TYPES AND USES OF BIOFERTILIZERS IN AGRICULTURAL PRODUCTION

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INTRODUCTION

Biofertilizers are substance that contains microbes, which helps in promoting the growth of plants and trees by increasing the supply of essential nutrients to the plants. It comprises living organisms which include mycorrhizal fungi, blue-green algae, and bacteria. Mycorrhizal fungi preferentially withdraw minerals from organic matter for the plant whereas cyanobacteria are characterized by the property of nitrogen fixation.

Nitrogen fixation is defined as a process of converting di-nitrogen molecules into ammonia. For instance, some bacteria convert nitrogen to ammonia. As a result, nitrogen becomes available for plants.

TYPES OF BIOFERTILIZERS

Following are the important types of biofertilizers:

Symbiotic Nitrogen-Fixing Bacteria: Rhizobium is one of the vital symbiotic nitrogen-fixing bacteria. Here bacteria seek shelter and obtain food from plants. In return, they help by providing fixed nitrogen to the plants.

Loose Association of Nitrogen-Fixing Bacteria: Azospirillum is a nitrogen-fixing bacteria that live around the roots of higher plants but do not develop an intimate relationship with plants. It is often termed as rhizosphere association as these bacteria collect plant exudate and the same is used as food by them. This process is termed associative mutualism.

Symbiotic Nitrogen-Fixing Cyanobacteria: Blue-Green algae or Cyanobacteria from the symbiotic association with several plants. Liverworts, cycad roots, fern, and lichens are some of the Nitrogen-fixing cyanobacteria. Anabaena is found at the leaf cavities of the fern. It is responsible for nitrogen fixation. The fern plants decay and release the same for utilization of the rice plants. Azolla pinnate is a fern that resides in rice fields but they do not regulate the growth of the plant.

Free-Living Nitrogen-Fixing Bacteria: They are free-living soil bacteria that perform nitrogen fixation. They are saprotrophic anaerobes such as *Clostridium beijerinckii*, Azotobacter, etc.

Among all the types of biofertilizers, Rhizobium and Azospirillum are most widely used.

COMPONENTS OF BIOFERTILIZERS

The components of biofertilizers include:

Bio Compost: It is one of the eco-friendly products composed of waste material released from sugar industries which are decomposed. It is magnified with human-friendly bacteria, fungi, and various plants.

Tricho-Card: It is an eco-friendly and non-pathogenic product used in a variety of crops as well as in horticultural and ornamental plants, such as paddy apple, sugar cane, brinjal, corn, cotton, vegetables, citrus, etc. It acts as a productive destroyer and antagonistic hyper parasitic against eggs of several bores, shoot, fruit, leaves, flower eaters and other pathogens in the field.

Azotobacter: It protects the roots from pathogens present in the soil and plays a crucial role in fixing atmospheric nitrogen. Nitrogen is a very important nutrient for the plant and about 78% of the total atmosphere comprises nitrogen.

Phosphorus: Phosphorus is one of the essential nutrients for plants growth and development. Phosphate solubilizing microorganisms, hydrolyze insoluble phosphorus compounds to the soluble form for uptake by plants. Many fungi and bacteria are used for the purpose such as *Penicillium, Aspergillus, Bacillus, Pseudo monas, etc.*

Vermicompost: It is an Eco-friendly organic fertilizer that comprises vitamins, hormones, organic carbon, sulphur, antibiotics that help to increase the quantity and quality of yield. Vermicompost is one of the quick fixes to improve the fertility of the soil.

IMPORTANCE OF BIOFERTILIZERS

Biofertilizers are required to restore the fertility of the soil. Prolonged use of chemical fertilizers degrades the soil and affects crop yield. Biofertilizers, on the other hand, enhance the water holding capacity of the soil and add essential nutrients such as nitrogen, vitamins and proteins to the soil. They are the natural form of fertilizers and hence, widely used in agriculture.

Biofertilizers are important for the following reasons:

- Biofertilizers improve the soil texture and yield of plants.
- They do not allow pathogens to flourish.
- They are eco-friendly and cost-effective.
- Biofertilizers protect the environment from pollutants since they are natural fertilizers.
- They destroy many harmful substances present in the soil that can cause plant diseases.
- Biofertilizers are proved to be effective even under semi-arid conditions.

APPLICATIONS OF BIOFERTILIZERS

Following are the important applications of biofertilizers:

Seedling root dip: This method is applicable to rice crops. The seedlings are planted in the bed of water for 8-10 hours.

Seed Treatment: The seeds are dipped in a mixture of nitrogen and phosphorus fertilizers. These seeds are then dried and sown as soon as possible.

Soil Treatment: The biofertilizers along with the compost fertilizers are mixed and kept for one night. This mixture is then spread on the soil where the seeds have to be sown.

ADVANTAGES OF BIOFERTILIZERS

- Biofertilizers are cost-effective.
- They reduce the risk of plant diseases.
- The health of the people consuming the vegetables grown by the addition of chemical fertilizers is more at risk.
- Biofertilizers do not cause any type of pollution.

DISADVANTAGES OF BIOFERTILIZERS

- Chemical fertilizers are supplemented by biofertilizers, not substituted for them.
- Biofertilizers only improve crop productivity by 20 to 30 percent. Unlike chemical fertilizers, they do not result in a significant improvement in productivity.
- For specific crops, specific fertilizers are necessary. This is more applicable to microorganisms that live in a symbiotic relationship. If non-specific Rhizobium is applied as a fertilizer, root nodulation, and crop production will not rise.
- Strict aseptic precautions are required during the manufacture of microbial fertilizer. During microbial mass manufacturing, contamination is a common problem.
- Microbes are killed when exposed to sunlight for an extended period of time because they are light-sensitive.
- When stored at room temperature, microbial fertilizers must be used within six months, and when stored at chilling temperature, it must be used within two years.

MICROORGANISMS USED AS BIOFERTILIZERS

Rhizobium: - It is a more powerful and widely used biofertilizer that works with legumes to fix atmospheric nitrogen. Legumes produce root nodules that fix atmospheric nitrogen as a result of their symbiotic association with the bacterium rhizobium. The availability of a suitable stain for a certain legume is crucial for the successful rhizobium nodulation of leguminous crops. The presence of legume crops in the field has an impact on the Rhizobium population in the soil. Rhizobium numbers in the soil decline when legumes are absent.

Azospirillum: - Azospirillum has a symbiotic interaction with higher plant systems that is associative. Sorghum, maize, pearl millet, finger millet, foxtail millet, and other minor millets, as well as fodder grasses, contain these bacteria.

Azotobacter: - It is a bacterium that lives in dirt. In Indian soil, *A. chrococcum* is common. The amount of organic matter in the soil plays an important role in the growth of these bacteria.

Blue Green Algae (BGA): - Blue green algae are known as rice animals because of their abundance in rice fields. Many species of Tolypothrix, Nostic, Schizothrix, Calothrix, Anoboenosois, and Plectonema can be found in tropical environments. The bulk of nitrogen-fixing BGA are filamentous, which are made up of a chain of vegetative cells with specialized cells called heterocyst that act as a micronodule for synthesis and N-fixing machinery.

BIOFERTILIZERS IN AGRICULTURE

Biofertilizers are made in laboratory with live or latent cells of organisms, either nitrogen fixers, solubilizers of phosphates, cellulites microorganisms, growth promoters, among others, which are applied to seeds or plants in order to boost their growth. Biofertilizers are considered as a feasible and sustainable attractive biotechnological alternative to increase crop yield, improve and restore soil fertility, stimulate plant growth, reduce production costs and the environmental impact associated with chemical fertilization. Several microorganisms are commonly used as biofertilizers, including nitrogen-fixing soil bacteria (e.g. *Azotobacter*, *Rhizobium*), nitrogen-fixing cyanobacteria (e.g. *Anabaena*), solubilizing phosphate bacteria (e.g. *Pseudomonas*), and arbuscular mycorrhicical fungi Similarly, the producer bacteria of phytohormones (e.g. auxins) and those cellulite microorganisms are also used as a biofertilizers. In addition, the use of plant growth promoting bacteria can be useful in developing strategies to facilitate plant growth under normal and abiotic stress conditions.

Table 1. Groups of microbial inoculants for agriculture.

Phylum	Genus	Host	Benefit
Actinobacteria	*Arthrobacter, Brevibacterium, Cellulomonas, Corynebacterium, Kocuria, Microbacterium, Micrococcus, Mycobacterium, Rhodococcus, Streptomyces, Streptomonospora, Haloglycomyces, Haloactinospora, Actinopolyspora, Amycolatopsis, Prauserella*	Maize, pea, rice, soybean, sugarcane, sunflower, wheat.	Increase plant vigor (growth promoters), and tolerance to biotic and abiotic stress. Improve nutrients use efficiency.
Firmicutes	*Bacillus, Paenibacillus, Alicyclobacillus, Aneurinibacillus, Virgibacillus, Salibacillus, Gracilibacillus, Brevibacillus, Amphibacillus, Paraliobacillus, Oceanobacillus, Salimicrobium, Halobacillus, Pontibacillus, Thalassobacillus, Sediminibacillus, Alkalibacillus, Tenuibacillus, Ammoniphilus, Salinibacillus, Exiguobacterium, Marinilactibacillus,*	Amaranth, apple, barley, buckwheat, maize, mustard, oat, pepper, rice, sorghum, sunflower, tomato, wheat	Solubilization of phosphorus, potassium, zinc; production of indole acetic acids, hydrogen cyanide, gibberellic acid, and siderophore. Nitrogen fixation, biocontrol.

Phylum	Genus	Host	Benefit
	Alkalinebacterium, Sporosarcina, Planomicrobium, Lysinibacillus, Planococcus		
Proteobacteria	*Allidiomarina, Marinobacter, Aquisalimonas, Microbulbifer, Marinobacterium, Pseudomonas, Salicola, Deleya, Halomonas, Marinospirillum, Methylophaga, Achromobacter, Alcaligenes, Rhizobium, Albimonas, Paracoccus, Pantoea, Enterobacter, Kluyvera, Azospirillum, Methylobacterium, Arcobacter, Oceanibaculum, Fodinicurvata, Altererythrobacter, Glycocaulis, Xanthobacter, Bradyrhizobium, Amorphus, Sinorhizobium*	Amaranth, barley, bean, buckwheat, cotton, cowpea, maize, millet, mustard, oat, pea, rice, soybean, sunflower, tomato, wheat.	Increase plant vigor (growth promoters), nitrogen fixation, solubilization of nutrients, and biocontrol.
Bacteroidetes	*Flavobacterium, Shingobacterium*	Barley, Millet, Wheat	Plant growth promoting attributes
Ascomycota	*Trichoderma, Penicillium, Fusarium, Phoma, Aspergillus, Phomatropica, Acremonium*	Horticultural, fruit and forest crops	Biocontrol, biodegradation
Glomeromycota	*Glomus, Gigaspora, Acaulospora, Scutellospora, Sclerocystis, Laccaria, Pisolithus, Boletus, Amanita, Pezizella.*	Horticultural, fruit and forest crops	Phosphate-mobilizing
Cyanobacterias	*Asterocapsa, Chroococcus, Aphanothece, Gloeocapsa, Microcystis, Synechococcus, Rhabdoderma, Merismopedia, Aphanocapsa, Coelosphaerium, Leptolyngbya, Pseudanabaena, Komvophoron, Oscillatoria, Lyngbya, Phormidium, Nostoc, Anabaena, Scytonema*	Bean, maize, rice.	Fixation of nitrogen, bioremediation, biocontrol.

Biofertilizers and Plant growth promoting rhiobacteria (PGPR) have been evaluated in a wide variety of crops, including: rice, cucumber, wheat, sugarcane, oats, sunflower, corn, flax, beet, tobacco, tea, coffee, coconut, potato, fan cypress, grass sudan, eggplant, pepper, peanut, alfalfa, tomato, alder, sorghum, pine, black pepper, strawberries, green soybeans, cotton, beans, lettuce, carrots, neem, among others.

The most important example of the use and importance of biofertilizers in crop production are:

- In soybean. Soybean production is mainly carried out by inoculating the seed with selected strains of *Bradyrhizobium japonicum*, *Bradyrhizobium diazoefficiens* or

Bradyrhizobium elkanii (jointly referred to as *Bradyrhizobium* spp.).

- Paddy was positively influenced by the use of *Azolla*, which allowed a rise in the number of grains per panicle, panicle per m^2, and consequently, a significant increase in yields. In addition, it was observed that the association regulated the temperature and pH of the water.
- The inoculation of wheat with arbuscular fungi significantly increased grain yield and the NUE.
- The mixture of *Pantoea. agglomerans* or *Pseudomonas putida* and *Microbacterium laevaniformans* substantially increased biomass and improved potato tuber growth. The higher yield was due to the higher supply of phosphorus (P) from the bacteria to the growing plants.
- Tomato is influenced by the application of growth promoters. Inoculation of seedlings with *Burkholderia tropica* has an effective colonization of the roots that spread to aerial tissues. This effective colonization led to an increase in tomato production in growing seasons.
- Biofertilizers, *Azospirillum brasilense* and *Rhizobium etli* as well as the fungus *Glomus intraradices* applied in cereals, legumes, and citrus recorded an increase in production
- Biofertilizers are also used in forest species. Inoculum prepared with the ectomycorrhizal fungi *Suillus luteus* and *Rhizopogon luteolus*, and the saprobes *Coriolopsis rigida* and *Trichoderma harzianum*, alone and combined, were evaluated as potential biofertilizers for the growth of *Pinus radiata* seedlings in greenhouse. .

MECHANISM OF ACTION OF THE BIOFERTILIZERS

Biofertilizers increase the growth and yield of crops in an eco-friendly manner. They show synergistic and antagonistic interactions with the soil native microbiota and participate in many process of ecological importance. Biofertilizers promote plant growth by enhancing biotic and abiotic plant stress tolerance and supporting its nutrition by fixing atmospheric nitrogen and solubilizing soil nutrients

The action modes that PGPRs use to benefit plant growth can be classified into direct and indirect mechanisms, which occur inside and outside the plant, respectively. PGPRs directly promote plant growth by enhancing nutrient acquisition and by regulating phytohormones. The indirect effects of PGPRs on plant growth are caused by the induction of systemic resistance of plants against a wide range of pathogenic microbes. Direct action modes include an improvement in plant nutrition by providing nutrients, such as nitrogen, or solubilized minerals from the soil (e.g. P, K, Fe, Zn, among others) and/or stimulating plant growth by regulating the levels of phytohormones (e.g. gibberellins, auxins, ethylene, cytokinins, and abscisic acid). Indirect effects on plant development are given by the suppression of pathogens and other harmful microorganisms through parasitism, competing for nutrients and niches within the rhizosphere, producing antagonistic substances (e.g. antibiotics, hydrogen cyanide and siderophores) and enzymes. lytic (e.g. glucanases, proteases and chitinases), and the induction of plant systemic resistance against a wide spectrum of pathogens

CONCLUSION

The use of biofertilizers have proved to be an efficient way to produce food in a sustainable manner. Many scientific reports assure the benefits of PGPR in the growth and yield of several crops, including: corn, rice, cucumber, wheat, sugar cane, oats, sunflower, flax, beet, tobacco, tea, coffee, coconut, potato, cypress, sudan grass, pepper, peanuts, alfalfa, tomato, sorghum, pine, black pepper, strawberries, soybeans, cotton, beans, lettuce, carrots, among others. The most important microorganisms that have been used in biofertilizer formulations are Rhizobium, Azotobacter, Azospirillum, Pseudomonas, Bacillus, and vesiculo-arbuscular mycorrhizae.