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Biofertilizer: Sustainable approach for crop production

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Abstract

Crop plants require essential nutrients such as nitrogen and phosphorus to grow and develop. Severe environmental risks have been identified as a result of the overuse of synthetic fertilizers. As a result, bio-fertilizers have a huge potential to boost plant nutrition while also being environmentally beneficial by replacing synthetic fertilizers. Bio-fertilizers have a great tendency to reduce the need for synthetic fertilizers while maintaining crop yield. Bio-fertilizers contain plant growth-promoting rhizobacteria (PGPR) viz; *Azotobacter*, *Azospirillum* and phosphorus solubilizing bacteria (PSB) viz; *Pseudomonas sp*. and *Bacillus sp.* and capable of fixing atmospheric nitrogen and solubilizing soil phosphorus, respectively. Bio-fertilizers are more cost-effective than synthetic fertilizers because to lower market pricing and help in enhancing soil structure and environmental restoration for agricultural leverage.

Keywords: Biofertilizer, PGPR, environment-friendly, cost-effective.

What is a biofertilizer?

A biofertilizer is a substance that contains living micro-organisms that, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and encourage growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers supply nutrients to plants through natural processes such as nitrogen fixation, phosphorus solubilization, and the synthesis of growth-promoting substances. Biofertilizers contain microorganisms that restore the soil's natural nutrient cycle and increase soil organic matter. Healthy plants can be developed with the application of biofertilizers while also improving the soil's sustainability and health.

Biofertilizers: why their need is inevitable?

To meet the increased demand for food, indiscriminate use of chemical fertilizers has surely resulted in contamination and significant damage to microbial ecosystems and beneficial insects. Despite this, the use of excessive chemical inputs has made crops more susceptible to disease and lowered soil fertility. To feed the world's rising population with the limited number of nutrients available, the world certainly needs to flourish agricultural productivity, and it must do so in a sustainable and environmentally friendly manner. Hence, it is unavoidably required to re-evaluate many of the existing agricultural approaches which comprise of using chemical fertilizers, pesticides, herbicides, fungicides, and insecticides. Considering the hazardous effects of conventional fertilizers, biofertilizer is considered to be a safe alternative to chemical inputs and reduces ecological disturbance to a large extent. Biofertilizers are cost-effective and environmentally friendly, and their long-term application significantly improves soil fertility. It has been observed that using biofertilizer increases crop output by 10–40% by increasing protein, vital amino acids, vitamins, and nitrogen fixation content. The advantages of employing biofertilizer include a low-cost source of nutrients, good suppliers of micro chemicals and micronutrients, organic matter, secretion of growth hormones, and counteracting the negative effects of chemical fertilizers. Different microorganisms are important components of soil, and they play an important part in the biotic activities that keep the soil ecosystem dynamic for nutrient mobilization and long-term crop production.

Types of biofertilizer

Biofertilizers may be broadly classified into nitrogen-fixing bacteria, phosphate-Solubilizing microorganisms, and organic matter decomposers.

1. Nitrogen-fixing biofertilizer (NFB)

Nitrogen-fixing organisms are utilized as a living fertilizer in biofertilizer, which is made up of microbial inoculants or groups of microorganisms that can fix atmospheric nitrogen and convert it to organic nitrogenous compounds. Nitrogen-fixing bacteria can work in two ways: as symbiotic bacteria (Rhizobium, Frankia) or as free-living bacteria (*Azotobacter* and *Azospirillum*).

a. Symbiotic

The symbiotic N_2-fixing bacteria belong to the Rhizobiaceae family. Because of their potential to fix atmospheric N2 in association with certain legumes, Rhizobium inoculants are of greatest importance. On a global scale, N2 fixation by Rhizobium in legume root nodules is estimated to be on the order of 14 million tonnes, accounting for over 15% of all industrial N fixation.

Other filamentous bacteria of the genus Frankie belonging to the family Frankiaceae, like Rhizobium, are found in the root nodules of nonlegumes like trees and shrubs. These bacteria coexist with actinorhizal plants in a symbiotic relationship. These actinorhizal plants are utilized in the production of timber and fuelwood, and also for wind barriers and shelterbelts in coastal and arid areas, as well as for land reclamation.

b. Nonsymbiotic

In nonsymbiotic or free-living nitrogen, fixation does not require host plant, and bacteria do not form nodules. *Azotobacter* is an example of free-living bacteria. They fix atmospheric N2 in a nonsymbiotic manner, and the quantity of fixation is directly proportional to the number of carbohydrates they consume. *Azotobacter* populations are harmed by soils with low organic matter and antagonistic relationships with other soil microorganisms. It may also generate growth-promoting chemicals such as auxins, gibberellins, and to some extent vitamins, in addition to nitrogen fixation. It also helps to improve seed germination and crop growth due to the positive response of naphthalene acetic acid (NAA), B vitamins, gibberellic acid (GA), and chemicals produced during the biochemical process showing antagonistic interaction with root pathogen.

c. Cyanobacteria

Cyanobacteria are blue-green algae (BGA). Cyano means blue, so that means it is blue bacteria. These are phototrophic, and generate auxins, indole acetic acid (IAA), and GA. N-fixing blue-green algae are the most significant in sustaining and enhancing the productivity of rice fields. Favorable condition for biological nitrogen fixation by BGA is considered to be one of the reasons for more consistent rice yield under flooded conditions. BGA develops symbiotic associations with fungi, ferns, and flowering plants to fix nitrogen, however, the most common symbiotic association has been found between a free-floating aquatic fern, the *Azolla*, and the *Anabaena azollae* (BGA). This group association generates 40–60 tons of organic matter per acre each year.

d. Azolla

Azolla is a free-floating water fern that fixes atmospheric nitrogen in rice fields in a symbiotic relationship with BGA (*Anabaena azollae*). They are free-living organisms that fix nitrogen using energy derived from photosynthesis. It's a quick-growing water fern that can double in size in a week. *A. pinnata* is the most common species found in India. Azolla is high-quality organic manure that quickly mineralizes soil nitrogen, making it available to the crop in a short amount of time. Azolla can help rice or other crops through dual cropping or green manuring of soil.

2. Phosphate-solubilizing biofertilizer (PSB)

In the rhizosphere, phosphorus-solubilizing bacteria are common, and secretion of organic acids such as citric, oxalic, tartaric, acetic, and lactic helps in the conversion of insoluble phosphorus to plant-available form. Achromobacter, Agrobacterium, Micrococcus, Enterobacter, and Erwinia are some of the bacterial genera. Pseudomonas and Bacillus are the most efficient phosphate solubilizers in soil bacterial communities. The presence of more organic substances in the rhizosphere stimulates phosphate-solubilizing bacteria, and the population of these bacteria is larger in rhizospheric soil than in non-rhizospheric soil.

3. Phosphate-mobilizing biofertilizer (PMB)

The word "mycorrhizal association" refers to the symbiotic relationship between plant roots and fungus. About 90% of land plant species have a symbiotic connection with arbuscular mycorrhizal fungus (AMF). There are two varieties of these: ectomycorrhiza, which is found in trees and is advantageous to forest trees, and endomycorrhiza, which is beneficial for crop plants. The functional symbiosis in mycorrhizal fungus is obligatory and depends on host photosynthates and energy. Mycelium that spreads from the root surfaces into the soil matrix helps the fungi collect nutrients from the soil solution. When mycorrhizal fungi colonize root systems, it results in more effective nutrient uptake and enhanced plant growth.

Name	Crops suited	Benefits usually seen	Remarks
Rhizobium strains	Legumes like pulses, groundnut, soybean	10-35% yield increase, 50-200 kg N/ha.	Fodders give better results. Residual N in the soil through Leaves.
Azospirillum	Non-legumes like millet, barley, oats, sorghum, Sugarcane, maize, rice, etc	10-20% yield increase	Fodder response is higher for the Fodder crop. Produces growth-promoting substances. applied to legumes as co-inoculants
Blue-green algae and Azolla	Rice/wetlands	20 -30 kg N/ha, Azolla can give biomass up to 40-50 tones and fix 30-100 kg N/ha	Reduces soil alkalinity, used as feed material for fishes. They have growth-promoting effects.
Azotobacter	Soil treatment for non-legume crops	10-15% yield increase- adds 20-25 kg N/ha	Also controls certain diseases.
Microhizae (VAM)	trees, crops, and some ornamental plants	30-50% yield increase, uptake of P. Zn, S, and Water enhances.	Usually inoculated to seedlings.
Phosphate Solubilizers	Soil application for all crops	5-30% yield increase	Can be mixed with rock phosphate.

4. Organic matter decomposer

Composting is a significant technology for utilizing various forms of organic wastes (crop residues, rural and urban wastes), and it matures in around 4–6 months for use as a source of plant nutrients. Some cellulolytic and lignolytic microbes are added to help degrade these organic wastes at a faster rate, allowing them to be ready for use within 2–3 months. *Aspergillus niger*, *Penicillium*, *Trichoderma* *viride*, *Trichurus spiralis*, *Phanerochaete chrysosporium*, and other soil-borne fungal species act as activators in the degradation of plant materials containing cellulose or lignin.

5. Potassium-Solubilizing biofertilizer (KSB)

Some soil microbes may dissolve potassium from potassium-bearing minerals like muscovite, mica, orthoclase, and illite. These minerals may be a source of readily accessible K in the soil. Organic compounds produced by microorganisms react with these K-bearing minerals to solubilize K and increase its availability in the soil solution. These organisms also create a variety of amino acids, growth-promoting chemicals (IAA, GA, etc.), and vitamins, all of which help to boost crop output and growth. *Frateuria aurantia*, K-solubilizing bacteria, is capable of mobilizing a mixture of potassium from mica into a usable form for plants, and it has been safely applied to crops in combination with another biofertilizer without any antagonistic effects.

6. Zinc-Solubilizing biofertilizer (ZSB)

Zinc is one of the micronutrients whose deficiency influences crop growth and crop yield. Zinc fertilizers are expensive, and their availability is restricted. As a result, zinc solubilizers can play a critical role in ensuring a sufficient supply of zinc to the crop while also boosting crop development and production. *Bacillus subtilis*, *Thiobacillus thiooxidans*, and Saccharomyces sp. are well-known for their ability to solubilize zinc. These strains are employed as zinc biofertilizers and have a favorable crop response.

7. Plant growth-promoting rhizobacteria (PGPR)

Plant growth-promoting rhizobacteria (PGPR), when grown in association with the host plant, result in the stimulation of growth of their host. It represents a wide variety of soil bacteria. The mechanisms by which these bacteria promote plant development vary, but they all influence growth through P solubilization, nutrient uptake enhancement, and the synthesis of plant growth hormones. The PGPR inoculants stimulate growth by one of three mechanisms: I plant disease suppression (bioprotectants), (ii) better nutrient uptake (biofertilizer), or (iii) phytohormone synthesis (biostimulants).

Mode of application of formulated biofertilizer

There are many ways for applying formulated biofertilizer into the soil and these are

Seed treatment **:** Each packet (200g) of inoculants is mixed with 200 ml of rice gruel or jaggery solution. The seeds for one hectare are stirred in the slurry so that the inoculants are evenly distributed over the seeds, then shade dried for 30 minutes. Within 24 hours, the treated seeds should be planted. One package of inoculants is enough to treat 10 kilograms of seeds. Rhizobium, *Azospirillum*, *Azotobacter*, and Phosphobacteria are applied as a seed treatment.

Seedling root dip : This method is used for transplanted crops. For one hectare, five packets (1.0 kg) of inoculants must be blended with 40 liters of water. The seedlings' roots are submerged in the solutions for 5 to 10 minutes before being transplanted. *Azospirillum* is commonly used for rice seedling root dip.

Soil treatment : 4 kg each of the recommended biofertilizers are combined in 200 kg of compost and maintained overnight. This mixture is incorporated into the soil at the time of sowing or planting.

Precautions to take while using biofertilizer

Packets of biofertilizer should be kept in a cool, dry place away from direct sunshine and heat. The right biofertilizer combinations must be used. Rhizobium is crop-specific; hence it should only be used for that crop. Biofertilizers should not be mixed with other chemicals. While purchasing one should ensure that each packet is provided with important information like name of the product, name of the crop for which intended, name and address of the producer, date of manufacturing, date of expiry, batch number, and instructions for use. The packet must be used before it expires, only for the crop specified, and only with the recommended application method. Biofertilizers are live products that must be stored with care. To achieve the optimum results, both nitrogenous and phosphatic biofertilizers should be used. Biofertilizers, in addition to chemical fertilizers and organic manures, should be used. Biofertilizers are not fertilizer replacements, but they can help plants meet their nutrient needs.

Conclusion

Environmental stresses are becoming a major problem and as a detrimental consequence of the effect, the productivity of crops is decreasing at an unprecedented rate. Our too much dependence on chemical fertilizers and pesticides to meet the huge demand for food for growing populations has encouraged the industries to produce life-threatening chemicals as a form of pesticides or fertilizers. These substances are not only harmful to human health, but they also hurt the environment's ecological equilibrium. In this adverse situation, biofertilizers can provide a viable alternative that will not only feed the growing population but will also protect agriculture from the effects of numerous environmental challenges. Therefore, it is required to realize the various important and beneficial aspects of biofertilizer and the implementation of its application in modern agriculture.