

Biofertilizer for Sustainable Agriculture Development

Abstract

Global population is expected to increase 10 billion by 2050. It necessitates a sustainable solution to address food security while mitigating environmental degradation caused by chemical fertilizer. Use of plant growth promoting microorganisms has its own benefits when it comes to soil and plant health and enhanced crop yield. Biofertilizers comprising microbial inoculants like bacteria, algae, fungi offer a promising avenue for achieving these goals. They fix nitrogen, solubilize phosphate, zinc, and silicate, enhancing plant health. These fertilizers are cost effective and eco-friendly. The utilization of biofertilizers presents a viable strategy to practice sustain agriculture. By embracing these microbial inoculants agricultural systems can enhance productivity while minimizing adverse ecological impacts.

Keywords- Sustainable agriculture, biofertilizers, nitrogen fixers, phosphorus/potassium/zinc solubilizers, plant growth promoting rhizobacteria, *Rhizobium*, *Azotobacter*, *Azospirillum*.

I. Introduction

Currently, the world population is 8 billion and according to some estimates, it will be 10 billion by 2050. Ensuring food security for the growing population is an immense challenge (Gu *et al* 2021). Also, increased use of chemical fertilizers to boost productivity of food has had severe adverse effects on the environment. These chemical fertilizers lower soil water retention and decrease soil fertility (Wu *et al* 2020). They reduce soil pH which decreases the number and diversity of soil microflora. Besides, these fertilizers leach into the ground water which is often a source of drinking water for a population. Overall, excessive use of chemical fertilizers pollute the ecosystem and create nutritional imbalances in the soil (Nosheen *et al* 2021). In this scenario, it is crucial to increase productivity to feed the growing population. This can be done by various interventions such as breeding for higher yielding varieties, optimum resource utilization, agronomic operation and practice of sustainable agriculture. Biofertilizers are an important tool for practicing sustainable agriculture. They play a role in plant nutrient acquisition and plant growth promotion (Fasusiet *al* 2021).

II. Biofertilizers and their benefits

Biofertilizers are microbial inoculants which may be bacterial, algal or fungal. *Rhizobium*, *Azotobacter*, *Azospirillum*, phosphate-solubilizing bacteria (PSB) and arbuscular mycorrhiza (AM) have been recommended as commercialization biofertilizers it has become cost effective and eco-friendly alternative than chemical fertilizers. They are nitrogen fixing, phosphate solubilizing/mobilizing, phytohormone producing and disease suppressing. Also, biofertilizers help in improving plant's tolerance to biotic and abiotic stresses (Gamalero *et al* 2022). Plant Growth Promoting Rhizobacteria (PGPR) is a term used to describe these beneficial organisms that inhabit the rhizosphere. PGPRs act as bio-protectants and provide tolerance to high temperatures and salinity stresses (Singh 2023). *Pseudomonas putida*,

Bacillus megaterium and AM fungi are effective in alleviating drought stress. Their quality specifications are defined in the government of India Fertilizer Control Order (FCO) 1985.

Nitrogen fixing biofertilizers: Nitrogen fixing bacteria are those bacteria which fix atmospheric nitrogen and convert it to plant absorbable forms (ammonia, nitrite and nitrate) which can be used by plants. These can be of two main groups including symbiotic bacteria associated with leguminous plant (*Rhizobium*), non-leguminous *Frankia* and non-symbiotic free living bacteria Cyanobacteria and some genera including *Azotobacter Pseudomonas Arthrobacter* (Masson-Boivin *et al* 2018).

Phosphate solubilizing/mobilizing biofertilizers: Phosphate solubilizing bacteria (PSB) are beneficial microbes that help plants access stored phosphorus in soil. They release organic acids to lower soil pH, thus making phosphorus soluble. PSB also secrete enzymes like phytases and phosphatases which break down complex organic phosphorus compounds aiding in nutrients available for plants. Examples of PSB include *Pseudomonas* sp, *Bacillus* sp and *Enterobacter* sp. (Bakhshandeh *et al* 2020)

Potassium solubilizing biofertilizers: The application of potassium solubilizing bacteria (KSB) is an efficient and sustainable practice in plant production. KSB transforms insoluble potassium from minerals like feldspar and aluminosilicates into forms usable by plants, thus improving potassium uptake. It employs various mechanisms including synthesis of organic acids like oxalic acid, succinic and tartaric acids which lower the pH. Polysaccharides attach to mineral surfaces aiding potassium dissolution. KSB *Bacillus mucilaginosus*, *Pseudomonas putida* have demonstrated their ability to facilitate potassium availability (Yaghoubi *et al* 2019).

Zinc solubilizing biofertilizers: Zinc solubilizing biofertilizers (ZSB) are equally important in crop production owing to the worldwide Zn deficiency in soils. This deficiency is prevalent in most arable land and is caused by nutrient mining due to crop harvesting. ZSB can increase Zn uptake by plants for improved growth and yield. *Pseudomonas*, *Azotobacter*, *Azospirillum* and *Rhizobium* sp have exhibited significant Zinc solubilizing ability (Kamran *et al* 2017).

Important biofertilizers

1. *Rhizobium*: A bacterium known as *Rhizobium* inhabits soil and grows symbiotically in legume roots to fix atmospheric nitrogen. *Rhizobium* can have a variety of morphologies and physiologies, ranging from free-living conditions to nodule-forming bacteroids. In terms of the amount of nitrogen fixed in question, they are the most effective biofertilizer. They belong to the cross-inoculation category and contain seven genera. They are very particular when it comes to forming nodules in legumes. It fixes 200-300 kg N/ha (Purwaningsih *et al* 2024).
2. *Azotobacter*: Of the various species of *Azotobacter*, *A. chroococcum* is the most common resident in arable soils and has the ability to fix N₂ in culture media (2–15 mg N₂ fixed/g of carbon source). The bacterium makes a lot of slime, which aids in the aggregation of soil. Because of the absence of organic matter and the existence of hostile microorganisms in the soil, the amount of *A. chroococcum* in Indian soils seldom reaches 10⁵/g soil (Mishra *et al* 2023).
3. *Azospirillum*: *Azospirillum lipoferum* and *A. brasilense* (formerly published as *Spirillum lipoferum*) are the principal occupants of graminaceous plant soil, rhizosphere, and

intercellular gaps in root cortex. They grow graminaceous plants in an associative symbiotic connection. Other advantages of *Azospirillum* inoculation include disease resistance, drought tolerance, growth stimulating substance synthesis (IAA), and nitrogen fixation (Suhameena *et al* 2020).

4. *Cyanobacteria*: In India, rice is grown using cyanobacteria, or blue green algae, both free-living and symbiotic. It was once widely advertised as a biofertilizer for rice crops, but rice growers throughout India are not currently interested in it. Under ideal circumstances, the benefits of using algae could reach 20–30 kg N/ha; nevertheless, the labour-intensive process of making BGA biofertilizer is a drawback in and of itself (Bhuyan *et al* 2023).
5. *Azolla*: *Azolla* is a type of free-floating water fern that works with the nitrogen-fixing blue green algae *Anabaena azollae* to fix atmospheric nitrogen. *Azolla* can be added to commercial nitrogen fertilizers or used as an alternative source of nitrogen. *Azolla* is known to contribute 40–60 kg N/ha per rice crop and is utilized as a biofertilizer for wetland rice (Marzouk *et al* 2023).
6. Phosphate solubilizing microorganisms (PSM): To dissolve bound phosphates in soil, a number of soil bacteria and fungi, including species of *Bacillus*, *Aspergillus*, *Penicillium*, and *Pseudomonas*, release organic acids and reduce the pH in the area around them. The introduction of *Bacillus polymyxa* and *Pseudomonas striata* cultures based on peat resulted in increased yields of wheat and potatoes (Kumar *et al* 2017).
7. AM fungi: Intracellular obligate fungal endosymbionts of the genera *Glomus*, *Gigaspora*, *Acaulospora*, *Sclerocystis*, and *Endogone*, which have vesicles for storing nutrients and arbuscules for channeling these nutrients into the root system, transport nutrients, primarily phosphorus but also zinc and sulfur, from the soil milieu to the cells of the root cortex. Of all the genus, *Glomus* seems to be the most prevalent, with multiple species found in soil (Madawala 2021).
8. Silicate solubilizing bacteria (SSB): Microorganisms known as silicate solubilizing bacteria (SSB) are able to break down silicates, including aluminum silicates. Numerous organic acids are created by bacteria during their metabolism, and these acids have two roles in the weathering of silicate. They provide the medium with H⁺ ions, which encourage hydrolysis. Additionally, organic acids such as citric, oxalic, keto, and hydroxy carboxylic acids, which form complexes with cations, facilitate the removal of cations from the medium and their retention in a dissolved state (Kumar *et al* 2017).
9. Plant growth promoting rhizobacteria (PGPR): Plant growth promoting rhizobacteria (PGPR) are a class of bacteria that are good for crops and colonize roots or rhizosphere soil. The PGPR inoculants stimulate growth by inhibiting plant disease (called Bioprotectants), enhancing nutrient uptake (called Biofertilizers), or producing phytohormones (called Biostimulants). Certain *Pseudomonas* and *Bacillus* species have the ability to create phytohormones or growth regulators that, although not fully understood, cause crops to have more fine roots. This increases the plant roots' absorptive surface area, which increases their ability to absorb nutrients and water. The phytohormones that these PGPR, also known as biostimulants, generate include gibberellins, cytokinins, indole-acetic acid, and inhibitors of ethylene synthesis (Singh 2023).

III. Conclusion and future prospects

Agriculture can profit greatly from the eco-friendly nature of the biofertilizers. Biofertilizers can potentially reduce agriculture dependence on chemical fertilizers. Also, they are low cost agri-inputs. Biofertilizers, as explained earlier, have immense benefits. It is pertinent to

mention that maintaining inoculant quality and effectiveness is critical to the future of biofertilizers technology (Macik *et al* 2020). Biofertilizers are used by applying them onto the seeds, seedling roots or by soil mixing. They do not require any agricultural machinery and are not labour intensive either. However, despite these advantages biofertilizers are not used commonly. Effort is required to educate and train farmers about biofertilizer technology. This can be done by organizing farmer outreach programs/lectures at district or village level. Also important is manufacturers compliance to government quality specifications so that marketing of spurious biofertilizers is discouraged. Farmers should be made aware of procedures and advantages of biofertilizers. Scientists can contribute by working on qualitative, affordable and environmentally beneficial production of biofertilizer (Parveen and Tyagi 2023).

IV. References:

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