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Biofertilizers- Towards Sustainable Agriculture Development

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Authors' contributions

This work was carried out in collaboration among all authors. Author GS did the concept and framework of the manuscript, did literature searches, prepared the draft. Authors KN and BK prepared the Manuscript, conformance to journal format. All authors read and approved the final manuscript.

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ABSTRACT

By 2050, there will be approximately 10 billion people on the planet, therefore finding greener methods to produce food will be crucial. A significant greener method involves the use of beneficial bacteria known as plant growth-promoting microorganisms. These microscopic organisms can increase crop yields, strengthen the soil and foster healthier plant growth. Beneficial microbes include bacteria, fungi, algae. They are eco-friendly and enhance nutrient absorption by the plants. These nutrients include nitrogen, phosphorus and potassium. In addition, some species of biofertilizers produce plant growth hormones. The opinion article outlines the advantages and important biofertilizers strains which are used commercially.

Keywords: Biofertilizers; nitrogen fixers; nutrient solubilizers; plant growth promoting rhizobacteria; rhizobium; azotobacter.

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1. 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 [1]. Also, increased use of chemical fertilizers to boost productivity of food has severe adverse effects on the environment. These chemical fertilizers lower soil water retention and decrease soil fertility [2]. 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 [3]. 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 high yielding varieties, optimum resource utilization, agronomic operation and practice of sustainable agriculture. Biofertilizers are an important tool for practicing sustainable agriculture. They contribute towards acquisition of nuttrients by plants and promote plant growth [4].

2. BIOFERTILIZERS AND THEIR BENEFITS

Biofertilizers are microbial inoculants which may be bacterial, algal or fungal. *Rhizobium Azotobacte*r, *Azospirillum,* phosphate-solubilizing bacteria (PSB) and arbuscular mycorrhiza (AM) are used commercially as they offer a cost effective and eco-friendly alternative to chemical fertilizers. They are nitrogen fixing, phosphate solubilizing**/**mobilizing, phytohormone producing and disease suppressing. They improve plants` tolerance to biotic and abiotic stresses [5]. 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 [6]. *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.

a) 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-symbiotic bacteria associated with leguminous plant *(Rhizobium*), non-leguminous *Frankia;* non-symbiotic free living bacteria as *Azotobacter* and associative nitrogen fixers as *Azospirillum* [7].

b) 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. [8].

c) 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 which are usable by plants, thus improving potassium uptake. It uses various mechanisms including synthesis of organic acids like oxalic acid, succinic and tartaric acids which lower the pH. which help to dissolve potassium. Potassium solubilizing bacteria like *Bacillus mucilaginosus, Pseudomonas putida* have demonstrated their ability to facilitate potassium availability [9].

d) 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 [10].

3. IMPORTANT BIOFERTILIZERS

a) ***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 [11].

b) ***Azotobacter***: Of the various species of Azotobacter, A. *chroococcum* is the most common resident in arable soils and has the ability to fix N_2 in culture media (2–15 mg N_2 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 10^{-5}/g soil [12].

c) ***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 with 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 [13].

d) ***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 crop, but rice growers throughout India are not currently interested in it. Under ideal circumstances, BGA can fix up to 30 kg N/ha; nevertheless, the labour- intensive process of making BGA biofertilizer constitutes a major drawback for its popularization [14].

e) ***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 of rice crop and is utilized as a biofertilizer for wetland rice [15].

f) **Phosphate Solubilizing Microorganisms (PSM)**: The number of soil bacteria and fungi, including species of *Bacillus, Pseudomonas, Aspergillus, Penicillium* solubilize bound phosphates in the soil. They release organic acids and reduce the pH which solubilizes the phosphorus. The introduction of *Bacillus polymyxa* and *Pseudomonas striata* cmultures based on peat resulted in increased yields of wheat and potatoes [16]. As per FCO, PSM must solubilize minimu 30% phosphorus when estimated spectrophotometrically.

g) **AM fungi**: Intracellular obligate fungal endosymbionts of the genera *Glomus, Gigaspora, Acaulospora, Sclerocysts,* 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 sulphur from the soil to the cells of the root cortex. Of all the genus, *Glomus* seems to be the most prevalent, with multiple species found in soil [17].

h) **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 [16].

i) **Plant growth promoting rhizobacteria (PGPR):** Plant growth promoting rhizobacteria (PGPR) are a class of bacteria that are good for crops and colonize roots. 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 help 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 [6,18,19].

4. CONCLUSIONS

Biofertilizers offer a promising avenue for sustainable agriculture by providing eco-friendly and cost-effective alternatives to chemical fertilizers. Their numerous benefits, including improved soil health and reduced dependence on external inputs, make them a valuable tool for enhancing agricultural productivity while minimizing environmental impact. However, the successful implementation of biofertilizers depends on maintaining their quality and effectiveness, which requires efforts from both manufacturers and farmers. Educating farmers about biofertilizer technology through outreach programs and ensuring compliance with government quality standards are essential steps towards promoting their widespread adoption. Moreover, ongoing research and development initiatives aimed at enhancing the production and efficacy of biofertilizers will further contribute to their future prospects in agriculture.

FUTURE PROSPECTS

Looking ahead, the future of biofertilizers in agriculture appears promising. Continued advancements in biofertilizer technology, coupled with increased awareness and adoption among farmers, hold the potential to revolutionize agricultural practices and contribute to sustainable food production systems. Collaboration between scientists, manufacturers, and policymakers will be crucial in addressing challenges related to biofertilizer production, quality assurance and dissemination. By investing in research, education, and infrastructure, the study can unlock the full potential of biofertilizers and pave the way for a more resilient and environmentally sustainable agricultural sector.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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