Chapter

Application of Bacteria as a Prominent Source of Biofertilizers

Prabakaran Elavarasi, Muthuraman Yuvaraj and Pandurangan Gayathri

Abstract

There are different types of microorganisms are used in the biofertilizers. Biofertilizers being essential components of organic farming play vital role in maintaining long-term soil fertility and sustainability; biofertilizers would be the viable option for farmers to increase productivity per unit area. These potential biological fertilizers would play a key role in productivity and sustainability of soil and also in protecting the environment as eco-friendly and cost-effective inputs for the farmers. At the same time, overlooking the significance of ensuring and maintaining a high quality standard of the product will have negative impact. Hence, a proper knowledge of bio-inoculants and its functioning will pave way to tape the resources in a better way. Thus, the chapter provides overview knowledge about different bacterial biofertilizers, its associations with plants and transformations of nutrients in soil. Adopting a rational approach to use and management of microbial fertilizers in sustainable agriculture thrives vast potential for the future.

Keywords: biofertilizers, microorganisms, rhizobium, mycorrhiza, biological nitrogen fixation

1. Introduction

One of the present day challenges in agriculture is eco-friendly practices. Though the benefits of Green revolution have been reaped by us in terms of production, the other side of it i.e., over usage of chemical fertilizers and its subsequent deterioration of soil health has been realized these days [1]. Hence, awareness of practicing organic agriculture has been taken to various spheres and products of organic agriculture are fetching up huge market. One of the organic agriculture practices includes usage of biofertilizers in farming [2]. The biofertilizers has several other advantages as well like they are cost effective, eco-friendly and renewable source of plant nutrients hence forms one of the important components of integrated nutrient management. As of now we could not claim bio-inoculants as a right alternative to chemical fertilizers but in near future the scientific understanding of the same will pave way for its right use and reap full benefits [3]. In addition to this in global scale, recent published works on bio fertilizers states about the varied role of bio-inoculants *viz.*, other than nutrient transformations in different crops. To mention few, increase in root growth has been observed in wheat due to inoculation of bio-inoculant consortia. The *Rhizobium* inoculation increases deaminase activity in pulses crops. Hence this chapter focuses on different bio-inoculants and its uses in farming.

2. Importance of soil microbes in nutrient transformations

It is well established fact that soil microbes have versatile enzyme systems hence perform various nutrient transformations in soil which is very important for maintaining soil equilibrium and its health. Among the nutrient transformations, nitrogen and phosphors transformations forms significant importance, since they are the major plant nutrients derived from the soil.

3. Biological nitrogen fixation

Biological nitrogen fixation is a component of nitrogen cycle which involves fixing up of atmospheric nitrogen by particular soil microorganisms. Nitrogen fixing ability has been restricted only to certain bacteria and few actinomycetes which belong to various groups and they are referred to as diazotrophs. The diazotrophic microbes are ubiquitous to soil and are classified according to mode of nitrogen fixation to plants.

The process of biological nitrogen fixation has been first documented in anaerobic bacterium *Clostridium pasteurianum* from which the enzyme nitrogenase has been isolated. However, today, the organism has not been commercially used for the purpose. The nitrogen fixation is mediated by nitrogenase enzyme which reduces gaseous nitrogen to ammonia. All diazotrophs seemed to possess the enzyme and found to deliver quite similar mechanism of nitrogen fixation.

4. Phosphorus solubilizing bio-inoculants

The fate of phosphorus is that it forms apatites with the salts present in the soil. In acid soil phosphorus will becomes Aluminium phosphates and Iron phosphates while in alkaline soils it becomes calcium phosphates or sodium phosphates and becomes unavailable to plants. In order to make these form of phosphorus to available form some of the bio-inoculants produces organic acids which convert them to soluble form like hypophosphites which can be taken by plants. Examples of phosphorus solubilising bacteria: *Bacillus megatherium var phosphaticum*, *Bacillus megaterium* var. *phosphaticum*, *Bacillus subtilis*, *Bacillus circulans*, *Pseudomonas striata*.

5. Phosphorus mobilising bacteria

The soil microorganisms able to solubilize precipitated forms of P or mineralize organic P has been characterized. The most important phosphorus mobilising bacteria is *Pseudomonas* and *Bacillus* being predominant. These organisms ordinarily related to the rhizosphere and, when inoculated onto plants, often result in improved growth and P nutrition with responses being observed under both glasshouse and field conditions. Despite this, there are few examples of successful application of microbial inoculants. Essentially, a lack of consistent performance under different environmental conditions in the field has precluded their wider use. A number of things may be known to clarify this variable performance [4].

The *Bacillus spp*. convert the complex form of essential nutrients, such as P and N, to a simple available form that is used during uptake by plant roots [5, 6]. Phosphate is involved in nucleic acid, phospholipid, and adenosine triphosphate (ATP) metabolism, among other metabolic pathways, in plant cells. The secretion

Bacillus species	Plant growth promotion	References
B. insolitus, *B. subtilis*, *B. methylotrophicus*	Increase the length and biomass of shoot, root and leaves	[18]
B. megaterium, *B. subtilis*	Enhance fruit and grains yield	[6]
B. pumilus, *B. megaterium*	Solubilize the P and fix the N in soil and increase their transport to roots	[20]

Table 1.
Biofertilizer effect of Bacillus spp *on crop plants.*

of phosphatases and organic acids from *Bacillus spp.* acidifies the surrounding environment to facilitate the conversion of inorganic phosphate into free phosphate [7, 8]. Additionally, N is an important component of proteins, nucleic acids and other organic compounds in plants, and the available form of N in soil is limited, which slows plant growth in natural habitats. Some of the Bacillus spp. release ammonia from nitrogenous organic matter [9]. The *Bacillus spp*. have the nif H gene and produce nitrogenase (EC 1.18.6.1), which can fix atmospheric N_2 and provide it to plants to enhance plant growth and yield by delaying senescence [10]. The iron-chelating properties of Bacillus spp. via siderophore production help to solubilize iron from minerals and organic compounds in rhizospheres [11]. Siderophores bind Fe^{3+} in complex substances and reduce the Fe^{3+} to Fe^{2+} which then enters plants (**Table 1**).

Seed germination is regulated by sugars, nitrate, and phytohormones, such as auxin, cytokinins, ethylene, abscisic acid (ABA), GAs, brassinosteroid (BR) and light [12, 13]. Salt deposition in soil decreases the osmotic potential of the growth medium for plants and reduces the water availability [14]. Plants respond to salt-induced osmotic stress by closing their stomata, thus limiting the loss of cellular water content and gas exchange, which reduces the photosynthetic rate.

6. Plant growth promoting rhizobacteria (PGPR)

Plant growth promoting rhizobacteria (PGPR) a heterogeneous group of microorganisms are known to improve plant growth by their ability to colonize the rhizosphere besides their effect as biocontrol agents and producers of plant hormones. PGPR also alter the plant physiological processes resulting in enhanced nutrient uptake. These organisms possess the ability to produce siderosphere, a class of high affinity iron transport molecules which also act as a growth promoting factor. The ability of PGPR to produce siderophore or to affect the activity of siderophores produced by under Fe-deficient condition siderophore producing pseudomonads form a yellow, green fluorescent siderophore iron complex. A few microorganisms are known to chelate iron through production of siderophores. The well-known PGPR include *Azotobacter, Azospirillum, Azoarcus, Klebsiella, Bacillus, Pseudomonas, Arthrobacter, Enterobacter, Burkholderia, Serratia*, and *Rhizobium* [15].

7. Important diazotrophs in commercial use

Rhizobium is the most studied bio-inoculant which forms symbiotic association with legume plants. It was first shown by Boussingault that leguminous plant can fix atmosphere N2 which hellriegel and wilfarth clarified that the process is done by bacteria residing in the roots of leguminous plants. The purified bacterium was put into various examinations and now well-developed nitrogen fixing strains are available in various commercial production units.

This bio-inoculant is specific for legume crops and forms nodules in the roots of the plants. It enriches the soil fertility also after harvesting of the crop. Hence it is the most preferred bioincoulant. Other than root nodulating *Rhizobium* some of the strains found to nodulate stem known as *Azorhizobium* present in *Sesbania rostrata.* Rhizobium species are specific to legume crops because of nod factors they produce. However, some leguminous plants found to develop effective nodules on inoculation with the *Rhizobia* obtained from the nodules from other legume groups, which are referred to as cross inoculation grouping [16].

8. *Azospirillum*

Azospirillum is considered as very important diazotrophs as it form associative symbiotic relationship with the roots of graminaceous plants. It is generally recommended for rice crop. The organism is microaerophillic, some are aerobic motile and gram negative in nature hence suits well for rice field conditions. It was first isolated by Beijernick and was named as *Spririllum lipoferum* later named as *Azospirillum.* In addition to nitrogen fixing ability, they also produce growth promoting substances such as indole acetic acid [17]. Some of the important species of *Azospirillum* has been listed below:

- *A. brasilense*
- *A. lipoferum*
- *A. amazonense*
- *A. halopraeferens*
- *A. irkense*
- *A. dobereinerae*
- *A. largimobilis*

9. *Azotobacter*

Azotobacter are gram-negative free living bacterium in the rhizosphere soil of many plant species, discovered by Beijernick. The bacterium is very well recognised diazotroph and fixes atmospheric nitrogen in its habitat. Owing to its versatile adaptability and nitrogen fixing ability, they are commercially used in agriculture for many crops and are known with a brand name azotobacterin. Some species of *Azotobacter* known to produce alginic acid, a compound used in medical industry and in food industry it is used as additive in ice creams and cakes. Apart from its nitrogen fixing ability, it also synthesise many phytohormones such as auxins and helps in promoting growth of the plants. They are involved in mobilising heavy metals in the soil thus used for bioremediation purposes as well. Many species of *Azotobacter* are pigment producers and found to degrade aromatic compounds in the agriculture lands [18].

10. Gluconoacterobacter diazotrophics

They are endotrophic bacterium which resides insides the stem of sugarcane as it prefers high sucrose and acid content for its survival. They have the ability of capturing atmospheric nitrogen and converting into ammonical form [19]. Moreover they are known for stimulating plant growth by tolerant to acetic acid. The bacterium was first discovered in Brazil by scientists Vladimir *A. cavalcante* and Johanna Dobereiner. They are originally known as *Acetobacter* belong to Acetobacteriaceae family and got the current name due to carbon source requirement. Besides nitrogen fixing ability they are known to synthesise indole-3 acetic acid which promote the growth of the associated plant species [20]. Also reports suggest this bacterium controls pathogen especially *Xanthomonas albilineans* in sugarcane. Thus in recent years it is the most recommended bio-inoculant for sugarcane [16].

11. Algal biofertilizers

The potentiality of algal biofertilizers are realised long before by 1939, when WHO attributed the tropical rice natural fertility to green blue cholorphytic algae. Among algae, only blue green algae have biological nitrogen fixing ability due to the presence of heterocysts cells in them [17]. This bio-inoculant is recommended only for rice crop and was proved to improve soil fertility by nitrogen fixation and organic matter enrichment after harvest. In some places, practice of culturing algae as dual crop along with rice has been done which found to inhibit small weed growth during cropping. Apart from this some of the algal species also promote growth by producing growth promoting substances [18].

The following list is some of the nitrogen fixing algal species: (a) Examples of unicellular nitrogen fixing algae: *Gloeothece*, *Gloeobacter*, *Synechococcus*, *Cyanothece*, *Gloeocapsa*, *Synechocystis*, *Chamaesiphon*, *Merismopedia*; (b) filamentous non heterocystous forms of *Cyanobacteria*, *Oscillatoria*, *Spirulina*, *Arthrospira*, *Lyngbya*, *Microcoleus*, *Pseudanabaena*; (c) Filamentous heterocystous forms *Anabaena*, *Nostoc*, *Calothrix*, *Nodularia*, *Cylinodrosperum*, *Scytonema.*

12. *Anabaena azollae*

Anabaena is a special type of algae which forms symbiotic association with free floating water fern *Azolla*. Water fern is bilobed in nature and algae resides in the roots of the fern. The common species of algae forming symbiotic association with Azolla are *A. microphylla*, *A. filiculoides*, *A. pinnata*, *A. caroliniana*, *A. nilotica*, *A. rubra and A. mexicana*. This alga takes shelter and carbon from the water fern and in turn fixes atmospheric nitrogen. They need sunlight and water for its multiplication and hence can be used for rice crop as dual crop. Azolla as dual crop in crop estimate to reduce nitrogen requirement by 20–25% [21].

13. Conclusion

In developing countries, the most important challenge is to produce sufficient food for the growing population from inelastic land area. These microbes siphon out appreciable amounts of nitrogen from the atmospheric reservoir, solubilise phosphorus and enrich the soil with this important but scarce nutrient. The crop bacterial soil ecosystem can, therefore, be energized in sustainable agriculture with considerable ecological stability and environmental quality.

Author details

Prabakaran Elavarasi*, Muthuraman Yuvaraj and Pandurangan Gayathri
Adhiparasakthi Agricultural College, Kalavai, Tamil Nadu, India

*Address all correspondence to: elavarasi.praba94@gmail.com

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