Available online at
http://agrospheresmagazine.vitalbiotech.org/

ISSN (E): 2582 – 7022

Agrospheres:e- Newsletter, (2025) *6*(11), 63-65

Agrospheres e-Newsletter

Article ID: 832

Biofertilizers and Microbial Inoculants for Sustainable Soil Fertility

Rita Fredericks

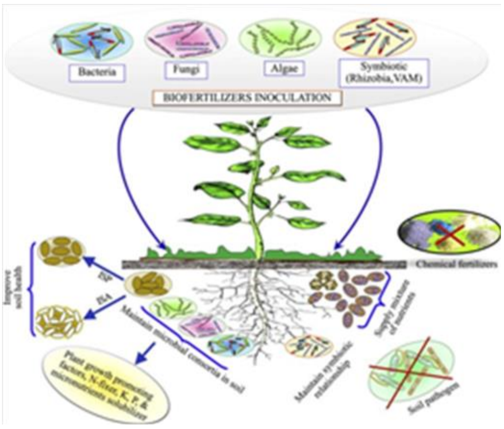
CEO, Precision Grow (A Unit of Tech Visit IT Pvt Ltd)

*Corresponding Author
Rita Fredericks*

Article History
Received: 1. 11.2025
Revised: 5. 11.2025
Accepted: 10. 11.2025

INTRODUCTION

Sustainable agriculture aims to increase crop production while maintaining ecological balance and preserving soil fertility over the long term. In the last few decades, overuse and often indiscriminate use of chemical fertilizers have seriously affected soil health by causing nutritional imbalances, reducing organic content, deteriorating structural properties, and lowering the population of viable microorganisms in the soil. The aforementioned negative impacts have led to low nutrient-use efficiency, environmental pollution, and also decreased resistance of crops to natural stresses. In this context, biofertilizers and microbial inoculants represent promising alternatives, being eco-friendly and cost-effective to supplement or completely replace the use of chemical fertilizers. These living microbial inputs help improve soil fertility through biological nitrogen fixation, solubilization of minerals, decomposition of organic matter, and improved plant nutrient uptake, thereby supporting sustainable crop production systems.



(Source, Mahmud et al., 2021)

2. Concept of Biofertilizers

Biofertilizers are special formulations that contain useful microorganisms, which improve fertility and plant growth through biological processes in nature. These microbes colonize the rhizosphere and sometimes the root tissues, where they improve nutrient availability, stimulate plant metabolic activities, enhance soil biochemical reactions, and restore soil microbial diversity. They play an important role in nutrient cycling and soil health improvement.

ISSN (E): 2582 – 7022

Types of Biofertilizers

Nitrogen Fixers:

Microorganisms like Rhizobium, Azotobacter, and Azospirillum fix atmospheric nitrogen into plant-usable forms, thus minimizing the use of synthetic nitrogen fertilizers. The nitrogen-fixing symbiotic association of Rhizobium occurs with leguminous crops, whereas Azotobacter and Azospirillum function as free-living or associative nitrogen fixers in cereals and other crops. Blue-green algae (cyanobacteria) and Azolla are also important contributors to biological nitrogen fixation in rice ecosystems.

Phosphate-Solubilizing Bacteria (PSB):

Species such as Bacillus, Pseudomonas, and Aspergillus convert the insoluble forms of phosphorus into soluble ones, easily absorbable by plants. They produce organic acids and enzymes that release the bound phosphorus from soil minerals, hence enhancing phosphorus-use efficiency.

Potassium-Solubilizing Bacteria (KSB):

Certain microorganisms like *Frateuria aurantia* and *Bacillus mucilaginosus* solubilize potassium from mineral sources such as feldspar and mica, thereby making it available to crops, which in turn helps improve tolerance to stresses and yield.

Zinc Solubilizers:

Various strains of Bacillus and Pseudomonas aid in the solubilization of Zinc compounds from the soil, thereby increasing its availability as a micronutrient to crops and preventing disorders caused by zinc deficiency.

Mycorrhiza (VAM – *Vesicular Arbuscular Mycorrhiza*):

VAM fungi form symbiotic associations with plant roots and significantly improve phosphorus acquisition. Besides, they enhance the uptake of such other nutrients as zinc, sulfur, and micronutrients, improve drought tolerance, and contribute to better soil aggregation.

Plant Growth-Promoting Rhizobacteria (PGPR):

These microbes stimulate plant growth by producing growth hormones, improving nutrient availability, suppressing plant pathogens, and enhancing root development that leads to better vigor and yield of crops.

3. Microbial Inoculants: Modes of Action

Microbial inoculants improve soil fertility and plant performance through a variety of biological and biochemical processes.

3.1 Biological Nitrogen Fixation (BNF)

Certain microorganisms can convert atmospheric nitrogen into a plant-usable form through specific enzymatic reactions. This will greatly reduce the use of synthetic nitrogen fertilizers, decrease the cost of production, and contribute to sustainable cereal, legume, and horticulture crop cultivation.

3.2 Nutrient Solubilization and Mobilization

The bound nutrients are released by PSB and KSB through the production of organic acids, enzymes, and chelating compounds. Mycorrhizal fungi increase the surface area of the root and make available to the plant nutrients such as P, S, Zn, and micronutrients from soil pools that are otherwise unavailable.

3.3 Production of Plant Growth Regulators

PGPR microbes produce plant hormones like auxins, gibberellins, and cytokinins that promote root elongation, shoot development, and better nutrient absorption, leading to improved growth of the plant, higher biomass production, and increased yield.

3.4 Amendment of Soil Structure

Beneficial microbes produce polysaccharides and other organic compounds that bind soil particles together as aggregates. Soil aggregation increases aeration, improves water infiltration and water retention, decreases erosion, and allows for deeper root penetration, which promotes overall soil health.

3.5 Soil-Borne Pathogen Suppression

Certain microbes limit the growth of noxious pathogens by ways that include the production of antibiotics, lytic enzymes, siderophores, and competitive exclusion. They reduce the incidence of diseases like wilt, damping-off, and root rot, thereby minimizing yield losses and decreasing the need for chemical pesticides.

4. Advantages of Biofertilizers in Sustainable Agriculture

Various advantages provided by biofertilizers make them indispensable inputs for sustainable agriculture. They are non-toxic and safe for the environment, and their use does not result in any adverse ecological effects even after long periods of application. They reduce the cost of cultivation by reducing the consumption of expensive chemical fertilizers. Biofertilizers maintain soil microbial diversity, improve nutrient cycling, and thus contribute to ecological balance. They improve NUE, soil organic matter, and soil structure. They increase crop yield and quality, with reduced soil, water body, and food product contamination. Biofertilizers contribute to climate-smart agriculture and environmental sustainability through a reduction in GHG emission associated with the use of chemical fertilizers.

5. Application Methods

5.1 Seed Treatment

Seed treatment with biofertilizers is one of the common methods followed for Rhizobium, PSB, and Azotobacter. This treatment ensures early root colonization, increases nutrient uptake in the early stages of growth, and helps establish vigorous seedlings.

5.2 Seedling Root Dip

Seedlings, particularly for rice, vegetables, and horticultural crops, are dipped in biofertilizer slurry before transplanting. This aids in quickly establishing the desirable microorganisms in the rhizosphere and helps in better survival and growth of plants.

5.3 Application to Soil

Biofertilizers can be mixed with well-decomposed FYM or compost and broadcast in the field. It enhances microbial activity in the soil, improves nutrient availability, and hence maintains long-term soil fertility.

5.4 Drip Irrigation/Fertigation

Liquid formulations of PGPR and mycorrhiza can be delivered via drip irrigation systems. This method assures even distribution of microbes, saves labor, and fosters increased interactions between plants and microbes.

5.5 Foliar Application

Certain microbial consortia can be sprayed on the foliage for stress tolerance, disease suppression, and enhanced nutrient assimilation. This method is especially effective in horticultural crops under abiotic stress.

6. Challenges and Limitations

However, there are some drawbacks with biofertilizers: poor shelf life for some microbial strains reduces viability over time; field performance is sometimes inconsistent because of climatic variations, different soils, and the indiscriminate growth of native microorganisms. A general lack of knowledge by farmers concerning methods of application and handling limits full acceptance. Besides, variability in standards and quality among the products available in the market demands stringent regulation and testing to ensure their functionality.

7. Future Prospects

The potential to transform modern agriculture into more sustainable and climate-resilient is indeed vast with biofertilizers. Future developments can include multi-strain microbial consortia which will be able to perform many functions simultaneously. Biotechnological applications in the advancement of stress-tolerant microbial formulations may result in products to suit different climatic conditions. Nano-biofertilizers are expected to ensure better nutrient delivery and microbial efficiency. Integration with precision agriculture tools, such as remote sensing and GIS, may improve recommendation and application accuracy. More intensive research on mycorrhiza-based products and increased supportive government policies will further enhance the use of these sustainable inputs.

8. CONCLUSION

Biofertilizers and microbial inoculants represent a cornerstone of sustainable soil fertility management. The ability of this resource to enhance nutrient availability, improve soil health, promote plant growth, and reduce dependency on chemical inputs further underlines its importance in modern agriculture. By adopting such eco-friendly technologies, farmers can improve productivity of their soils, reduce environmental pollution, and thus contribute to long-term agricultural sustainability and ecosystem protection. The incorporation of biofertilizers into farming systems goes hand-in-hand with the future of sustainable agriculture, in line with various global initiatives for food security and protection of the environment.

REFERENCES

Bhardwaj, D., Ansari, M. W., Sahoo, R. K., & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial cell factories*, *13*(1), 66.

Mahmud, A. A., Upadhyay, S. K., Srivastava, A. K., & Bhojiya, A. A. (2021). Biofertilizers: A Nexus between soil fertility and crop productivity under abiotic stress. *Current Research in Environmental Sustainability*, *3*, 100063.

Shahwar, D., Mushtaq, Z., Mushtaq, H., Alqarawi, A. A., Park, Y., Alshahrani, T. S., & Faizan, S. (2023). Role of microbial inoculants as bio fertilizers for improving crop productivity: A review. *Heliyon*, *9*(6).

Yadav, K. K., & Smritikana Sarkar, S. S. (2019). Biofertilizers, impact on soil fertility and crop productivity under sustainable agriculture.