A Review of Biofertilizers' Potential Application in Green Agriculture

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Abstract

India's most common job is farming, which is essential to the country's economy. Fertilisers used in agriculture are necessary for healthy crop development and productivity. Farmers have increasingly resorted to chemical fertilisers in an effort to expedite and boost production. Conversely, these fertilisers endanger soil, plants, animals' and people's lives, and ecosystems. Conversely, natural biofertilizers are safe for use around people and offer a larger yield. In an effort to promote sustainable agriculture, biofertilizers are becoming more and more popular as a practical substitute for hazardous chemical fertilisers. The production of crops and the maintenance of soil fertility over the long term depend on biofertilizers. Biofertilizers play a critical role in crop development and long-term soil fertility management, both of which are essential to meeting the world's food needs. Crop plants and microbes may work together to enhance the plants' growth, development, and immunity. The primary nutrients that plants need for healthy development are silica, nitrogen, phosphorus, potassium, and zinc; nevertheless, these minerals are inherently complex or insolubilized. They become soluble and available to the plants thanks to certain microbes. The potentials of microorganisms, their mechanism of action, and their effects on crops are covered in this review. Chemical fertilisers may be replaced with biofertilizers, which are safer, more affordable, and less damaging. Understanding the importance and workings of microbial generation as biofertilizers for agricultural sustainability may be facilitated by the information acquired from this review.

Keywords: Microorganisms, Biofertilizers, Environment, Sustainability, Solubilizers.

1. Introduction

The global population is projected to reach 9.7 billion by 2050. (Erlich and Harte, 2015). Rapid growth is closely tied to intensive industry, urbanisation, and agricultural productivity. Traditional agriculture is crucial for meeting the world's food demands, which are projected to reach 321 million tonnes by 2020. It also helps nations improve their food production self-sufficiency (Gizaki et al., 2015; Mahanty et al., 2016; Santos et al., 2012).Conventional agriculture relies heavily on synthetic fertilisers and pesticides for plant nutrition and disease control (Vasileet al., 2015). Proper use of chemicals benefits crop growth and quality, as well as farmers' revenue. The usage of artificial sources may harm the natural ecosystem by contaminating water, air, and soil (Rahman and Zhang, 2018).Overuse of agrochemicals and insufficient biodegradation may cause buildup belowground, negatively impacting soil structure, fertility, and water retention capacity (Savci, 2012).

The agricultural outlook for 2008-2017 by the Organisation for Economic Cooperation and Development (OECD) and the Food and Agriculture Organisation of the United Nations (FAO) recommends increasing land use for agriculture and addressing new food demands.

To boost plant nutrient uptake, consider using microbial inoculants due to the high cost of mineral nitrogen and phosphorus fertiliser.

Sustainable crops are crucial for optimising soil health via the use of herbicides, pesticides, and organic manures.Constant crop production depletes the soil of nutrients, including nitrogen. An regular crop uses the usual nitrogen (N) from an acre. Therefore, farming removes components from the soil over time. Rising fertiliser costs and concerns about sustainable soil production and ecological stability have become critical challenges. Relying heavily on chemical fertilisers benefits farmers with larger hectares economically. Biofertilizers and organic manures, including FYM, compost, and green manures, are gaining popularity due to these factors.

2. Biofertilizers.

Green manure and organic materials are biofertilizers. Biofertilizers are inoculants used by farmers to improve soil productivity by fixing airborne phosphates, solubilizing phosphates, and stimulating plant growth through the synthesis of growth-promoting substances. These inoculants contain efficient strains of bacteria.

Biofertilizers are microorganisms that provide nutrients, particularly nitrogen and phosphorus, to enhance agricultural yield. These biofertilizers are inexpensive, simple to use, and ecologically benign. Proper application of biofertilizers and organic plant nutrients may boost production, improve soil health, and meet plant fertiliser needs.

3. The role of biofertilizers

Biofertilizers have a significant impact on the immobility (P, Zn, Cu) and movement of plant components (C, S, Ca, K, Mn, Cl, Br, and N) (Tinker, 1984). Bacteria in the rhizosphere produce growth chemicals and secondary metabolism that help plants germinate and flourish (Subba Rao, 1982, 2002; Dwivedi, 1989). Azotobacter, Rhizobium, and Bacillus megaterium are preferred bacteria for phosphate solubilization.

According to Mishra et al. (2013), biofertilizers improve plant development while minimising environmental impact and increasing harvest yields. Schutz et al. (2018) found that inoculating crops with biofertilizers boosted crop output by an average of 16.2 percent compared to non-inoculated control groups.

Microbial biofertilizers help preserve soil fertility by influencing particle aggregation and structure (Rashid et al., 2015).Xiang et al. (2012) found that they improve plant-water interactions. They provide dry protection, lower plant prices for soil-borne illnesses, such as fungal diseases that create mycotoxins (Simarmata et al., 2016) and minimise insect pests (Dey et al., 2014).

4. Biofertilizers and Their Types

Biofertilizers promote plant development and protect them from pests and diseases (El-yazeid et al. 2007). Many researchers throughout the globe have investigated the significance of soil microorganisms in sustainable agricultural growth (Lee and Pankhurst 1992, Wani et al., 1995). Biofertilizers are increasingly being employed in crop production, with several options available on the market.

In 1896, Nobe and Hiltner patented microbial inoculation, starting with the Rhizobium inoculant for legumes (Fred et al., 1932). In wealthy nations like the US and France, biofertilization is confined to Rhizobium. However, in Brazil, China, and India, it now includes a variety of bacteria, fungi, and actinomycetes. There are three types of biofertilizers: nitrogen, phosphate, and plant growth-supporting biofertilizers, which use microorganisms to dissolve potassium.

Table 1. Biofertilizers and its target crops

Biofertilizer	Target Crop
Rhizobium	Leguminous crops
Azotobacter	Wheat, maize, cotton, mustard, and vegetables (potato, onion, tomato, brinjal, and others)
Azospirillum	Cereal crops like wheat, maize, millets, sorghum, barley, and sugarcane
Blue green algae (BGA)	Rice
Phosphate solubilizing microorganisms	All
Potassium solubilizing microorganisms	All
Plant Growth Promoting Rhizobacteria (PGPR)	All
Arbuscular mycorrhiza	Nursery raised crops and orchard trees

Biofertilizers are categorised into several types depending on their functions and ways of action. Common biofertilizers include N-Fixers, K-Solution stabilisers, PSs, and PGPR. One gramme of rich soil contains up to 1010 bacteria with a life weight of 2000 kg/ha. Soil bacteria may be classified as cocci (0.5 µm), ruby (0.5-0.3 microns), or spiral (1-100 microns). Bacteria in soil are influenced by its physical and chemical qualities, organic matter, and phosphorus levels.

Table 2. Characteristics of different biofertilizers

Sr. No	Types of Biofertilizers	Characteristics	Microorganisms
1.	Nitrogen fixing biofertilizers	Obtain Nitrogen from the atmosphere and convert this into organic forms usable by plants	Rhizobium, Azospirillum, Azotobacter
2.	Phosphorous solubilizing biofertilizers (PSB)	Solubilize insoluble inorganic phosphate compounds	Bacillus, Pseudomonas, Aspergillus
3.	Phosphate mobilizing biofertilizers	Symbiotic association between host plants and certain group of fungi at the root system	Mycorrhiza
4.	Plant growth promoting biofertilizers	Increasing the growth and yield of plants	Pseudomonas sp.

4.1 Nitrogen-fixing Biofertilizers

Nitrogen is one of the most critical elements for plant development and production. Although there is 78% N2 in the atmosphere, plants cannot use it. Biological nitrogen fixation converts atmospheric nitrogen to ammonia, which plants may readily ingest (Tairo and N dakidemi 2013).There are two types of nitrogen-fixing species: symbiotic and non-symbiotic. Symbiotic species include those from the Rhizobiaceae family that live in tandem with leguminous plants (Ahamed and Khan 2012). Non-symbiotic organisms include free-living and endophytic microbes like Cyanobacteria, Azospirillum, and Azotobacter.

4.1.1 Rhizobium.

Rhizobium, a member of the Rhizobiaceae bacterial family, is the most effective symbiotic nitrogen fixer. It can fix N2 in legumes as well as non-legume plants. Rhizobium can fix up to 300 kg of nitrogen per hectare per year in diverse legume crops. Rhizobium includes Bradyrhizobium, Sinorhizobium, Azorhizobium, and Mesorhizobium. Diazotrophic rhizobacteria may develop non-binding connections with host plants and attach nitrogen to them, unlike symbionts (Verma et al. 2010). Rhizobial development is also a significant factor. Most bean plants generate root lateral structures known as "root nodules" to house the symbiotic bacterium Rhizobium. This enhances plant growth, soil microbial population, and biomass, while also reducing weed population.

4.1.2 Azospirillum.

The Spirilaceae family includes gram-negative, aerobic nitrogen-fixing bacteria that do not form nodules. Azospirillum amazonense, Azospirillum halopraeferens, and Azospirillum brasilense are common, although Azospirillum lipoferum and A. brasilense are particularly advantageous (Mishra et al. 2013). Azospirillum inoculation significantly improves root growth and exudation (Trabelsi and M hamdi, 2013). Maize, sugarcane, sorghum, and pearl millet are often recommended for development. They create growth promoters and optimise the usage of plant nutrients (IAA, gibberellins, and cytokinin) (N, P, and K).

4.1.3 Azotobacter.

Azotobacter, a nitrogen-fixing diazotrophic bacteria, plays a crucial part in the nitrogen cycle via different metabolic processes. This biofertilizer from the Azotobacteriaceae family is effective for non-leguminous plants such as rice, cotton, vegetables, sugarcane, sweet potato, and sweet sorghum. It fixes almost 30 kg of nitrogen per year and boosts sugarcane output by 25-50 tonnes per hectare and sugar content by 10-15%. Azotobacter may live in both acidic and alkaline soils.

4.1.4 Anabaena Azollae.

It is a symbiotic bacteria that is mostly employed in rice to fix atmospheric nitrogen. It is typically linked to Azolla, a free-floating fern. Using Azolla as a biofertilizer is beneficial since it rapidly decomposes in the soil and provides nitrogen to rice plants. Additionally, it provides essential micronutrients such phosphorus, potassium, zinc, iron, and molybdenum (Al Abboud et al. 2013).

The Azolla-Anabaena system offers 1.1 kg N/ha/day to rice crops, with a single Azolla crop providing 20-40 kg N/ha in 20-25 days.

4.1.5 Blue-green algae (cyanobacteria)

Nitrogen-fixing bacteria Cyanobacteria are the most abundant nitrogen fixers on the earth. Cyanobacteria, sometimes referred to as blue green algae, include Nostoc, Anabaena, Oscillatoria, Aulosira, and Lyngbya.

When treated at 10 kg/ha, they fix 20-30 kg/N/ha in submerged rice fields, increasing crop yields by 10-15%. Cyanobacteria have been shown to enhance wheat and rice seed germination, shoot and root growth, and yield.

4.2 Phosphate-Solubilizing and Mobilising Biofertilizers

Plants create around 0.2 percent of phosphorus, an essential mineral for growth and development. Phosphorus is the least transportable macronutrient accessible to plants in most soil conditions, as compared to other macronutrients. PSB convert insoluble phosphates (HPO4 and H2PO4) into soluble forms by several methods such as organic acid production, chelation, and ion exchange. The PSB provides phosphorus and trace elements such as Fe and Zn, promoting plant growth.

4.3 Potassium-Solubilizing and Mobilising Biofertilizers

After nitrogen and phosphorus, potassium (K) is the second most prevalent and necessary nutrient in plants.

Although K is plentiful in soil, only 1-2% is accessible to plants. The remaining K is present as mineral K, which plants cannot absorb. It is crucial for plant growth and development. Without enough water, plants will grow slowly, have weak roots, generate little seeds, and provide low harvests.

Potassium-solubilizing biofertilizers include Bacillus spp., Aspergillus niger, Arthrobacter spp., Cladosporium, and Sphingomonas aminobacter, with various levels of K solubilization.

4.4 Sulphur Oxidising Biofertilizers.

Plants also need sulphur as a micronutrient. Sulphur improves the biological and physical qualities of soil. Sulphur is recognised for its capacity to protect soil from excessive pH. Thiobacillus spp., including Thiobacillus thioparous and T. thioxidans, are sulfur-oxidizing microbes that convert sulphur to plant-usable sulphates, enhancing plant nutrition. Sulphur oxidising bacteria help safeguard the environment by eliminating sulphur emissions via biological processes.

4.5 Zinc Solubilising Biofertilizers

Plants need tiny levels of zinc (5-100 mg/kg) for growth and reproduction. Zinc deficiency in soil is often caused by improper fertiliser application, intensive agriculture, and poor soil health. If relevant causes are neglected, zinc deficiency is projected to increase from 42% to 63% by 2025. Mycorrhiza, Saccharomyces spp., and other rhizobacteria, such as Pseudomonas and Bacillus spp., have been shown to improve Zn availability in soil.

4.6 Plant Growth Promoting Rhizobacteria (PGPR).

PGPR are bacteria that colonise plant roots and promote plant growth. Biofertilizers promote plant growth, increase stress tolerance, and improve soil mineralization by decomposing organic materials.

5. Usage of microbial biofertilizers

Biofertilizers are often delivered as carrier-based inoculants, which are cost-effective and easy to manufacture.

5.1 Seed Treatment.

Seed treatment is a safe, cost-effective, and extensively utilised method for all inoculants (Sethi et al. 2014). Seeds are covered uniformly with a slurry of inoculant and 200 mL rice kanji, then shade-dried for 24 hours before planting.

5.2 Dipping the Seedling Roots

Plantation crops including cereals, grains, fruits, trees, sugarcane, cotton, grapes, bananas, and tobacco are widely employed in this way. Crop treatment timeframes differ, with vegetable crops being treated for 20-30 minutes and paddy treated for 8-12 hours prior to transplanting.

5.3 Soil Application.

This practice involves applying biofertilizer directly to the soil, either alone or in combination. A combination of phosphate-solubilizing microbial biofertilizer, cow dung, and rock phosphate is applied to soil with a moisture content of 50% after being kept in the shade overnight. (Pindi, Satyanarayana 2012).

6. Biofertilizers' potential for sustainable crop production

Biofertilizers are essential for enhancing crop output and restoring soil fertility. When employed in soil, they promote nutrient cycling, enhance soil structure, and increase crop production. Microbes' particular abilities in the environment and culture make them promising candidates for agricultural solutions to food challenges. Using biofertilizers improves efficiency and soil sustainability, while also protecting the environment and improving food quality.

7. Conclusion.

Although biofertilizers are cost-effective, organic, and ecologically friendly, they cannot fully replace chemical fertilisers. Biofertilizers are necessary for both Integrated Nutrient Management and organic farming. Sustainable agriculture involves environmentally friendly agricultural practices that promote crop and animal production without negatively impacting human or natural systems. Sustainable agriculture aims to provide human needs while conserving the environment, benefiting present and future generations. These technologies are becoming more significant in modern agriculture practices. Biofertilizers will play a more important role in the future due to changing farming practices and environmental dangers linked with chemical fertilisers.

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