

Biofertilizer's application strategies for agricultural sustainability development

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Agriculture serves as the backbone of economies worldwide, with the livelihoods of billions of people dependent on its success. However, achieving food security and increasing farmers' income remain significant challenges, especially in developing countries. This article explores the pivotal role of bio-fertilizers in contributing to the ambitious goal of doubling farmers' income under sustainable agriculture system. To double farmer's income sustainably, it is imperative to overcome challenges associated with application of bio-fertilizers. These include raising awareness among farming community about their benefits, ensuring quality control in bio-fertilizer production, and providing adequate support in terms of training and government subsidies. Government policies and initiatives can play a crucial role in incentivizing the use of bio-fertilizers and promoting their integration into mainstream agricultural practices. Bio-fertilizers, derived from living organisms, are environmentally friendly and economically viable alternatives to agrochemicals. They enhance soil fertility, improve crop yields, reduce production costs, and promote sustainable agricultural practices.

Keywords: Application, Biofertilizer, Precautions, Sustainable agriculture

There are two primary categories of inputs: fertilizers and pesticides. In the intensive cropping system, fertilizers can be equated to the 'food' for plants, while pesticides serve as the 'medicine' to protect them. In contrast, in sustainable or environmentally friendly agricultural systems, the terms bio-fertilizers and bio-pesticides are used to describe these inputs. Bio-fertilizers, specifically, serve as cost-effective and renewable sources of essential plant nutrients that complement agro-chemicals. These bio-fertilizers consist of potential strains of beneficial microbial diversity that are cultured in a laboratory, evaluated in fields and then packaged in a suitable carrier. They can be applied either as seed treatment or directly to the soil.

Bio-fertilizers operate by facilitating gradual release of essential plant nutrients like nitrogen and phosphorus through

their activities in rhizosphere, making these essential nutrients available to plants over time. The recent surge in the popularity of bio-fertilizers are largely attributed to growing emphasis on soil health maintenance, reduction of environmental pollution and decrease in agro-chemical usage in intensive cropping system. In rain-fed agriculture, these inputs gain even more significance due to their affordability, particularly among small and marginal farmers who may struggle to afford expensive agro-chemicals.

Additionally, bio-fertilizers are well suited for reducing the overall cost of cultivation and are integral to practice of organic farming. Bio-fertilizer is still an unclear term. It can be easily found that bio-fertilizers are identified as plant extract, composted urban wastes and various microbial mixtures with unidentified constituents, and

chemical fertilizer formulations supplemented with organic compounds. However, biofertilizer is most commonly referred to the use of potential microbial diversity to increase availability and uptake of mineral nutrients for plants. Therefore, it is necessary to define the term Biofertilizer.

Bio-fertilizers

Bio-fertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants in uptake of essential nutrients by their interactions in rhizosphere through seed or soil application. They accelerate certain microbial processes in the soil, which augment the extent of availability of essential nutrients in a form easily assimilated by plants.

How do bio-fertilizers work?

Bio-fertilizers fix atmospheric

nitrogen in the soil through biological nitrogen fixation in legumes and make them available to plants. They solubilize insoluble forms of phosphate, such as tri-calcium, iron and aluminium phosphates, into available forms. They scavenge phosphates and produce phytohormones and anti-metabolites, which promote root growth via plant microbial interactions. They decompose organic matter and help in the mineralization of soil. When applied to soils or seeds, these bio-fertilizers increase the availability of essential nutrients and improve the yield by 10% to 20% without adversely affecting soil and environment. Bio-fertilizers are ready-to-use live formulates of such potential beneficial microorganisms, which upon application to seeds, roots or soil, mobilize the availability of macro-as well micro-nutrients by the direct and indirect mechanisms and help in the improvement of soil health, productivity and profitability for farming communities (Fig. 1).

Main roles of bio-fertilizers

- Make water and nutrients available efficiently
- Make the root rhizosphere livelier
- Diverse-growth-promoting substances are produced
- Better germination and more root proliferation
- Improve the quality and quantity of bio-formulation
- Improve the fertilizer-use efficiency and water-uptake efficiency
- Higher biotic and abiotic stress tolerance
- Improve soil health
- No residual harmful effect
- Make the system more sustainable under changing climatic conditions

Importance of bio-fertilizers

For crops

- Increase in percentage of seed germination
- Stimulate plant growth and symbiotic efficiency in the legumes

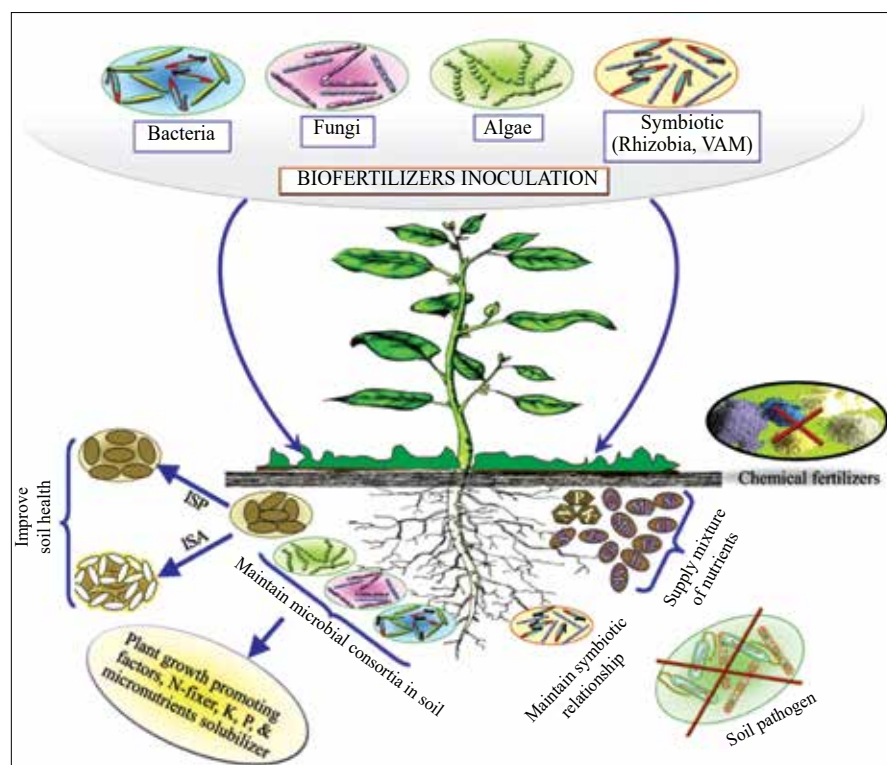


Fig. 1. Systematic representation of indirect and direct impact of bio-fertilizers on plants

- Increased root and shoot length, chlorophyll content and photosynthesis activities
- Reduction in disease incidence
- Improved post-harvest seed quality in terms of germination

For soil

- Eco-friendly (Friendly with nature)
- Improved water and nutrient uptake efficiency
- Replace chemical nitrogen and phosphorus by 25%
- Increase crop yield by 20-30%
- Activate the soil biological (microbes) and restore natural soil fertility as well as soil health
- Provide protection against drought, salinity (abiotic stress) and some soil borne diseases (biotic stresses)
- Bio-fertilizers also promote healthy soil, leading to greater farming sustainability
- Cost effective, reduces the costs towards fertilizers use, especially regarding nitrogen and phosphorus
- When applied to plant surfaces, they promote plant growth by increasing the supply of primary nutrients to the host plant
- Involved microorganisms

could easily convert complex organic material into simpler compounds

Microbial bio-fertilizers

- *Rhizobium* sp.
- *Azotobacter* sp.
- *Azospirillum* sp.
- Blue green algae
- *Azolla*
- Phosphate-solubilizing microorganisms
- Mycorrhiza fungi
- K-solubilising and mobilising microorganisms

Rhizobium: *Rhizobium* is a bio-fertilizer that contains symbiotic *Rhizobium* bacteria, which is an important nitrogen-fixing organism (Fig. 2). These microbes have ability to drive atmospheric nitrogen and supply it to plants for better growth. *Rhizobium* sp. is symbiotic in nature, fix atmospheric nitrogen 50-300 kg/ha in association with legumes. It can increase yield up to 10-35%. *Rhizobium* bio-fertilizers are recommended for crops like groundnut, soybean, green gram, red gram, and bengal gram etc.

Azotobacter: *Azotobacter* sp. is free-living nitrogen-fixing bacteria. It fixes molecular nitrogen from the atmosphere, releasing it in the form

of ammonium ions into the soil that is made available to the plants. It can fix N up to 25 kg/ha and increase yield up to 50%. These bio-fertilizers are recommended for several non-leguminous and vegetable crops.

Azospirillum: These will form symbiotic association with many plants. In addition to their N fixing ability of about 20-40 kg/ha, they also produce growth regulating substances. They do not produce any visible nodules or out growth on root tissue. It is mainly recommended for maize, sugarcane, sorghum and pearl millet etc.

Cyanobacteria: Blue green algae (*Cyanobacteria*) are photo-synthetic, free living which fixes nitrogen asymbiotically but some *Cyanobacteria* are known to form symbiotic associations. *Cyanobacteria* produce nitrogenase and nitrogen fixation occurs in specialized structure called heterocyst. *Cyanobacteria*, also known as blue-green algae, can be used as bio-fertilizers in agricultural and horticultural practices.

Azolla: *Azolla* is a free-floating water fern that fixes atmospheric nitrogen in association with nitrogen fixing blue green algae *Anabaena azollae*. It is used as biofertilizer for wetland rice and it is known to contribute 40-60 kg N/ha. *Azolla* can be applied as green manure by

incorporating in the fields prior to rice planting.

Phosphate solubilizing microorganisms (PSM): Several soil bacteria and fungi solubilize insoluble inorganic phosphate compounds into available form. Inoculation of seeds with PSB reduce 50% of the need for phosphatic fertilizers. These can be used for most of the crops.

AM fungi: It is the symbiotic association between plant roots and soil fungus. There are two types of Mycorrhiza. Ectomycorrhizae (external), the fungus produces a sheath or mantle around the root. This sheath then produces hyphae that grow into the root and out into the soil. *Endomycorrhizae* (internal) do not produce a mantle; the hyphae grow within the cells and out into the soil. Arbuscular mycorrhizal (AM) fungi play a crucial role in the ecosystem, particularly in plant growth and nutrient cycling. Here are some key aspects of their importance:

- **Enhanced nutrient uptake:** AM fungi form a symbiotic relationship with the majority of plants, where they colonize the plant's root system and extend their hyphae into the soil. They facilitate the uptake of essential nutrients, particularly phosphorus and nitrogen,

which can be otherwise limited in availability to plants. This nutrient acquisition is vital for plant growth and development.

- **Improved plant health:** The symbiotic association between AM fungi and higher plants not only enhances nutrient uptake but also improves plant health. Plants with AM fungal symbionts tend to be more robust, with increased resistance to diseases and environmental stressors such as drought and heavy metal toxicity.
- **Increased crop productivity:** Many crops benefit significantly from AM fungi. The increased nutrient uptake and improved stress tolerance can result in higher crop yields. This is of great importance in agriculture, where food production needs to meet the demands of a growing global population.
- **Ecosystem stability:** In natural ecosystems, AM fungi play a critical role in nutrient cycling. They help to redistribute nutrients, making them available to a wide range of plant species, thereby contributing to overall ecosystem stability and biodiversity.
- **Carbon sequestration:** AM fungi can also influence carbon cycling in ecosystems. They

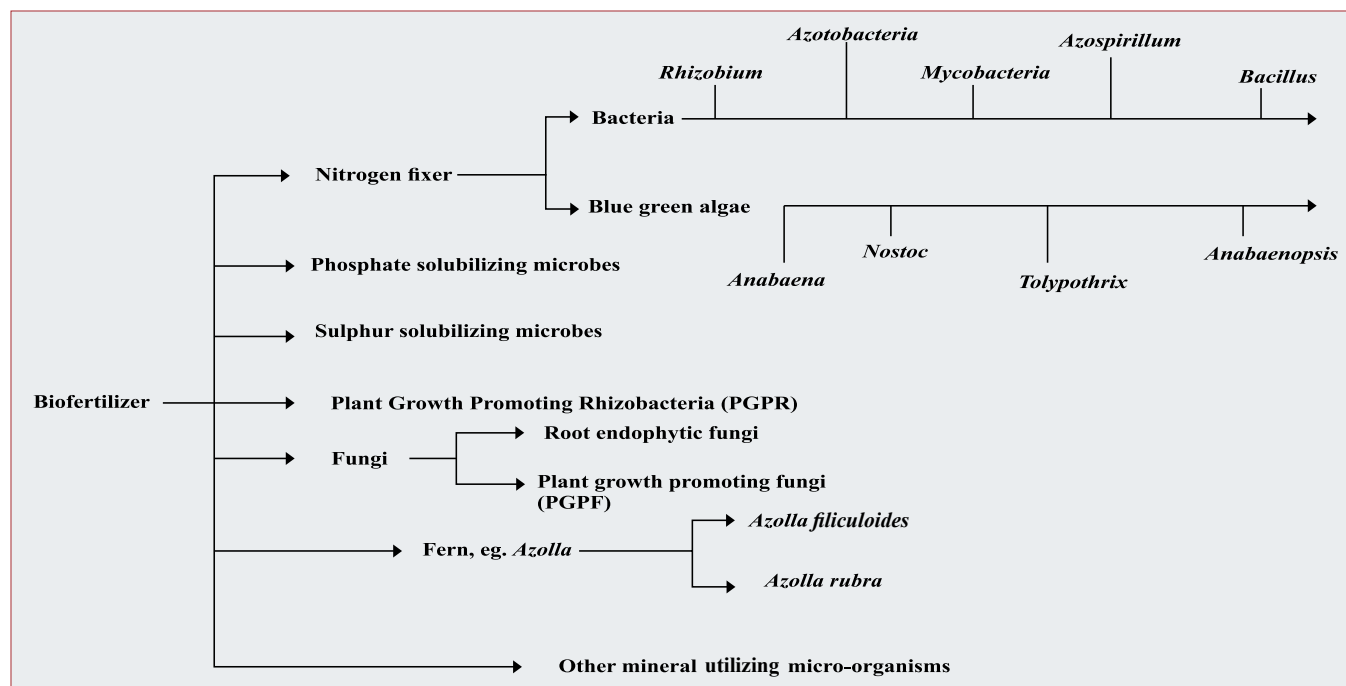


Fig. 2. Classification of efficient bio-fertilizers

can contribute to carbon sequestration by storing carbon in their hyphae and in soil aggregates, helping mitigate the effects of climate change.

- **Soil structure improvement:** The hyphal network of AM fungi enhances soil structure by creating aggregates that improve soil porosity, water retention, and aeration. This, in turn, can reduce soil erosion and improve soil quality.
- **Reduced need for fertilizers:** Because AM fungi enhance nutrient uptake, they can reduce the need for chemical fertilizers in agriculture. This has environmental benefits, as it can decrease nutrient runoff into water bodies, which can lead to water pollution.
- **Restoration of degraded soils:** AM fungi are valuable in the restoration of degraded or polluted soils. They can help revitalize ecosystems by improving soil health and facilitating the re-establishment of native plant species.
- **Biodiversity support:** AM fungi contribute to plant diversity by assisting a wide range of plant species. This, in turn, supports a variety of herbivores and other organisms that depend on these plants for food and habitat.

Potassium bio-fertilizers or K-solubilizing microorganism (KSMs): These are rhizospheric microorganism, which solubilizes the insoluble potassium (K) to soluble forms of K for plant growth and yield. It plays a vital role in the growth and development of plants. If not supplied in adequate quantity, the plants will grow slowly, have poorly developed roots, and produce small seeds and low yields. These microorganisms (e.g., *Bacillus* and *Pseudomonas* sp.) produce organic acids that break down insoluble potassium compounds into plant-accessible forms.

Application-method of bio-fertilizers

The important method of bio-fertilizers applications are listed below:

- **Seedling root dip:** This method

is usually applicable for rice crops. The seedlings are sowed in the bed of water and kept for 8-10 hours.

- **Seed treatment:** The seeds are soaked in the mixture of nitrogen and phosphorus fertilizers. These seeds are then left to dry and are sown as soon as possible. The bio-fertilizers along with the compost fertilizers are blended and kept for one night. This mixture is then scattered on the soil where the seeds have to be sown.
- **Main field application:** A mixture of four packets of the bio-inoculants and 20 kg of dried and powdered farmyard manure is broadcast in the main field just before transplanting.

Precautions that should be taken while using biofertilizer

- **Quality assurance:** Purchase bio-fertilizers from reputable sources that produce high quality, well-characterized products. Ensure they meet regulatory standards and have a proven record of accomplishment.
- **Storage conditions:** Store bio-fertilizers in cool, dry conditions, following the manufacturer's recommendations. Proper storage helps maintain the viability of the microorganisms in the product.
- **Avoid contamination:** Prevent cross-contamination with chemical fertilizers or pesticides. Use separate equipment, containers, and application methods for bio-fertilizers.
- **Application timing:** Apply bio-fertilizers at the appropriate time in the crop's growth cycle. Some bio-fertilizers are more effective when applied during specific stages of plant development.
- **Hygiene:** Maintain good personal hygiene when handling bio-fertilizers. Use protective clothing and equipment to prevent contaminations.
- **Soil testing:** Conduct soil tests before applying bio-fertilizers to determine the specific nutrient

requirements of your soil and crops.

- **Appropriate application rates:** Use the recommended application rates based on the type of bio-fertilizer and the specific crop. Over-application can lead to nutrient imbalances or reduced plant growth.
- **Educational training:** Ensure that farmers and agricultural workers are educated and trained in the proper use of bio-fertilizers to maximize their benefits.
- **Environmental considerations:** Be mindful of the potential environmental impacts, such as runoff, when applying bio-fertilizers near water bodies or sensitive ecosystems.
- **Safety data sheets:** Familiarize yourself with the safety data sheets (SDS) provided by the manufacturer, which contain important information about handling, storage, and emergency procedures.

Way Forward

Bio-fertilizers offer an eco-friendly and cost-effective solution for enhancing soil fertility and nutrient management. As farmers adopt bio-fertilizers like nitrogen-fixing bacteria and phosphate-solubilizing microorganisms, they can reduce their dependence on expensive chemical fertilizers. This cost-saving measure alone can lead to higher net incomes for farmers. Furthermore, ongoing research and development in microbiology and biotechnology are likely to yield more efficient and specialized strains of beneficial microorganisms. These advanced strains will provide even better nutrient uptake efficiency. Additionally, knowledge dissemination and farmer education programs are essential for harnessing the full potential of bio-fertilizers. When farmers are equipped with the knowledge and skills to effectively use these biological inputs, they can optimize their impact on crop yields and soil health. Government support and incentives can play a pivotal role in facilitating this knowledge transfer.

CONCLUSION

Bio-fertilizers play a pivotal role in the endeavour to double farmer income. They offer a holistic approach to agriculture that not only boosts productivity and income but also fosters sustainable and resilient farming practices. However, it is essential to provide farmers with the necessary knowledge and resources to effectively implement bio-fertilizer-based strategies and maximize their income potential. In modern-day agricultural practices, the role of bio-fertilizers is becoming increasingly vital due to changing scenarios and environmental

hazards associated with agro-chemicals. Bio-fertilizers play a crucial role in increasing availability of plant nutrients and maintaining soil fertility over an extended period.

As previously discussed, certain microorganisms have beneficial functions, such as biological nitrogen fixation to supply nitrogen to crops, solubilizing insoluble phosphates into plant-available (soluble) forms, and synthesizing biomass for crop manuring, particularly in the case of rice cultivation. While bio-fertilizers are known for their economic, renewable and eco-friendly qualities, it is important

to note that they cannot entirely replace chemical fertilizers. Instead, bio-fertilizer use serves as an essential component of Integrated Nutrient Management (INM) and organic farming. As we look ahead, the changing agricultural landscape and growing concern about environmental risks associated with chemical fertilizers underscore need for a more significant role for bio-fertilizers in the years to come.

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HANDBOOK OF INTEGRATED PEST MANAGEMENT

To reverse the loss of environmental resources and also to reduce biodiversity loss, the Government of India has Integrated Pest Management (IPM) as part of the National Agricultural Policy. Integrated Pest Management emphasizes the growth of a health crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. IPM is not new – mechanical, cultural and biological tactics were used by farmers for hundreds of years before chemical pesticides became available. Besides, there are IPM techniques that have been developed more recently and are effective in suppressing pests without adversely affecting the environment.



The task of spreading the message of IPM across is tough due to poor awareness about the subject among people in line-departments as also among the farmers. The information on integrated pest management as a whole is scattered. This *Handbook* comprehensively deals with all the aspects of integrated pest management in field crops, horticultural crops under traditional, protected systems. Information on basic strategies and tactics of different methods of management including mass production of biocontrol agents, IPM policy and pesticide registration is provided in comprehensive form.

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