

1. Need of Bio-Fertilizers:

The indiscriminate use of chemical fertilizers to satisfy the growing demand for food supplies has inevitably resulted in pollution and seriously damaging natural environments and insects. Nevertheless, the effect of using unnecessary chemical additives has made the crops more susceptible to disease and less soil fertility. It is projected that by 2021, the demand for nutrients will be 27.8 million tons, while the supply will be only 20.5 million tons, producing a shortfall of about 7.1 million tons of required nutrients, to meet the planned output of 320 million tons of food grain to feed 8 billion populations worldwide.

To serve the increasing population with the deficit volume of nutrients accessible, the world certainly requires to expand agricultural productivity, and that too, in a safe and environment-friendly manner. Therefore, many of the current farming methods including the use of chemical fertilizers, herbicides, chemicals, insecticides and fungicides will eventually be re-evaluated. Bio-fertilizers are supposed to be a safe substitute to conventional inputs, taking into account the harmful consequences of chemical fertilizers, which significantly minimizes ecological disruption. Bio-fertilizers are in their essence cost-effective, environmentally friendly and their sustained usage greatly enhances soil fertility.

Bio-fertilizer use has been documented to raise crop yield by growing protein content, vitamins, essential amino acids, and nitrogen fixation to around 20–30 per cent. The advantages of using bio-fertilizers include inexpensive nitrogen supply, outstanding supplies of micro-chemicals and micronutrients, organic matter sources, growth hormone production, and counteracting the negative impact of chemical fertilizers. Different microbes are vital components of the soil and play a crucial role in different soil ecosystem biotic activities which render the soil dynamic for mobilization of nutrients and sustainable for crop production.

2. Plant growth-promoting bacteria:

"Plant growth-promoting bacteria" (PGPB) involve free-living bacteria that establish unique symbiotic relationships with plants, bacterial endophytes that may colonize on certain portions of plant tissue, and cyanobacteria. Even though all the bacteria vary in different ways from each other, they all show the same processes when fostering bacterial growth. The researchers will specifically promote growth by either promoting the accumulation of capital or altering plant hormone levels, and indirectly growing the inhibitory effects of various pathogenic agents on plant growth and development (Fig.1).

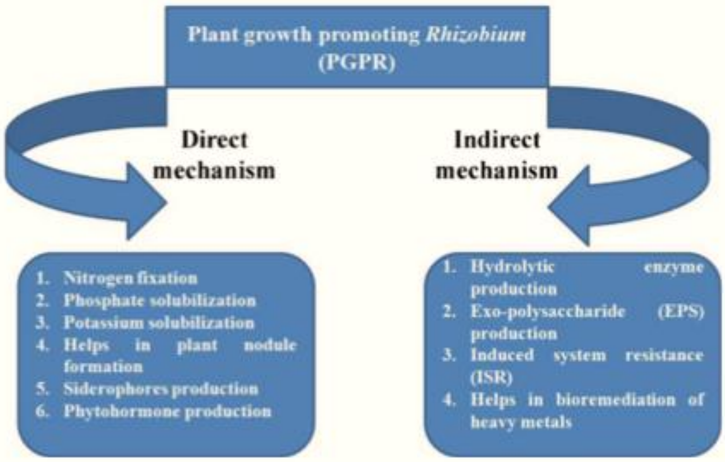

Fig.1: Plant growth-enhancing mechanisms of plant growth-promoting rhizo-bacteria (PGPR)

3. Promoting plant's growth by rhizo-bacteria:

The bio-fertilizer plays an important role in fixing nitrogen, sequestrating iron and solubilizing phosphate, rendering these complex organic compounds usable for use by the plants.

i) Nitrogen fixation:

Nitrogen is termed as most essential nutrients for productivity and growth of plants. While N2 is present in the atmosphere at 77 per cent, it remains inaccessible for plant application. To use the atmospheric nitrogen, the nitrogen must be transformed for ammonia that can be readily assimilated by plants through the biological nitrogen fixation (BNF) cycle. During BNF, nitrogen-fixing microorganisms use an enzymatic complex known as nitrogenise to transform atmospheric nitrogen to ammonia[1].The species which fix nitrogen are known as non-symbiotic and symbiotic. Symbiotic organisms involve Rhizobiaceae representatives that form a symbiotic relationship with the plants which are leguminous. Non-symbiotic organisms, on the other, involve free-living and endophytic types of micro-organisms including cyanobacteria, azotobacter, azospirillum, etc. [2].

Rhizobium Symbiotic N2-fixing rhizobacteria refer to the genus of rhizobiaceae (α-proteobacteria), which infects and develops a symbiotic relationship with the leguminous plant roots[3]. This establishment involves a complex interplay between the host and the symbiont culminating in nodule development in which Rhizobia colonizes as a symbiont intracellular. Rhizobium, Azorhizobium, Brady-rhizobium, Meso-rhizobium, and Sino-rhizobium are called Rhizobia as a collective term. Often named diazotrophsare non-symbiont rhizobacteria that trap nitrogen in non-leguminous plants, and are capable of forming a non-obligatory relationship with the host plants[4].The cycle of nitrogen fixation is performed by the structure of complex enzyme, nitrogenase, which consists of iron-containing dinitrogenase reductase (Fe) as its cofactor and molybdenum (Mo) and iron (Fe) as its cofactor. The nitrogen fixation schematic diagram by nitrogenase enzyme is provided in Fig. 2. Dinitrogenase reductase supplies electrons and these electrons are used to convert N2 to NH3 via dinitrogenase. There are three different types of nitrogenase complexes, such as Mo-nitrogenase, Fenitrogenase, and V-nitrogenase, identified depending on the variability in the dinitrogenase cofactor[5].

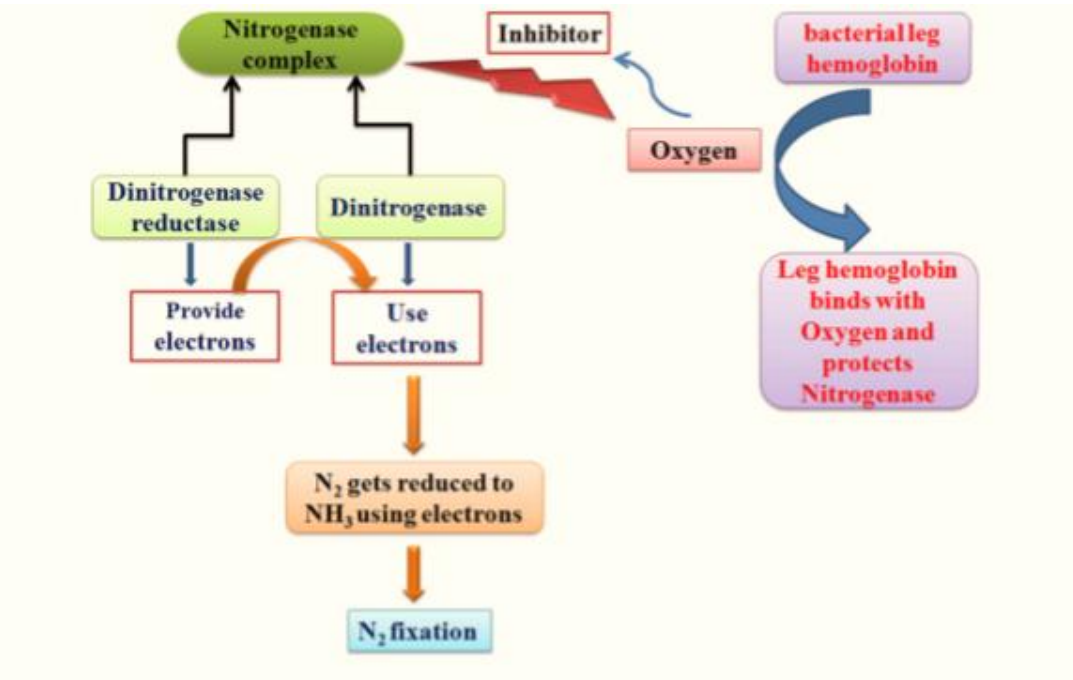

Fig. 2: Molecular N2 fixation mechanism by plant growth-promoting rhizobacteria

Nif genes comprises of structural genes involved in Fe protein activation, electron donation, Fe-Mo cofactor biosynthesis, and regulating genes necessary for the enzyme's synthesis and action. Because oxygen is a negative regulator of the expression of the nif gene, Rhizobium sp needs this bacteroid respiration[6]. Haemoglobin in the bacterial leg will bind to high affinity oxygen to prevent the enzyme from oxygen working (Fig. 2).Therefore, adequate supply of O2 to the bacteroid for breathing and protection of O2 supply to the nitrogenase enzyme complex should be performed simultaneously to successfully follow the nitrogen fixation method. The easiest way to accomplish this function is to add bacterial Hb which by genetic engineering binds O2 to the rhizobacteria[7].

ii) Phosphate solubilisation:

Due to the presence of phosphorus in huge amounts in the soil, most of this phosphorus is soluble and therefore remains unable to support plant growth, as plants only consume it in two soluble types-dibasic and monobasic. Insoluble phosphorus is either present as inorganic material such as apatite, or as one of several organic forms including inositol phosphate (soil phytate), phosphomonoesters, and phosphotriesters. However, much of the soluble inorganic phosphorus used as chemical fertilizers will be immobilised shortly after it is added to the ground.It thus is useless to plants, and thus gets wasted. This has contributed to the hunt for environmentally friendly and cost-effective solutions to increase crop production in less phosphorous soils. In these cases, microbes capable of solubilizing inorganic phosphorus play a pivotal role throughout supplying phosphorus to the plants as a viable replacement. These are therefore considered a successful bio-fertilizer because they can provide plants with sufficient phosphorus even from poor sources[8].

a) Phosphate solubilizers:

Due to the action of low molecular weight organic acids such as citric acids and gluconic that are synthesized by different soil bacteria, inorganic phosphorus solubilisation exists. In Fig.3, the schematic diagram of microorganism solubilisation of phosphate is shown. Such low molecular weight organic acids include groups of hydroxyl and carboxyl, which can chelate the phosphate-bound cations that aid in the transfer of insoluble phosphorus to its soluble form. On the other side, organic phosphorus mineralization is achieved through the synthesis of numerous phosphatases, which catalyse the hydrolysis of phosphoric esters.Most notably, the mineralization and solubilisation of phosphate can coexist within the same bacterial strain. Pseudomonas, Rhizobium, Bacillus, Burkholderia, Agrobacterium, Achromobacter, Micrococcus, Flavobacterium, Acetobacterium, and Erwinia are among the bacteria that have the ability to solubilize insoluble inorganic phosphorus. In addition, inconsiderable quantities of phosphate-solubilizing bacteria can be contained in soils and plant rhizosphere.It encompasses both aerobic and anaerobic strains of aerobic pressure occurrence in underwater soils. Nonetheless, higher concentrations of phosphate-solubilizing bacteria (PSB) have been identified generally in the rhizosphere compared to non-rhizosphere soil. PSB also improves the effectiveness of “Biological Nitrogen Fixation” (BNF) through nitrogen-fixing microorganisms in addition to providing phosphorus in soluble form to plants[9].

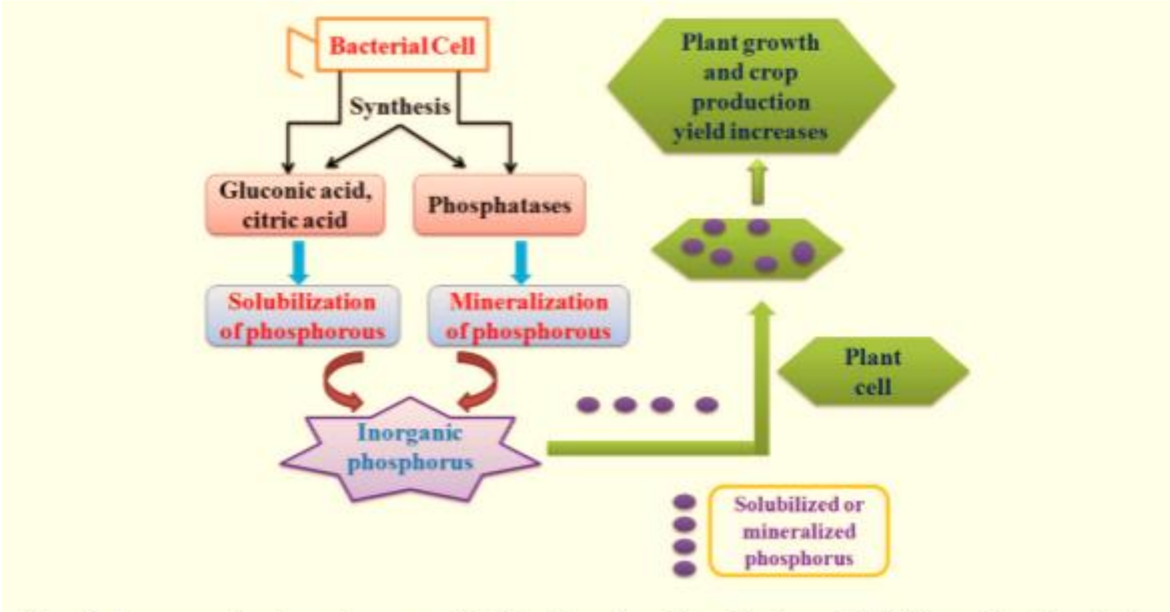

Fig. 3: Inorganic phosphorus solubilisation by phosphate-solubilizing rhizobacteria.

4. Bio-fertilizer's role in photosynthesis:

Better photosynthesis shows improved plant growth as approximately 80 per cent of plant biomass is produced by photosynthesis from CO2 assimilation. Bio-fertilizer inoculation namely "R. leguminosarum," "Rhizobium sp. IRBG 74," and "Brady-rhizobium sp. IRBG 271" improved the photosynthetic output of single-leaf plants relative to un-inoculated controls. Among the three candidates examined, IRBG strain displayed the plant's highest improvement in photosynthetic activity (13 per cent) compared with the un-inoculated control plant.

Some test strains of Rhizobia have been documented to significantly increase the surface area of plant leaves, net plant photosynthetic output, stomatal conductance, and efficiency in water utilization, suggesting that rhizobial inoculation of rice will significantly increase plant photosynthetic ability.

5. Bio-fertilizer's impact on eco-system:

While bio-fertilizers have been commonly used in agriculture for the last few decades, knowledge is poorly understood regarding their colonization and ecology. In fact, the process behind their contact with plant and resident microbial culture appears to be a subject of people's interest. The existence of endogenous microflora in rhizosphere is one of the main factors that determine the bio-fertilizer's effectiveness in natural systems. This highly competitive population of different rhizosphere species will influence the survival and development of plants promoting bio-fertilizer products[10].

In addition, bacterization of seeds and seedlings or soil modifications can bring about changes in the structure of indigenous microflora, which is important to remember as regards the protection of introducing the bacteria into the area. Finally, the non-target impact, which is characterized as the effect of microbial bio-fertilizer on species other than target pathogens, the effect on biogeochemical cycles, the effect on soil texture, soil properties like water retaining ability, porosity and fertility, erosion prevention should be carefully considered[11].

Conclusion

Stresses induced in environment are becoming a big problem and crop productivity is decreasing at an unprecedented rate as a negative consequence of the result. Too much reliance on industrial fertilizers and pesticides to quench the immense demand for food by growing populations has driven the factories to manufacture life-threatening chemicals as pesticides or fertilizers. Such pollutants are not only harmful to human consumption but also have a serious impact on the environmental balance.Bio-fertilizer can serve as a powerful solution in this adverse circumstance that can not only feed the growing populace but can also save agriculture from the intensity of various environmental stresses. It is therefore necessary to realize the various significant and beneficial facets of bio-fertilizers, and to incorporate their use in modern agriculture. While bio-fertilizers have a tremendous potential to increase the productivity of agricultural land, the coordinated approach to determining the most desirable relationship between plant micro-organisms is the most crucial factor resulting in increased productivity.

The new technology arose from using a strong molecular biotechnology method that can play a pivotal role in the analysis of the most beneficial relationship between plant and microorganism. Nevertheless, the recent advances in technology-related microbial research, plant pathogen interactions, genetic engineering and genomics will also help optimize the protocols needed for bio-fertilizer use. It must be noted that although bio-fertilizer use is flourishing with great acceleration, the technology is still nascent and developing.

References

1. J. Vacheron et al., “Plant growth-promoting rhizobacteria and root system functioning,” Front. Plant Sci., 2013.
2. S. M. Nadeem, M. Ahmad, Z. A. Zahir, A. Javaid, and M. Ashraf, “The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments,” Biotechnology Advances. 2014.
3. B. Allito, E.-M. Nana, and A. Alemneh, “Rhizobia Strain and Legume Genome Interaction Effects on Nitrogen Fixation and Yield of Grain Legume: A Review,” Mol. Soil Biol., 2015.
4. “Plant Growth Promoting Rhizobacteria: A Critical Review,” Life Sci. Med. Res., 2011.
5. W. T. Hong, R. E. Welsch, and Y. Shao-Horn, “Descriptors of Oxygen-Evolution Activity for Oxides: A Statistical Evaluation,” J. Phys. Chem. C, 2016.
6. C. Santi, D. Bogusz, and C. Franche, “Biological nitrogen fixation in non-legume plants,” Annals of Botany. 2013.
7. M. Ahemad and M. Kibret, “Mechanisms and applications of plant growth promoting rhizobacteria: Current perspective,” Journal of King Saud University - Science. 2014.

8. D. Muleta, F. Assefa, E. Börjesson, and U. Granhall, "Phosphate-solubilising rhizobacteria associated with Coffea arabica L. in natural coffee forests of southwestern Ethiopia," J. Saudi Soc. Agric. Sci., 2013.
9. L. Y. Yu et al., "Novel phosphate-solubilising bacteria isolated from sewage sludge and the mechanism of phosphate solubilisation," Sci. Total Environ., 2019.
10. M. E. Hibbing, C. Fuqua, M. R. Parsek, and S. B. Peterson, "Bacterial competition: Surviving and thriving in the microbial jungle," Nature Reviews Microbiology. 2010.
11. N. Eisenhauer, P. B. Reich, and S. Scheu, "Increasing plant diversity effects on productivity with time due to delayed soil biota effects on plants," Basic Appl. Ecol., 2012.