# Biofertilizers: Assets for Sustainable Agriculture

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**Abstract**

Demand for food products is growing day by day with the increase in world's population. To enhance agriculture productivity, farmers depend on usage of chemical fertilizers and pesticides. Excessive use of these chemicals has not only deteriorated the quality of soil but also damaged the ecosystem and human health to a great extent. Using biofertilizers is a natural, low-cost, environment friendly way out of this problem. Biofertilizers, being an essential component of sustainable farming, play a vital role to improve long term soil fertility, enhancing crop production and maintaining ecosystems. The present chapter focuses on types of biofertilizers, their requirements, role of biofertilizers in agriculture, advantages and disadvantages of using biofertilizers.

**Keywords**

Biofertilizers, Sustainable agriculture, Crop production, Ecosystem, Environment, Soil fertility, Farmers

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## 1. Introduction

A significant role in meeting food demands of the increasing population in the world has also led dependence upon chemical fertilizers and pesticides (Kaur and Purewal 2019). According to FAO, augmentation for green food will increase 60% by the year 2030 (FAO 2018). Therefore, it is necessary to increase agricultural production by managing the health of plants and soil in a relatively short period to ensure food security. It has been done through the provision of required nutrients such as Nitrogen (N), Phosphorus (P) and Potassium (K) to plants (Nosheen et al. 2021). Unfortunately, only a small percentage of these nutrients are used by plants, while a greater percentage is precipitated by metal cations present in soil. These chemicals harm the soil fertility, decrease water holding capacity, increase the salinity and deplete soil nutrients (Kumar et al. 2018). So, there is a need to use alternative resources to meet the demand of feeding a large population with eco-friendly means. Therefore, it is advisable to use biodegradable organic fertilizers for sustainable agriculture. Biofertilizers are non-toxic, low cost, environment friendly substances which improve soil quality and crop yield (Nosheen et al. 2021). Biofertilizers may be defined as "substances which contain living microorganisms that colonize the rhizosphere or the interior of the plants and promote growth by increasing the supply or availability of primary nutrients to the host plant when applied to soil, seeds or plant surfaces or interior of plants" (Kumar et al. 2018).

Sustainable agriculture is the efficient production of safe quality agricultural products in a way that protects and improves the natural environment along with the social and economic condition of farmers. Sustainable agriculture is an integrated system of plant and animal production practices to produce long term beneficial effects to humans and the environment (Kaur and Purewal 2019).

## 2. Types of Biofertilizers

Biofertilizers are divided into different groups according to their nature, functions and mechanism of action. Particular nutrient acquisition plays a key role to classify microbes. Table 1 displays different types of biofertilizers.

**Table 1: Microbes as biofertilizers and their applications**

| S. No. | Microbes | Groups | Recommended Crops |
|---|---|---|---|
| **Nitrogen ($N_2$) fixing Bio fertilizers** | | | |
| 1. | *Azotobacter, Clostridium, Nostoc, Anabaena,* | Free Living | Rice, Sugarcane, Gram |
| 2. | *Rhizobium, Frankia, Anabaena azollae* | Symbiotic | Legumes, Wheats, Jowar, Maize, Bajra |
| 3. | *Azospirillum* | Associative Symbiotic | Rice, Sugarcane, Sorghum, Wheat |
| **P-Solubilizing Bio Fertilizers** | | | |
| 1. | *Bacillus subtilis, B. circulans, Pseudomonas striata* | Bacteria | Potato, Radish, Sugarbeat |
| 2. | *Penicillium* sp., *Aspergillus awamori* | Fungi | Tomato, Brinjal, Mustard |
| **P-Mobilizing Bio fertilizers** | | | |
| 1. | *Glomus* sp., *Gigaspora* sp. | Arbuscular Mycorrhizae | Tomato, Soyabean, Wheat, Corn |
| 2. | *Laccarai* sp., *Pisolithus* sp., *Boletus* sp., *Amanita* sp., | Ectomycorrhiza | Eucalyptus, Oak, Peach, Pine |
| 3. | *Pezizella ericae* | Ericoid Mycorrhiza | Erica, Azalea, *Rhododendron* |
| **K-Solubilizers** | | | |
| 1. | *Frateuria aurantia* | Bacteria | Maize, Cotton, Wheat, Pepper, Sorghum |
| **Micronutrient solubilizers (Silicate and Zinc solubilizers)** | | | |
| 1. | *Bacillus* sp. | Bacteria | Wheat, Various Vegetables, Fruits |
| **Plant Growth Promoting Rhizobacteria** | | | |
| 1. | *Pseudomonas fluoresens* | Bacteria | Potato, Radish, Maize |

### 2.1. Nitrogen Fixing Biofertilizers

Nitrogen is an important element, plays a significant role in metabolism, growth and reproduction of plants. About 78% nitrogen is present in the atmosphere but it is chemically inert (Srivastava 2020). Therefore, it cannot be directly utilized by higher plants. So, atmospheric nitrogen is converted into its organic and inorganic compounds with the help of physical, chemical and biological means through a process called Nitrogen fixation (Fasusi et al. 2021). Biological nitrogen fixation is carried out by a group of microorganisms by symbiotic and asymbiotic means (Malusa et al. 2016). These microorganisms are known as biological nitrogen fixers (BNFs) (Mebrouk et al. 2018). These BNFs are grouped as:

(i) Asymbiotic microbes: *Azotobacter*, *Beijrinkia*, *Clostridium* and *Bacillus* sp.
(ii) Free living photosynthetic bacteria: *Chlorobium*, *Rhodospirillum*
(iii) Chemosynthetic bacteria: *Desulfovibrio*
(iv) Free living fungi: *Pullularia*, Yeast
(v) Blue-green algae (Cyanobacteria): *Nostoc*, *Anabaena*, *Calothrix*
(vi) Symbiotic Microbes: *Rhizobium* species, *Frankia*, *Anabaena azollae*
(vii) Associative form- *Azospirillum* species, *Azotobacterpaspali, Beijerinkia*

Some of BNFs which are commonly used as biofertilizers are described below:

**2.1.1.** ***Rhizobium*****:** *Rhizobium* are gram negative, microaerobic soil bacteria which belong to the family Rhizobaceae. It includes *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium*, *Azorhizobium* and *Mesorhizobium.* They show a high degree of host specificity, without a specific host they are unable to fix atmospheric nitrogen (Kumar et al. 2018). Rhizobium enters into the host plant through root hairs and forms root nodules where they reduce molecular nitrogen to ammonia (Yadav et al. 2017). It is a complex biochemical phenomenon which involves various enzymes like nitrogenase, hydrogenase, pigment laghemoglobin, Mo/Fe cofactor, an electron donor and constant supply of ATP (Akram et al. 2020). 'Nif' genes are carrying genetic information for nitrogen fixation. Rhizobium can fix nitrogen in legumes as well as non-leguminous plants like *Parasponia.*

**2.1.2.** ***Azospirillum*****:** *Azospirillum* belong to family Spirillaceae and it is gram negative bacteria. The genus include species like *A. amazonense, A. lipoferom* and *A. brasilense*, which are powerful nitrogen fixer. They remain in symbiosis with $C_4$ plants (Kumar et al. 2018). They produce growth regulators like auxin, gibberellic acid and cytokinin. Rice, sorghum, maize and sunflower are main crops where *Azospirillum* is used to increase nitrogen content.

**2.1.3.** ***Azotobacter*****:** They are free living, aerobic and photoautotrophic bacteria which belong to the family Azotobacteriaceae. Common species of *Azotobacter* are *A. chroococcum*, *A. beijerinckii*, *A. vinelandii*, *A. insignis* and *A. macrocytogenes*. Besides nitrogen fixation, Azotobacter also plays some other significant roles like synthesis of plant hormones viz. gibberellins, NAA, antibiotics, vitamins such as thiamine (vit. $B_1$) and riboflavin (vit. $B_2$) and some antifungal compounds (Nosheen et al. 2021). Wheat, rice, mustard, sugarcane, cotton etc. are crops where *Azotobacter* strain enhances yield and improves soil fertility (Fasusi et al. 2021).

**2.1.4. *Azolla*:** Azolla is an aquatic, free floating fern found in Asia, Africa and America belonging to the family Azollaceae (Mishra and Das 2014). *Anabaena azollae*, a cyanobacteria symbiotically associated with *Azolla*, fixes nitrogen specially in rice fields (Fasusi et al. 2021). It also has the ability to decompose the crop residues and add nutrients to soil which promote the growth and yield of the next crop, sown in the same field after rice crop.

**2.1.5. Cyanobacteria:** These are prokaryotic blue green algae (BGA) and have autotrophic mode of nutrition. These are filamentous algae having a special structure called heterocyst which is the site for nitrogen fixation e.g., *Nostoc, Anabaena*, *Calothrix* etc. (Malusa et al. 2016). They remain in symbiotic association with various groups of plants like liverworts, ferns, flowering plants and fungi. They also produce growth hormones like auxin and gibberellins. Also has ability to provide some other mineral elements too like potassium, phosphorous, zinc and molybdenum (Akram et al. 2020).

**2.2. Mycorrhiza:** Mycorrhiza is a symbiotic association between fungi and root of higher plants e.g., *Glomus* species. Mycorrhiza is a potential biofertilizers, it provides various nutrients like P, Zn, B, Fe and growth hormones to host plant. They also increase surface area of plants for more absorption of nutrients and provide resistance against pathogens to the plants (Nosheen et al. 2021). Depending upon niche of fungi mycorrhizae are of two types:

**2.2.1. Ectomycorrhiza:** These fungi lie in the intercellular space of cortex in host plant. The root cells of host plant secrete some carbohydrates and other nutrients which promote fungal growth. The fungal hyphae increase the surface area of root to stimulate the absorption of water and nutrients (Thomas and Singh 2019). Fungus also secretes some antimicrobial substances which protects plant from diseases. Ectomycorrhiza is characteristics of trees e.g., *Eucalyptus*, peach, oak, pine and fungi which belongs to Basidiomycotina.

**2.2.2. Endomycorrhiza (VAM fungi):** These are symbiotic soil fungi that colonize the roots of many vascular plants. They enhance the absorption of nutrients via special structures known as vessels and arbuscules. The fungi increase the uptake of phosphorus and other micro nutrients (Kizilkaya 2009) and also expand the length of root and shoot. Plant also absorbs large amount of water with the help of these fungi. Plant tolerance to various biotic and abiotic stresses can be increased with the presence of VAM fungi (Tarafdar 2019). Mobilization of less mobile nutrients like P, S, Mg, Zn, Ca and Cu could be increased by VAM fungi (Nosheen et al. 2021). The common fungi which remain in mycorrhizal association are– *Glomus*, *Acaulospora, Sclerocystis, Gigaspora, Entrospora* and *Scutellospora.* Further, VAM fungi secrete some enzymes and organic acids which enhance the uptake of nutrients in plants.

**3. Phosphate Solubilizing and Mobilizing Biofertilizers**

Phosphorus is less mobile essential nutrient which plays a key role in energy metabolism. In the soil, it is present as phosphate in the form of organic compounds or inorganic salts. Various microorganism converts insoluble form of phosphate to soluble form such as $HPO_4^{-}$, $H_2PO_4^-$ (Nosheen et al. 2021). Several bacteria and few fungal species are involved in this process. Microbes secretes some acids which reduce soil pH (Kaur and Purewal 2019) and dissolve bound phosphate to make it available to plants. Phosphate solubilizing bacteria (PSB) also provide other trace elements such as Fe and Zn, as well as they secrete some enzymes which kill pathogens and protect plant from diseases. PSB species are – *Pseudomonas, Bacillus, Rhizobium* and *Enterobacter* while fungal species are *Penicillium* and *Aspergillus niger* (Fasusi et al. 2021). Arbuscular mycorrhiza (AM) act for phosphate mobilization, the fungi mobilize insoluble phosphate from soil to root cortex. It increases the surface area of roots, stimulate metabolic process and absorption of nutrients, hence promote growth and yield of host plant (Bolan 1991).

**4. Biofertilizers which solubilize and mobilize Potassium**

Potassium (K) is one of the major elements required by plants, plays significant role in growth and development of plants and its deficiency produce small seeds with low yield. Though, it is present in large amount in soil but only 1-2% K is available for plants (Nosheen et al. 2021). Microorganisms like bacteria and fungi solubilize potassium present in soil and make it available to plants. Potassium solubilizing biofertilizers have some bacterial species and fungi like *Bacillus mucilaginous*, *B. edaphicus*, *Pseudomonas, Aspergillus niger*, etc. These microorganisms solubilize insoluble form of K through various chemical reactions like production of acids, chelation etc. (Fasusi et al 2021). Potassium solubilizers, provide regular supply of K to crop plants, also exert positive impact on availability of other essential elements (Barman et al. 2017) and thereby improve their productivity e.g., maize, cotton, wheat, pepper and sorghum.

### 5. Sulfur Oxidizing Biofertilizers

Sulfur is present in inorganic and organic form in the soil and is an important element. It plays important role in synthesis of chlorophyll and nodulation in legumes. Organic sulfur is made available to plants by biological oxidation by certain microbes. These are *Thiobacillus, Thioparous* and *Thoxidous*, which can oxidize sulfur to sulfates (Tarafdar 2019). Sulfur also promotes the efficiency of crop plants to uptake other micronutrients. Reduced form of sulfur causes environmental pollution so these bacteria also safeguard the environment from sulfur pollution along with enhancing the growth and yield of crops (Kumawat et al. 2019).

### 6. Zinc Solubilizing Biofertilizers

Zinc is a trace element required in small quantity by plants. Zinc plays an important role in synthesis of tryptophan which is a precursor of a plant growth hormone-auxin. Zn is distributed irregularly in the soil and present in insoluble form (Kumawat et al. 2019). Microbes like mycorrhiza, *Saccharomyces* sps. and several genera of rhizobacteria such as *Pseudomonas* and *Bacillus* sps. solubilize the complex form of Zn available in the soil (Thomas and Singh 2019), by chelating ligands and oxidoreduction reaction. These bacteria also produce phytochromes, antibiotics, vitamins and antifungal substance to protect plants in various ways (Fasusi et al. 2021).

### 7. Plant Growth Promoting Rhizobacteria (PGPR)

A group of bacteria that colonize plant root or rhizosphere and exert a beneficial effect on plant growth are called (PGPR) (Bhardwaj et al. 2014). *Bacillus* species and *Pseudomonas fluorescence* act as microbial pesticides. PGPR promote growth of plants by either of the following mechanism – suppression of plant diseases (Bio-protectants), improved nutrients acquisition (Biofertilizers), facilitating biotic and abiotic stress tolerance (Yadav et al. 2017). PGPR includes several microbes e.g., *Agrobacterium, Arthrobacterium, Micrococcus, Bacillus, Frankia, Pseudomonas, Rhizobium, Streptomyces, Thiobacillus, Xanthomonas,* and *Azotobacter* etc. (Fasusi et al. 2021).

## 8. Major Functions of Biofertilizers

Some of the major functions of biofertilizers are given below (Misra et al. 2020):

i. Play a key role in nitrogen fixation
ii. Make availability of nutrients to plant.
iii. Increases NPK and chlorophyll content in various crops.
iv. They are involved in production of growth hormones.
v. Increases surface area of root for better absorption of water and nutrients.
vi. Improve quality of plant products with enhanced yield.
vii. Increase plant strength to tolerate various stresses.
viii. Improve quality, texture and water holding capacity of soil.

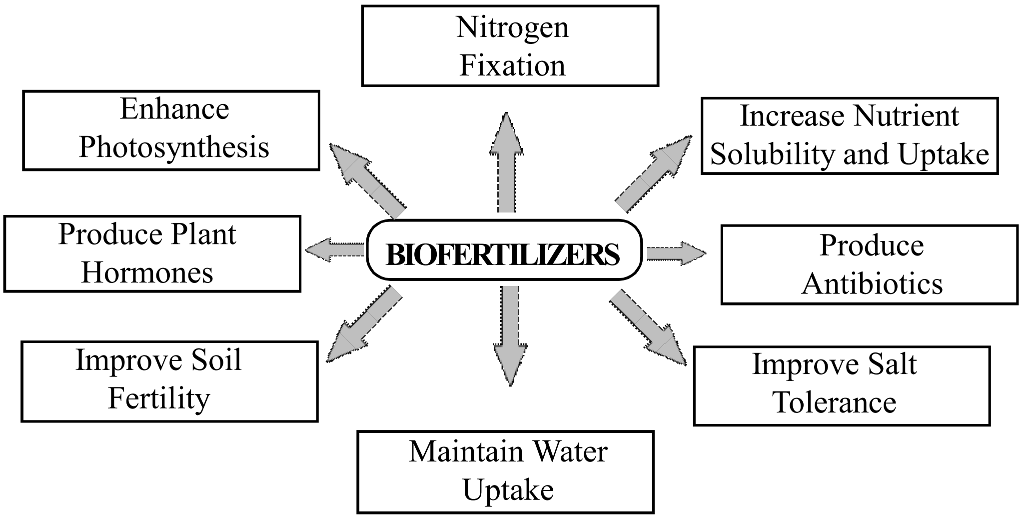


**Figure 2: Role of bio fertilizers in growth and development of plants**

## 9. The Advantages of Using Biofertilizers

Biofertilizers have various advantages (Kaur and Purewal 2019; Kumar et al. 2018; Nosheen et al. 2021) over chemical fertilizers, these are enlisted below:

i. Biofertilizers are low cost, ecofriendly products which stimulates growth of plants and protect environment too.
ii. They provide primary nutrients to host plant in balanced form.
iii. They biologically convert non-usable form of elements to usable form.
iv. PGPBs supply important phytohormones like auxin, cytokinin and gibberellin.

v. Microbes secretes some antibiotic and antifungal compounds which keep plants disease free.

## 10. Disadvantages of Using Biofertilizers

Some of the disadvantage (Kaur and Purewal 2019; Kumar et al. 2018; Nosheen et al. 2021) of biofertilizers are:

i. It is required in large amount to fulfill the nutrients requirement of crop.
ii. Due to presence of living organisms and bad odor it is difficult to store.
iii. Specific type of biofertilizer is needed for specific crops.
iv. A good knowledge of plants and microbe's interrelationship is required.
v. Being living organisms biofertilizers require proper facilities for handling, transportation and storage.

## 11. Conclusion

Biofertilizers are ecofriendly, cost-effective substances which provide essential nutrients to plant and significantly increase the crop yield. They also protect plants from various diseases, drought and salt stresses. With the growing concern for environment and to fulfill the demand of high yield farmers are switching over to biofertilizers. However proper practical training to farmers and dealers are required for its implementation. Scientists are doing their best efforts to overcome the shortcoming related to using these microbes as fertilizers, and it will be a major tool for sustainable agriculture in future.

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