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S&T REVIEW

BIOFERTILIZERS- A BRIEF INSIGHT

Sirpat Badhai*

IAS Banaras Hindu University, Varanasi-221005 U.P. India.
****Corresponding Author Email: sirpatbhu@gmail.com***

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ABSTRACT

Chemical fertilizers are more commonly used for crop production nowadays, which has a negative impact on soil and environmental quality. The rising use of chemical inputs in agricultural production systems harmed the sustainability of agricultural crop production systems, raised cultivation costs, and reduced partial factor productivity, making preserving global food security and environmental quality a difficult task. Increasing usage of commercial agrochemicals over the previous century led in bioaccumulation of various pollutants in agricultural soils and surrounding water bodies. Various scientists have observed that the constant and indiscriminate use of primary nutrients (N, P, and K) has resulted in numerous micro and secondary nutrient shortage as well as a negative impact on soil health. Microorganisms can play a variety of roles in organic farming's long-term sustainability. According to the literature, using nitrogenous fertilizers under certain meteorological conditions might result in the release of nitrous oxide (N_2O), which contribute to the greenhouse effect and causes environmental imbalances. As a result, biofertilizers microorganisms such as bacteria, fungi, and algae have been proposed as potential solutions for large-scale agricultural practices that are not only ecological, ecofriendly, and cost-effective, but also sustain soil structure and biodiversity. Microbes as biofertilizers are being investigated as an alternative to chemical fertilizers in the agricultural industry because of their vast potential for improving crop yield and food safety.

KEYWORDS

Biofertilizers, Chemical Fertilizers, Agrochemical, Sustainability, Pollutants, Organic Farming.

1. INTRODUCTION

The exponential increase in human population has necessitated the production and supply of food, notably from plants, at the same time. As a result, synthetic nitrogen and phosphorus chemical fertilizers have been used to create a highly productive and intense agriculture system. Since the beginning of the green revolution in Indian agriculture, this approach has become more prevalent. Genetic progress (high-yielding cultivars), nutrient management (organic or inorganic), utilisation of natural resources (water), and contribution of agricultural chemicals (pesticides and fungicides) were all part of the green revolution. Chemical fertilizer application that was excessive has a negative impact on soil productivity and soil health. In Punjab and Haryana, the optimal NPK application ratios are 4:2:1, which is completely distorted, and increase to 61.7:19.2:1 and 61.4:18.7:1 correspondingly (NAAS, 2014). The use of nitrogen (N) and phosphorus (P) fertilizers, as well as the exclusion of additional fertilizer applications, mostly caused multiple nutritional shortage and yield loss over time.

The indiscriminate use of synthetic fertilizers and pesticides has resulted pollution and contamination of the soil and plant, destroying/shattering microorganisms and beneficial insects, making the crop more susceptible to diseases, reducing soil fertility, and ultimately resulting in poor quality produce. Rhizobia nitrogen-fixing bacteria are employed to promote the growth of legumes. Furthermore, both blue-green algae (BGA) and Azolla contribute to the nitrogen budget of rice. Many plants rely on arbuscular mycorrhizal fungus for the uptake of phosphorus. Other benefits of Azospirillum include the ability to create growth-promoting compounds, resistance to diseases, and drought tolerance. As a result, using microbial biofertilizers is an excellent way to boost and maintain soil nutrient economy while minimising the usage of chemical fertilizers, resulting in more efficient and sustainable agriculture.

2. BIOFERTILIZERS

A biofertilizer is an organic product that contains a concentrated (10^7 to 10^9 g-1) version of a specific microorganism produced from the nodules of plant roots or the soil of the root zone (rhizosphere). Biofertilizers perform better under irrigated conditions, but they can also be effective in dryland farming. Rainfed areas are home to more than 90 percent of coarse cereals, 80 percent groundnut, 85 percent legumes, 70 percent cotton, 55 percent rice, and 22 percent wheat cultivation (Katyal et al., 1994). In rainfed areas, the average productivity of foodgrains (coarse cereals plus pulses) is roughly 680 kg/ha. Irrigated crop yields are two to three times higher than non-irrigated crop yields. Organic manure and biofertilizers are important natural resources that can help increase nutrient turnover. Under Sect. 3 of the Essential Commodities Act 1955, the Government of India ensured the quality and production of biofertilizers. Furthermore, the Government of India (GOI) issues a fertilizer (control) Amendment Order, 2006, with the gazette notification S.O. 391 (E) dated March 24, 2006, for the manufacturing of biofertilizers. This order was carried out, and four biofertilizers, namely Rhizobium, Azotobacter, Azospirillum, and phosphate-solubilizing bacteria, were placed under the FCO (fertilizer control order). In the recent 20 years, the development of biofertilizers has accelerated, and phosphate-solubilizing bacteria (PSB) placed on top of the soil are among the biofertilizers.

2.1 Use of Biofertilizers

(i) Complement organic and inorganic fertilizers by fixing atmospheric nitrogen,

(ii) Solubilize plant nutrients such as phosphates,

(iii) Promote plant development through synthesis of growth promoting chemicals, and

(iv) Aid in the uptake of available nutrients.

2.2 Types of Biofertilizers

Biofertilizers are more commonly used for crop production nowadays, and there are many different types of biofertilizers on the market. Based on

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their function of nutrient solubilization or fixation, biofertilizers can be classified into the following groups.

Table 1: Biofertilizers are Divided into Groups Based on Their Nature and Function

Groups	Example
N_2-Fixing Biofertlizers	
Free-Living	*Azotobacter, Beijerinckia, Clostridium, Klebsiella, Anabaena, Nostoc*
Symbiotic	*Rhizobium, Frankia, Anabaena azollae*
Associative Symbiotic	*Azospirillum*
P Solubilizing Biofertilizers	
Bacteria	*Bacillus Megaterium Var. Phosphaticum, Bacillus Subtilis, Bacillus Circulans, Pseudomonas Striata*
Fungi	*Penicillium spp., Aspergillus Awamori*
P Mobilizing Biofertilizers	
Arbuscular Mycorrhiza	*Glomus spp., Gigaspora spp., Acaulospora spp., Scutellospora spp., Sclerocystis spp.*
Ectomycorrhiza	*Laccaria spp., Pisolithus spp., Boletus spp., Amanita spp.*
Ericoid Mycorrhiza	*Pezizella*
Orchid Mycorrhiza	*Rhizoctonia Solani*
Biofertilizers for Micronutrients	
Silicates and Zn Solubilizers	*Bacillus spp.*
Plant Growth-Promoting Rhizobacteria	
Pseudomonas	*Pseudomonas Fluorescens*

Singh *et al.* (2014a, b)

2.2.1 Rhizobium

The German researchers Hellriegel and Wilfarth claimed the discovery of nitrogen fixation in 1886, claiming that legume producing root nodules have an inherent potential to utilize atmospheric nitrogen. In 1888, Beijerinck was able to isolate the Rhizobium leguminosarum was discovered in root bacterial strains from root nodules. Rhizobium is a heterotrophic and symbiotic bacterium that belongs to the Rhizobiaceae family.

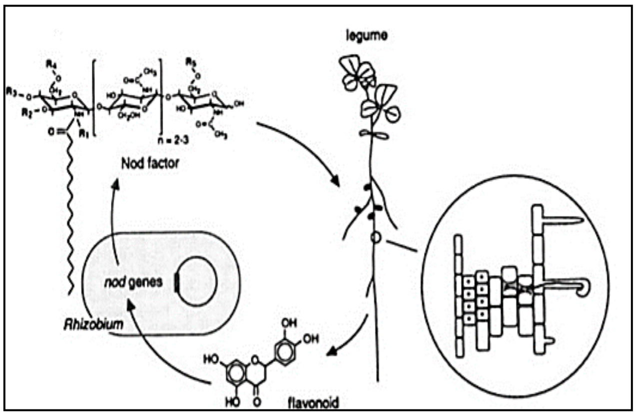

Figure 1: Signal exchange in the rhizobium–plant symbiosis (Schultze and Kondorosi, 1998)

Some plants in the Leguminosae family have a symbiotic relationship with nitrogen-fixing bacteria from the genus Rhizobium. Different rhizobia infect the root and travel to the root cortex through an infection thread, resulting in the production of a small outgrowth known as a legume root nodule. Leghemoglobin helped in the process of respiration and energy production.Sesbania rostrata also produces nodules on both the stem and roots. In these nodules, nitrogen is fixed. The relationship between legumes and rhizobia is host specific. The presence of flavonoids and isoflavonoids in the exudates of legume roots has been linked to host specificity (Figure 1 and Table 3). Flavonoids are also thought to be involved in the process of nodulation. There are two types of nodules.

(a) Determinate: Nodule growth stops after a certain period of time, as in mungbean;

(b) Indeterminate: Nodule growth continues, as in chickpea and clovers.

Rhizobia modify their morphology and physiology to become bacteroid, the real seat of N_2 -fixation, once they are introduced into cortical cells. The plant's peribacteroid membrane separates the bacteroids from the contents of the plant cell. Bacteroids contain the nitrogenase enzyme and are embedded in the hemeprotein leghaemoglobin. Leghaemoglobin regulates the delivery of oxygen to bacteroids and prevents nitrogenase from being exposed to oxygen. N_2 is transformed to NH_4+, which diffuses into the cytosol and is transported to the shoot for protein synthesis. Legumes are said to fix varying amounts of nitrogen depending on a variety of parameters such as soil, air, and host genotypes.

Table 2: Nitrogen (N) Contribution of N-Fixing Legumes of Indian Soils

Crops	N-Fixed (Kg/Ha/Year)
Alfalfa (*Medicago Sativa*)	100-300
Clover (*Trifolium Spp.*)	100-150
Chickpea (*Cicer Arietnum*)	20-63
Cowpea (*Vigna Sinensis*)	50-85
Green gram (*Vigna Radiate*)	50-55
Groundnut (*Arachis Hypogaea*)	112-152
Pea (*Pisum Sativum*)	46
Soyabean (*Glycine Max*)	49-130

Source: (Subaa Rao, 1988)

In general, the biological conversion of molecular N to ammonia (NH_3) followed the equation below.

$$N_2 + 16MgATP + 8e^- + 8H^+ \rightarrow 2NH_3 + H_2 + 16MgADP + 16Pi$$

Table 3: Shows Rhizobia and The Legumes They Nodulate in Cross-Inoculation Groupings (Adopted From Alexander, 1978).

Rhizobia Name	Legume Cross Inoculation Groups	Crops
Pea Rhizobia (*R. Leguminosarum*)	Pea Group	Peas (*Pisum Spp.*); Vetches (*Vicia Spp.*); Lentils (*Lens Culinaris*); Faba Bean (*Vicia Faba*)
Bean Rhizobia (*R. Phaseoli*)	Bean Group	Beans (*Phaseolus Vulgaris*); Scarlet Runner Bean (*P. Coccineus*)
Clover Rhizobia (*R. Trifolii*)	Clover Group	Clovers (*Trifolium Spp.*)
Alfalfa Rhizobia (*R. Meliloti*)	Alfalfa Group	Alfalfa (*Medicago Spp.*); Sweet Clovers (*Melilotus Spp.); Fenugreek (Trigonella Spp.)*
Chickpea Rhizobia (*Rhizobium Sp.*)	Chickpea Group	Chickpea (*Cicer Arietinum*)
Soybean *Rhizobia (Bradyrhizobium Japonicum)*	Soybean Group	Soybeans (*Glycine Max*)
Leucaena Rhizobia (*Rhizobium Sp.)*	Leucaena Group	Leucaenas (*Leucaena Leucocephala*; *L. Shannoni*; *L. Lanceolata; L. Pulverulenta*); *Sesbania Grandiflora*; *Calliandracalothyrsus*; *Gliricidiasepium*; *Acacia Farnesiana*

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2.2.2 *Azospirillum*

Azospirillum spp. are heterotrophic, associative, aerophilic, gram-negative, rod-shaped bacteria that may fix 15-40 kg of nitrogen per hectare and release plant growth regulators. It is a member of the Spirilaceaefamilyfound in crops ranging from acidic to alkaline. It is well-suited to tropical climates.*A. amazonense*, *A. halopraeferens*, and *A. brasilense* are only a few of the species found in this genus; however, *A.lipoferum* and *A. brasilense* are two of the most common species found across the world. In the instance of associative nitrogen fixers, *Azospirillumlipoferum* has been shown to be association with the roots of C4 (plants such as maize, Sorghum), whereas *Azospirillum brasilense* has been found to be associated with the roots of C3 (plants such as rice and wheat). Apart from nitrogen fixation, Azospirillum's primary function is the synthesis of growth-promoting substances (IAA). Disease resistance and drought tolerance are two additional advantages of Azospirillum inoculation. According to a study, immersing rice seedling roots in a 2 percent suspension of Azospirillum inoculum improved yield by 1 q ha^{-1} (Kennedy et al., 2004).

2.2.3 *Azotobacter*

Azotobacter is a nitrogen-fixing bacterium that is Gram negative free-living, aerobic and chemoheterotrophic bacteria that produce thick–walled cysts. Beijerink demonstrated in 1901 that there were free-living aerobic bacteria, Azotobacter chroococcum, capable of fixing atmospheric nitrogen. Inoculation with azotobacter has had a positive impact on dryland crops. It belongs to the Azotobacteraceae family. Azotobacters can be found in both neutral and alkaline soils, with A. chroococcum being the most prevalent species in croplands. Other identified species that play a role in N-nutrient dynamics include A. vinelandii, A. beijerinckii, A. insignis, and A. macrocytogenes. Under ideal conditions, it may fix 20–25 kg ha-1 of atmospheric nitrogen in the soil, resulting in a 40–50% boost in crop output. When kept at room temperature, the mixture is stable for 6 months(shelf-life). Azotobactor and nitrogenous fertiliser should not be used at the same time. Between their applications, there should be a 15-20-day break. If the seeds have been treated with synthetic chemicals, use a double dose of the formulation. The treated seed should be dry in the shade and sowed within 2-3 hours in a cool location. Azotobactor aids in the production of antibiotics that control or suppress a variety of fungal, bacterial, and viral illnesses that affect crop plants.

2.2.4 *Phosphate Solubilizers*

Agricultural crops contain phosphorus 0.1 – 0.5 %. Phosphorus is primarily taken up from the soil in the form of primary orthophosphate ions, with secondary orthophosphate ions being taken up by a few plants. The majority of Indian soil contains P in the 100–2,000 mg kg^{-1} range with the help of aluminium (Al-P), iron (Fe-P), and calcium (Ca-P) in key soil categories, more than 80% of inorganic fertilisers used during crop production changed into unavailable form (Dotaniya et al., 2013; 2014; Tandon, 1987). In general, Al-P and Fe-P make about 1–25% of total P in soil, with acidic soils accounting for the majority of it. In neutral or calcareous soils, Ca-P makes up around 40% of the total. Ca-P, on the other hand, is far more plentiful in soil than Al-P and Fe-P. The amount of labile P in soil solution is proportional to the pH of the soil (Figure 2). Both $H_2PO_4^{-1}$ and HPO_4^{-2} have the same concentration on the pH 7.2 (figure 2), however increasing pH increased the availability of PO_4^{-3}.

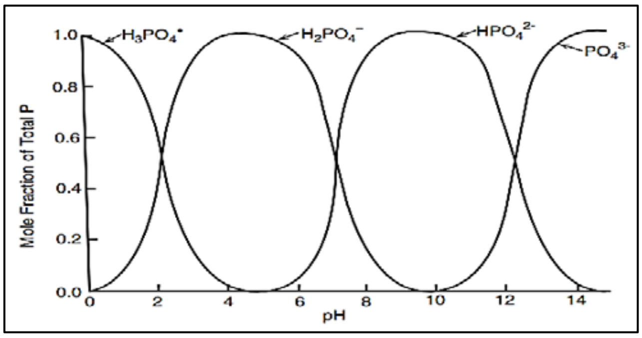

Figure 2: The accessibility of soluble forms of phosphate and the pH of the solution

Phosphate fertilizers should be applied as a single dose at the time of sowing, known as the basal dose. The mobility of P ions is sluggish, and plant roots typically travel a distance of 2–4 mm. Different bacterial species have been studied for their ability to solubilize inorganic phosphate compounds such as tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate. Pseudomonas, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Micrococcus, Enterobacter, Flavobacterium, and Erwinia are some of the most well-known bacterial genera for this. Pseudomonas, Bacillus, and fungus are the most common P-solubilizing bacteria in soil. PSB has the potential to minimise P fertiliser imports in India by using low-grade rock phosphate as an enhanced phospho-compost in crop cultivation (Basak and Biswas, 2016).

2.2.5 *Phosphorus and Other Nutrient Mobilizers*

The Arbuscular Mycorrhizal (AM) fungi are obligate biotrophs that create symbiotic relationships with over 90% of higher plant species (Gadkar et al., 2001). The intake of nutrients is aided by a symbiotic relationship between some fungus and plant roots, and this symbiosis is known as Mycorrhizae. They enhance the surface area for nutrient absorption by 8 to 10 times and carry the nutrients back to the plant from beyond the root zone. The fungi formed association in mainly P deficient soils. Therefore, higher phosphorus fertilizer application prevents the association.

2.2.6 *Algae*

Algae are chlorophyll-containing organisms that live in the soil. Because they are autotrophic, their growth is not limited by the availability of organic carbon. They can be found in large numbers in environments that are well-lit and well-watered. They are either unicellular, filamentous, or colonics made up of single cells. Soil algae are divided into four groups based on colour (pigments): Cyanophyta (blue green), Chlorophyta (grass green), Xanthophyta (yellow green), and Bacilliriophyta (yellow green) (golden brown). Blue green algae, commonly known as 'Cyanobacteria,' are particularly significant in rice crops in the tropics because they fix atmospheric nitrogen and contribute to soil nitrogen economy. It has been reported that blue green algae (BGA) may fix up to 20 kg of nitrogen per hectare. They fix nitrogen in specialised cellular structures known as "heterocysts," which have strong walls and a low oxygen content, allowing the enzyme nitrogenase to work properly.

P K De proved the capacity of BGA to fix N for the first time in the 1930s. R.N Singh discovered the agricultural importance of blue green algae in the nitrogen economy of rice fields in the early 1950s. submerged soil conditions create a great setting(habitat) for algae development, as the soils seldom dry up. These organisms are claimed to produce plant growth hormones and so aid plant development, in addition to assisting in N-nutrition of rice plants. Anabaena azollae, a nitrogen-fixing algae, develops a symbiotic relationship with Azolla, a freshwater plant, and fixes nitrogen. The Azolla biofertilizer not only supplies nitrogen to the soil but also organic matter. Algae can also be seen in groups with fungus known as lichens. The algae offer carbohydrates to the fungus, which are created by photosynthesis, while the fungal symbiont supplies mineral nutrition and controls water supply. Lichens can be found on rocks, soils, buildings, vegetation, tree trunks, and other surfaces all over the world. Lichens are usually among the first to colonise bare rocks and start the process of soil formation.

2.3 Advantage of Biofertilizers

1. Seed germination, seedling emergence, plant development, blooming, fruiting, and ripening of grains and fruits are all improved by biofertilizer.
2. Biofertilizers are inexpensive.
3. They are naturally eco-friendly.
4. They increase a plant's photosynthetic capacity.
5. Some biofertilizers aid in the development of pest resistance in plants.
6. Improves the soil's physico-chemical and biological qualities.
7. Aid in the prevention of soil-borne infections.
8. Improves soil biota of the soil

3. CONCLUSION

Conservation agriculture is a requirement of the modern period; it is a means of meeting the rising population's food needs. In the coming years, rapid overharvesting of nonrenewable natural resources may result in a food crisis. In accordance with this, low-cost, environmentally friendly biofertilizers are playing an increasingly important role in increasing agricultural output by reducing the usage of chemical fertilizers and increasing crop nutrient use efficiency while maintaining crop quality and environmental factors.

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