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Bio-fertilizers for sustain agricultural production and improve soil health

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Abstract
Each person's ability to obtain food is seriously threatened by the worldwide increase in human population since agricultural land is becoming increasingly scarce and, in some cases, disappearing. Therefore, in direct to meet the huge food stipulate of the expanding population during the next few decades, agricultural productivity must be significantly boosted. Not to mention that relying heavily on chemical fertilizers to boost agricultural productivity eventually has negative effects on the environment, human being health, and top soil health. Due to their enormous potential, microbes are being investigated as viable alternatives to inorganic fertilizers within the agriculture sector.

Keywords: Crop production, soil health, and bio-fertilizers

Introduction
Biological fertiliser is a word used to describe a chemical that contain living microbes. When applied on crop surfaces, they improve crop growth by increase the host plant's access to essential nutrients. Bio-fertilizers are enriched with nutrients through biological mechanisms such nitrogen fixation, phosphorus dissolution, stimulation of the development of plants, and the creation of development-promoting compounds. Plant development is accelerated, growth is raised by 20-30%, and non-natural N and P are substitute for 25-30% of the natural elements. It might offer resilience to several soil-borne diseases and drought. Bio-fertilizers are living compositions of helpful microorganisms that are ready to use when given to seeds, roots, or soil. This increases the microorganisms' availability and usefulness, which improves the health of the soil [7].

In order to feed the populace and maintain export opportunities, agriculture is essential to a nation's development and continued survival. In order to improve efficiency, science has made a number of advances in agriculture over time [3]. Since they operate as a fast food for plants, chemical fertilisers and pesticides are utilised in modern agriculture in an effort to increase the amount of food produced on a worldwide scale. Permanent use of chemical fertilisers results in decreased soil fertility with the build-up of Plant tissues receiving toxic metals, which reduces the nutritional importance & palatability of the fruit [9].

Animal dung, fertilisers, organic waste, residential sewage, and microbes like fungi and bacteria, used in biological fertilisation. They are used to improve the root zone nutrient a fixation, grow growth-stimulating plants, improve soil stability, provide biological control, biodegrade contaminants, recycle nutrients, foster fungi symbiosis, and develop biological remediation procedures for soils contaminated with toxic, xenobiotic, and recalcitrant substances. Relatively short period of time, bio-fertilizers increase productivity per acre, use fewer power, avoid top soil & water pollution, improve soil productiveness & encourage biological management of phyto-pathogenic microbes.

Categorization of Bio-fertilizers
A variety of microbes as well as their interactions with agricultural crops are employed to create natural fertilizers. A variety of factors, including their nature and purpose, they can be categorized in a number of ways.

Rhizobium

Rhizobium is a bacterium that symbiotically fixes atmospheric nitrogen in the roots of legumes. *Rhizobium* can take on many different forms, ranging from free-living to nodular bacteroids. They are the most effective bio-fertilizer in terms of the amount of nitrogen fixed. Because they contain seven species and are very selective when it comes to developing nodules in legumes, they are categorized as a cross inoculation category.

Azotobacter

Chroococcum is the most common *Azotobacter* species found in arable soils and is capable of fixing N_2 (2-15 mg N_2 fixed g^{-1} of carbon source) in culture conditions. The bacterium creates a lot of slime, which helps the soil clump together. Due to a lack of organic matter and the presence of hostile bacteria in Indian soils, the population of *A. chroococcum* rarely reaches 105 g^{-1} soil.

Azospirillum

The cereal crops, *Azospirillum* spp. (known to as Spirillum lipoferum in previous literature) reside in the soil, rhizosphere, and intercellular spaces. They interact symbiotically and subconsciously with cereal crops. Other advantages of *Azospirillum* colonization include the generation of growth-promoting chemicals (IAA), resistance to infectious diseases, and resilience to drought. Such benefits are in along with nitrogen fixation.

Cyanobacteria

The two floating or symbiont *cyanobacteria* (blue green algae) are being applied to paddy farming in India. It used to be heavily promoted as a bio-fertilizer for paddy the cultivation, but Indian rice growers are no longer enthusiastic about it. The beneficial effects of algalization could reach 20-30 kg Nitrozen ha^{-1} under perfect conditions, but this is limited by the time-consuming method used to make BGA biological fertilizer.

Azolla

Azolla is a floating freely water fern that fixes nitrogen from the atmosphere by interacting with the nitrogen-fixing blue-green alga Anabaena *Azolla*e. *Azolla* can be used in additional to or as a substitute for commercial nitrogen-rich fertilizers. For wetland rice, *Azolla* is a biofertilizer that adds 40–60 kg of n per hectare every paddy field.

Phosphate solubilizing microbes (PSM)

For the purpose of to cause the decomposition of linked phosphorus in soil, These bacteria Bacillus, *Penicillium*, Aspergillus, along with other soil microorganisms release organic acids and decrease the pH in their region. Wheat and potato production were boosted by inoculating peat-based cultures with *Pseudomonas* striata and Bacillus polymyxa.

AM fungi

The intracellular obligate fungal endosymbionts of the genera Glomus, Gigaspora, Acaulospora, Sclerocysts, and Endogone, which have vesicles for storing nutrients and arbuscles for funneling these vital nutrients into the plant's root mechanism, transmit minerals from the soil milleu to the cells of the root cortex. With many species found in the soil, Glomus seems to be the most widespread genus.

Silicate solubilizing bacteria (SSB)

Microorganisms can break down silicates and aluminium silicates. The metabolism of microorganisms produces a number of organic acids, and in the weathering of silicate, these naturally occurring acids have two distinct roles. Natural acids that form complexes with cations, such as citric, oxalic, keto & hydroxy carbolic acid improve their elimination and maintenance in the average in a dissolve status.

Plant growth promoting rhizobacteria (PGPR)

Plant growth-promoting rhizobacteria, also known as are bacterial species that colonize plant roots or the root zone of the soil bringing beneficial to crops. By inhibiting crop infection ("bioprotectants"), enhancing nutrient uptake (referred to as "bio-fertilizers"), PGPR inoculants promote growth (termed Biostimulants). Phytohormones and growth regulators produced by *Pseudomonas* and Bacillus spp. can make crops increase root hairs, which increases the surface of root systems that takes water and nutrients. Gibberellins, cytokinins, along with indole acetic acid (IAA) & ethylene production inhibiting agents are a few of the phytohormones that these PGPR, also referred to at the same time as "biostimulants," generate.

Methods of Application of Bio-fertilizers

Seed Treatment

Applying a bonding agent such glue acacia, jiggery solution, etc., 200 g of bio-fertilizer is carefully mixed with ten kilograms of seeds after being placed in 300–400 ml of water. The seeds are then subsequently employed for sowing after being laid out to dry on a clean sheet or cloth in the shade.

Seedling Root Dip

With plants which were recently replaced, this technique is used. A bed of water has been established in the field specifically for the rice crop. Before being transplanted, the roots of the seedlings remain submerged in this water for eight to ten hours along with the suitable biological fertilizers.

Soil Treatment

Four kg of each appropriate bio-fertilizer are mixed into 200 kg of manure and let to sit overnight. This combination gets absorbed into the soil throughout planting or sowing.

Potentially existing features of some biological fertilizers

Biological nitrogen fixation

The German researchers Hellriegel & Wilfarth They were among the first to discover nitrogen fixation after they noticed that legume with nodules in their roots were able to utilize gaseous nitrogen. *Rhizobium* leguminosarum was isolated in this particular strain. The microbiologists isolated the initial sprain of Clostridium pasteurianum, while *Azotobacter* spp. Later, it was originate that blue-green algae (BGA) be particularly inventive at fixing nitrogen. Research in these disciplines has recently revealed a number of advantageous characteristics [5].

Rhizobium

The *Rhizobium* individuals collaborate to fix atmospheric N2 and promote the development of plants. The host organism receives a consistent supply of reduced nitrogen from the bacteria through its enzyme system, which provides the bacteria both nourishment and energy for its activities [20].

Azospirillum
Inoculating plants to promote growth has significantly changed a variety of plant characteristics. *Azospirillum* inoculation alters the length of the plant's growth stages and boosts germination percentage, nitrogen dried weight build up & seed production.

Azotobacter
Gibberellins and cytokinins, two other plant hormones that *Azotobacter* can produce, help reduce plant stress & preserve yields [6]. According to [24] and related N2 fixing bacteria were inoculated into plants, and during water stress, positive plant growth responses were seen.

Azolla
Azolla is a floating pteridophyte that has the nitrogen-fixing cyanobacterium Anabaena *Azolla*e as an endosymbiont [8]. *Azolla* is useful in lowland paddy fields for bring about a numerous changes, including limiting increase in soil pH, lower water temperature, controlling NH_3 volatilization, control weeds & mosquito proliferation. *Azolla* be able to deliver additional than not whole of the essential nitrogen to the paddy field [16]. *Azolla* usage also boosted the soil's organic matter and potassium concentrations [8].

Phosphorus Mobilizers
In calcareous or normal soils, Ca2+ precipitation interactions by means of greatly reactive Al 3 + and Fe 3 + cause a significant quantity of the Phosphorus useful as fertiliser to reach the stationary pools (10 and 12). Despite the size of the overall P pool, plants only have access to a small percentage of it. In order to increase soil P availability, insoluble and fixed forms of P must be released and mobilised. Mycorrhizae are nutrient-receiving root symbiotic that give their host plants essential nutrients like N, P, K, Ca, S, and Zn. Cucumber seedling survival and fruit yield, as well as P and Zn shoot concentrations of substances, were all significantly improved by mycorrhiza inoculation.

P Solubilizers
Only 10 to 20 percent of the phosphorus fertiliser provided to the plants is usable; the remainder converts to insoluble phosphate forms like rock phosphate and tricalcium phosphate.
This insoluble inorganic phosphate is helped to release by PSB (phosphate solubilizing bacteria), making it accessible to plants [11].
With increase the efficiency of natural nitrogen addiction, creating phytohormones, and improve the availability of essential nutrients like z & iron, PSB promotes plant growth [25].
In contrast to the long-standing use of artificial fertilisers, the process of P solubilizing microbes boost the soil fertility & agricultural use of problematic soil [2].

Si Solubiliser
The amount of bio available ortho silicic acid is fairly low in the soil, despite the fact that Si is present in extent amount as silicates and silicon dioxide. Different soil silicates are converted by Silicate Solubilizing Bacteria (SSB) into ortho silicic acid, which is accessible to plants and helps to increase crop yield and improve crop growth and development. Many bacteria, such as Bacillus caldolytyicus, *Bacillus mucilaginosus* or siliceous, *Proteus mirabilis*, *Pseudomonas* spp., and *Penicillium* spp., have been shown to discharge silica from likely silicates [26, 4]. Silicate minerals contain potassium, calcium, magnesium, iron, and zinc in addition to silicon, so SSB inoculating the soil with this substance aids the pant by releasing a number of these nutrients [15].

Zn Solubilizers
Use of endogenous Zink source produces 96-99% of the Zn being converted keen on inaccessible form. Zn must be converted from an unavailable form by microbes into an accessible form in order to address the issue of Zn insufficiency. Based on [19] zinc, for example, can be absorbed by arbuscular mycorrhizal fungus (AMF) and transferred to plants, boosting plant nutrition [23]. Application of PGPR addressed the symptoms of Zn insufficiency, increasing total biomass (by 23%), grain yield (by 65%), HI, and Zink content in the crop seeds [22].

Plant Growth Promoting Rhizobacteria (PGPR)
With the goal to ensure future yields from agriculture, safety for the environment, and reduced expenses, rhizobacteria which encourage growth of plants are a successful substitute for chemical fertilizers and fungicides that Through the production of phytohormones that siderophores, HCN, nitrogen fixation, and solubilization of phosphate processes, PGPRs colonize roots, modify root architecture (increased root branching, root number), and promote development [18]. Important plant nutrients including potassium, phosphorus, and nitrogen, which are absorbed from the soil and the atmosphere, respectively, are supplemented by PGPRs [17]. They also help to increase Zn bioavailability by solubilizing Zn from ores like Zn_3 (PO4)2, $ZnCO_3$, and ZnO [21].

Table 1: PGPR and their effect on crop yields (1)

Plant growth promoting Rhizobacteria	Crop Parameter
Rhizobium leguminosarum	Promotion of canola and lettuce.
Pseudomonas putida	Before time development of canola seedlings, growth prompt in tomato plant.
Azospirillum brasilense and A. Irakense	Growth of wheat and maize plants.
P. flurescens	Growth of pearl millet, enhance growth, leaf nutrient contents and high yield of banana.
Azotobacter and *Azospirillum* spp.	Growth and productivity of canola.
P. alcaligenes, *Bacillus polymyxa*, and *Mycobacterium phlei*	Enhance the uptake of N, P and K by maize crop.
Pseudomonas, *Azotobacter*and *Azospirillum* spp.	Stimulates growth and increase the yield of chick pea.
R. leguminismarum and Pseudomonas spp.	Increase the yield and phosphorus uptake in wheat.

P. putida, P. flurescens, A. Brasilense and *A.lipoferum*	Promotes seed germination, seedling growth and yield of maize.
P. putida, P. fluorescens, P. fluorescens, P. putida, A. lipoferum, A. Brasilense	Increase seed germination, growth parameters of maize seedling in green house and also gain yield on maize.

Table 2: Amount of nutrients fixed by some bio-fertilizers in various crops (13)

Microorganisms used as Bio-fertilizer	Nutrient fixed (kg/ha/year)	Beneficiary crops
Rhizobium	50 to 300 kg Nitrgen ha^{-1}	Groundnut, Soybean, Redgram, Greengram, Black-gram, Lentil, Cowpea, Bengal-gram and Fodder legumes
Azotobacter	0.026 to 20 kg Nitrogen ha^{-1}	Cotton, Vegetables, Mulberry, Plantation Crop, Rice, Wheat, Barley, Ragi, Jowar, Mustard, Safflower, Niger, Sunflower, Tobacco, Fruit, Spices, Condiment, Ornamental Flower
Azospirillum	10-20 kg Nitrogen ha^{-1}	Sugarcane, Vegetables, Maize, Pearl millet, Rice, Wheat, Fodders, Oil seeds, Fruit and Flower
Blue Green Algae	25 kg Nitrogen ha^{-1}	Rice, banana
Azolla	25 kg Nitrogen ha^{-1}	Rice
Phosphate solubilising bacteria and fungi	Solubilize about 50-60% of the fixed phosphorus in the soil	All Crops (non- specific)

Importance of Bio-fertilizers

1. One of the benefits of using bio-fertilizers is that they are both economical and environmentally benign.
2. The soil is enriched as a result of their use, and the soil gets better over time.
3. Even though they might not show benefits right away, they have tremendous long-term effects.
4. These fertilizers pull nitrogen from the air and provide it directly to plants.
5. They increase the amount of phosphorus in the soil by releasing and solubilizing phosphorous that would not otherwise be soluble.
6. Bio-fertilizers enhance root proliferation by releasing hormones that promote development.
7. Microorganisms transform complicated nutrients for plant availability to some extent into simple nutrients.
8. Microorganisms in bio-fertilizers ensure that the host plants receive a sufficient amount of nutrients and that their growth and physiology are maintained.

Constraints in using of Bio-fertilizer

Despite being a low-cost, ecologically friendly technology, the usage and deployment of bio-fertilizers are restricted for a variety of reasons. Possible restrictions include:

1. Technological limitations, such as a lack of high-quality carrier material and technical personnel with the necessary qualifications in the manufacturing facilities.
2. Problems with the infrastructure, such as a lack of essential tools or power.
3. Financial challenges, such as a shortage of funds and trouble getting bank loans.
4. Environmental limitations, including, but not limited to, seasonal demand for bio-fertilizers, concurrent agricultural operations, and a brief planting/sowing season in a particular area.
5. Constraints on human resources and quality, such as a lack of technically skilled workers in manufacturing facilities and insufficient training in production techniques.

Conclusion

Bio-fertilizers, which are necessary elements of organic cultivation, serve a crucial function in guaranteeing enduring soil fertility and sustainability by fixing atmospheric di-nitrogen and mobilising fixed macro and micro nutrients in the soil into forms available to plants. The difference in plant nutrients between crop removal and the delivery of chemical fertilisers is already 10 million tonnes. Long-term viability is not possible due to the high costs of establishing fertiliser factories and maintaining output, both in terms of domestic resources and foreign exchange. This is true in terms of both cost and environmental impact. Bio-fertilizers would be the practical choice for farmers in this situation to boost productivity per unit area.

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