



Green Growth: Harnessing Biofertilizers for Sustainable Farming

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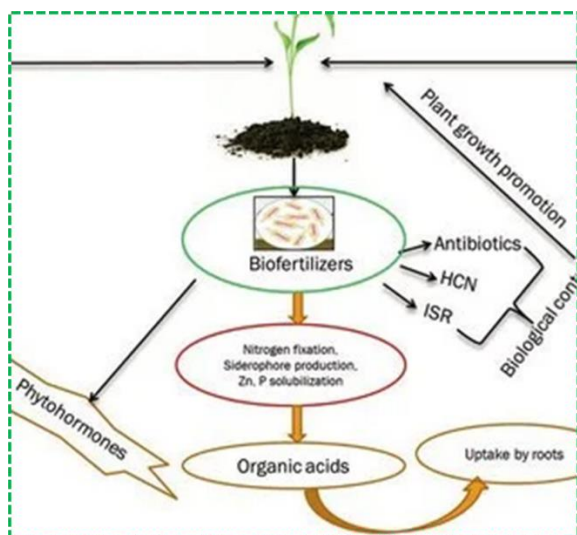
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Introduction:

The term 'Biofertilizer' in India specifies fertilizers to meet the nutritional requirements of a crop through microbiological means, other countries use the term microbial inoculants. These biofertilizers are usually carrier based microbial preparations containing beneficial microorganisms in a viable state intended for seed or soil application, which enhance plant growth through nutrient uptake and/ or growth hormone production. Biofertilizers are soil microbe cultures that can be employed as microbial or soil inoculants to increase plant and soil fertility and productivity. Biofertilizers are economical and sustainable plant nutrition sources. A biofertilizer is simply a product that contains living microorganisms that colonize the rhizosphere and stimulate development by increasing the supply or availability of nutrients to the host plant when applied to the soil, seed, or plant surface. Some of the most often used biofertilizers include nitrogen-fixing soil bacteria (*Azotobacter*, *Rhizobium*), nitrogen-fixing cyanobacteria (*Anabaena*), phosphate-solubilizing bacteria (*Pseudomonas* sp.), and Arbuscular Mycorrhiza (AM) fungus. Phytohormone

(auxin)-producing bacteria and cellulolytic microorganisms are also included in biofertilizer formulations. By increasing specific microbial processes, these microbial formulations are used to increase the availability of nutrients in a form that can be digested by plants. An organic fertilizer enhanced with helpful microbes is called a biofertilizer. All organic resources for plant growth that are converted by microbes, plant associations, or interactions into a form that plants may absorb are known as biofertilizers. Biofertilizers are liquid-based or carrier products made of living or dormant microbes (such as bacteria, fungi, algae, and actinomycetes), either alone or in combination, that help fix atmospheric N₂ or solubilizers of various soil nutrients while also producing growth-promoting compounds to increase crop yield and growth (Dineshkumar *et al.*, 2018). Microorganisms with unusual roles, such *Azospirillum*, which fixes nitrogen, and P-solubilizing bacteria, are found in biofertilizers. It makes P available to plants by solubilizing it from soil and fertilizer (Saraswati & Sumarno, 2008). In order to get high-quality harvests while lowering pollution, biofertilizers are

becoming increasingly important. For the highest seed yield in agriculture, both phosphate and nitrogen fertilizers must be applied. Biofertilizers are formulated in an easy-to use, low-cost carrier substance that can increase plant availability and/or mineral nutrient uptake. A biofertilizer, according to Vessey (2003), is a substance which when applied to seed, plant surfaces (leaves), roots, or soil and promote growth through several approaches and that helps to elevate the supply or accessibility of primary nutrients to the host plant containing living microorganisms that colonize the rhizosphere or the interior of the plant. Biofertilizers should not be confused with green manure, manure, intercrop, or organic supplemented chemical fertilizer.

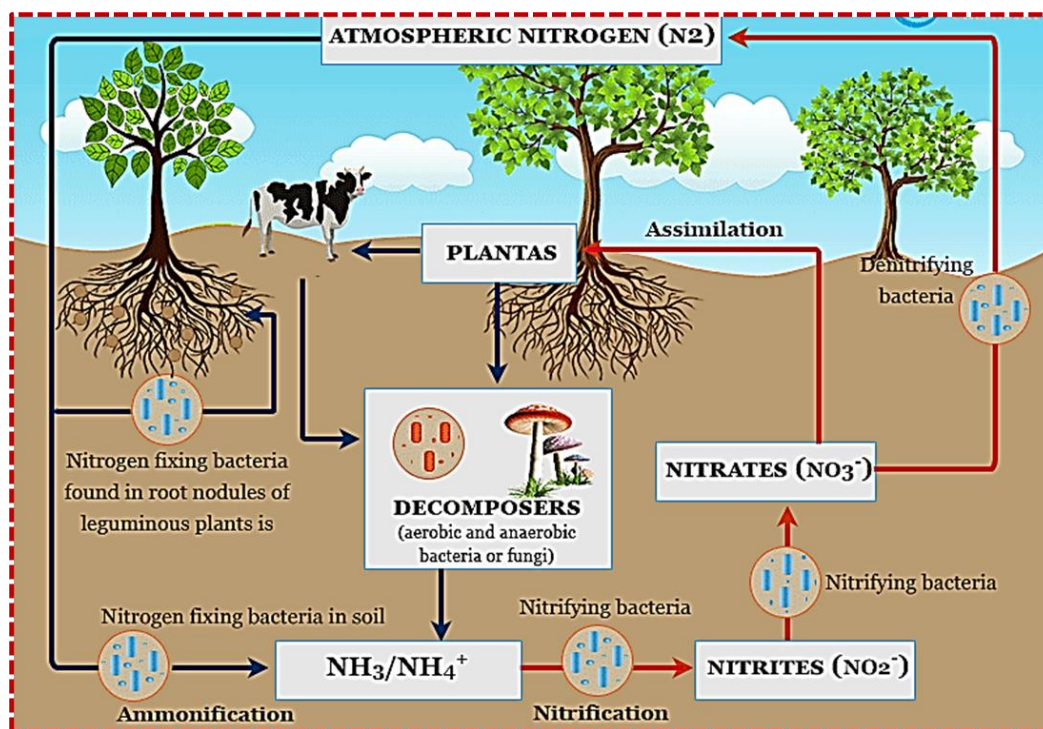


Biofertilizers: why their need is inevitable ?

There is little question that the careless use of chemical fertilizers to satisfy the increasing demand for food has contaminated and seriously harmed microbial habitats and beneficial insects. However, the use of excess chemical inputs has decreased soil fertility and increased crop susceptibility to disease (Aktar *et al.* 2009). By 2020, it is projected that in order to meet the target production of 321 million tons of food grain to feed 8 billion people worldwide, 28.8 million tons of nutrients will be needed, but only 21.6 million tons will be available, resulting in a deficit of roughly 7.2 million tons. The globe must undoubtedly increase agricultural output in a sustainable and environmentally friendly manner in order to feed the expanding population with the lack of available nutrients. Therefore, many of the current agricultural practices which include the use of chemical fertilizers, pesticides, herbicides, fungicides, and insecticides must unavoidably be reevaluated. Biofertilizers are thought to be a safe substitute for chemical inputs and significantly reduce ecological disturbance in light of the harmful impacts of chemical fertilizers. Biofertilizers are economical, environmentally friendly, and significantly increase soil fertility over time.

Table 1: Different groups of biofertilizers

Sl. No.	Groups	Examples
1. Nitrogen (N₂) fixing Bio fertilizers		
i.	Free living	<i>Azotobacter, Clostridium, Anabaena, Nostoc</i>
ii.	Bio Symbiotic	<i>Rhizobium, Frankia, Anabaena azollae</i>
iii.	Associative- Symbiotic	<i>Azospirillum</i>
2. P-Solubilizing Bio fertilizers		
i.	Bacteria	<i>Bacillus subtilis</i> <i>Pseudomonas striata</i>
ii.	Fungi	<i>Penicillium sp., Aspergillus awamori</i>
3. P-Mobilizing Bio fertilizers		
i.	Arbuscular Mycorrhizae	<i>Glomus</i> sp., <i>Gigasporasp.</i>
ii.	Ectomycorrhiza	<i>Laccarai sp., Pisolithus sp., Boletus sp., Amanita sp.</i>
iii.	Ericoid Mycorrhiza	<i>Pezizellaericae</i>
4. K- solubilizers		
i.	Bacteria	<i>Frateuria aurantia</i>
5. Micronutrient solubilizers (Silicate and Zinc soloubilizers)		
i.	Bacteria	<i>Bacillus sp.</i>
6. Plant Growth Promoting Rhizobacteria		
i.	Bacteria	<i>Pseudomonas fluorescens</i>



Nitrogen Fixing Biofertilizers:

Nitrogen is the most abundant element in the earth, comprising 78.09 and 79.2% of the atmosphere and soil respectively; still is the limited element for the plant due to difficulty with its fixation in soil and uptake by the plant roots. Some microbes, either in the associated or non-associated form, help to fix the atmospheric nitrogen in the plant-available form, thus reducing the problem of fixation of N_2 , denitrification and leaching loss of this element. The nitrogen-fixing biofertilizers which depend on their association with plants are broadly classified into two types: the symbiotic nitrogen fixers, which can fix the nitrogen when in association with the plant root system; and asymbiotic nitrogen fixer, which can fix nitrogen in soil in a free-living state, i.e. they don't require the plant association. The former group includes *Rhizobium* species, *Frankia* species, Cyanobacteria etc., whereas *Azotobacter chroococcum*, *Beijerinckia mobilis* and *Clostridium* species, free-living cyanobacteria (blue-green algae) etc., are placed in the latter group.

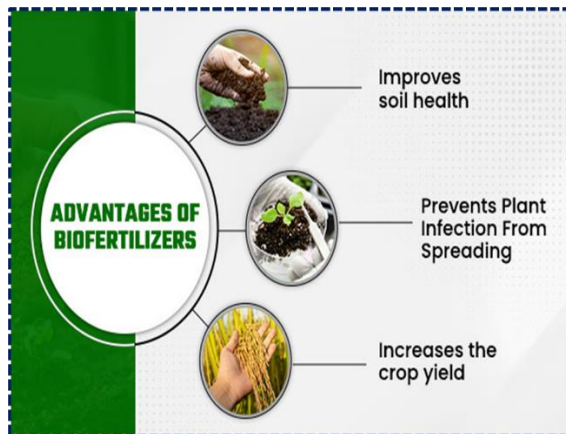
Phosphorous Solubilizing Biofertilizers:

Phosphorus, one of the major plant nutrients, is next only to nitrogen, accounting for 0.2% (w/w) of plant dry weight (Maharajan *et al.*, 2018), and is the most restrictive factor for plant growth. Phosphorus, a light-bearing, nonmetallic plant nutrient, once absorbed from the soil solution as monovalent (H_2PO_4) and divalent (HPO_4) orthophosphate anions, facilitates the root morphogenesis including development, root anatomy modifications, and root hair density,

leading to yield increase of crops and plant resistance against multiple diseases. Phosphate solubilizing microorganism including several bacteria and fungi which can grow in the medium containing tricalcium, iron and aluminium phosphate, hydroxyl apatite, bonemeal, rockphosphate and some insoluble phosphate compound. The most efficient PSM genera belong to *Bacillus* and *Pseudomonas* among bacteria and *Aspergillus* and *Penicillium* amongst fungi. Some rhizospheric microorganisms (except mycorrhizal fungi), particularly P-solubilizing bacteria (PSB) and fungi (PSF), can enhance plant P acquisition by directly increasing solubilization of P or by indirect hormone-induced stimulation of plant growth (Richardson *et al.*, 2009). The PSB or PSF may mobilize soil P by the acidification of soil, through the release of enzymes (such as phosphatases and phytases) or the production of carboxylates such as gluconate, citrate and oxalate.

Potassium Solubilizing Biofertilizers:

Some rhizobacteria can solubilize the insoluble forms of potassium, which is another essential nutrient necessary for plant growth. The higher bio mass yields due to increased potassium uptake have been observed with *Bacillus edaphicus* (for wheat), *Paenibacillus glucanolyticus* (for black pepper) and *Bacillus mucilaginosus* in coinoculation with the phosphate-solubilizing *Bacillus megaterium* (for eggplant, pepper and cucumber).



Plant Growth Promoting Rhizobacteria (PGPR):

Plant Growth Promoting Rhizobacteria (PGPR) The group of bacteria that colonize roots or rhizosphere soil and beneficial to crops are referred to as plant growth promoting rhizobacteria (PGPR). They are also called as microbial pesticides e.g. *Bacillus* spp. and *Pseudomonas fluorescense*. PGPR inoculants currently commercialized that seem to promote growth through at least one mechanism; suppression of plant disease (termed Bio-protectants), improved nutrient acquisition (termed Bio-fertilizers), or phyto-hormone production (termed Bio-stimulants). Species of *Pseudomonas* and *Bacillus* can produce as yet not well characterized phyto-hormones or growth regulators that cause crops to have greater amounts of fine roots which have the effect of increasing the absorptive surface of plant roots for uptake of water and nutrients. These PGPR are referred to as Bio-stimulants and the phyto-hormones they produce include indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production. *Rhizobacteria* induce

resistance through the salicylic acid-dependent SAR pathway, or require jasmonic acid and ethylene perception from the plant for ISR. *Rhizobacteria* belonging to the genera *Pseudomonas* and *Bacillus* are well known for their antagonistic effects and their ability to trigger ISR. Resistance-inducing and antagonistic *rhizobacteria* might be useful in formulating new inoculants with combinations of different mechanisms of action, leading to a more efficient use for biocontrol strategies to improve cropping systems.

Methods of Application of Biofertilizers:

Seed Treatment: Seed treatment is a very effective, economic, and most common method implemented for all types of inoculants (Sethi *et al.* 2014). The seeds are mixed and uniformly coated in a slurry (inoculant mixed with 200 mL of rice kanji) and then shade-dried, before being sown within 24 h. For liquid biofertilizers, depending upon the quantity of seeds, the coating can be done in either plastic bag (if quantity is small) or bucket (if quantity is large). The seed treatment can be done with two or more bacteria (for instance, nitrogen-fixing bacteria such as *Rhizobium*, *Azotobacter*, and *Azospirillum* can be taken along with phosphorus-solubilizing microbes), without any antagonistic effect, and provide maximum quantity of each bacterium on individual seed required for better results (Chen, 2006).

Seedling Root Dip: This application is common for plantation crops such as

cereals, vegetables, fruits, trees, sugarcane, cotton, grapes, banana, and tobacco where seedling roots are dipped in a water suspension of biofertilizer (nitrogen-fixing *Azotobacter* or *Azospirillum* and phosphorus-solubilizing microbial biofertilizer) for sufficient period of time. The treatment time differs for different crops, for instance, vegetable crops are treated for 20-30 min and paddy for 8-12 h before transplantation.

Soil Application: In this practice, Biofertilizers is applied directly to the soil either alone or in combination. A mixture of phosphate-solubilizing microbial Biofertilizers, cow dung, and rock phosphate is kept in shade overnight while maintaining its moisture content at 50% and then applied to the soil. Some examples of biofertilizers in which soil application is employed are Rhizobium (for leguminous plants or trees) and *Azotobacter* (for tea, coffee, rubber, coconuts, all fruit/agro forestry plants for fuelwood, fodder, fruits, gum, spice, leaves, flowers, nuts, and seeds).

Conclusion:

In modern-day agricultural practices, biofertilizers form an important component of sustainable organic farming in terms of a viable alternative of chemical fertilizers that are associated with various environmental hazards. Biofertilizers can fix and make available atmospheric nitrogen in soil and root nodules, solubilize phosphate (from insoluble forms like tricalcium, iron, and aluminum phosphates) into available forms, sift

phosphates from soil layers, produce hormones and antimetabolites to uphold root growth, and decompose organic matter for soil mineralization. Biofertilizers technology, which is an inalterable part of sustainable agriculture, has to be appropriate for the social and infrastructural situations of the users, economically feasible and viable, renewable, applicable by all farmers equally, stable in long-term perspective, acceptable by different societal segments, adaptable to existing local conditions and various cultural patterns of society, practically implementable, and productive.

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