Biofertilizers to enhance soil fertility and alternate to synthetic fertilizers

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The agricultural productivity should be enhanced significantly due to increase in population and the land for agriculture is limited. Last few decades agriculture is much dependence on synthetic chemical fertilizers for more crop productions to meet the large demand of food by emerging population. Regardless the enormous use of chemical fertilizers in agriculture but simultaneously damages the environment to a great extent and causes harmful impacts on both environmental ecology and human health with great severity. Further, chemical fertilizers are expensive, non- eco-friendly, cause eutrophication, reduce organic matter and microbial activity in the soil. Therefore, organic farming is an alternative to conventional agriculture with chemical fertilizers and ensures maintenance high quality and biodiversity of soils. Organic farming methods such as composting, mulching, and using biofertilizers will help promote healthy crop growth, as well as soil richness. In organic farming, biofertilizers has become of paramount importance in agricultural sector due to their potential role in food safety and sustainable crop production. Many researches on biofertilizers have revealed capability of providing required nutrients to the crop in sufficient amounts that resulted in the enhancement of crop yield.

What are biofertilizers?

Biofertilizers are also living or biologically active products or microbial inoculants of bacteria, algae and fungi, when applied to seed, plant surfaces or soil, colonizes the rhizosphere (narrow region of soil that is directly influenced by root secretions and associated soil microorganisms) or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. The microorganisms use as biofertilizers, establish symbiotic relationships with the plants and enrich the soil with nitrogen, phosphorus, organic matter etc.

Types of biofertilizers

These microorganisms that use as biofertilizer not only function as fertilizers but also transform the inaccessible forms of soil elements into ones accessible to plants. Bio-fertilizers are classified into different types depending on the type or group of microorganisms they contain. The different types of bio-fertilizers include:

<u>Nitrogen-fixing biofertilizers</u>

Nitrogen is essential for plants to synthesis amino acids, nucleic material and chlorophyll. Even though about 78% of the earth's atmosphere is made up of nitrogen plants cannot utilize this nitrogen directly from air. The molecular nitrogen gets assimilated into plants in two ways either through the process of lightning or the prokaryotes such as bacteria, cyanobacteria and fungi in the soil converts atmospheric nitrogen into nitrates/ammonia which is so called nitrogen-fixing. Some of these microorganisms have been using as biofertilizers and they can be classified in to three groups as free-living (*Azotobacter and* Azospirillium), symbionts (*Rhizobium*, Frankia, and *Azolla)* and associative symbionts (*Azospirillum* spp., *Herbaspirillum* spp.). Different biofertilizers have an optimum effect for different soils, so the choice of nitrogen biofertilizer to be used depends on the cultivated crop. Rhizobia are used for legume crops, *Azotobacte*r or *Azospirillum* for non-legume crops, Acetobacter for sugarcane, and blue green algae and *Azolla* for lowland rice paddies.

Phosphorus biofertilizers

Phosphorus is another important element for plant nutrition as it is vital for photosynthesis, signal transduction, biomolecule synthesis and metabolic processes. Phosphorus in the soil occurs mostly as insoluble phosphate which cannot be absorbed by plants. However, several soil bacteria and fungi possess the ability to convert these insoluble phosphates to their soluble forms so that plants can use them. There are two types of phosphorus biofertilizers, include phosphorous solubilizing biofertilizers and phosphorus mobilizing biofertilizers.

Phosphorous solubilizing biofertilizers consist of phosphate solubilizing bacteria (PSB) such as species of *Bacillus*, *Pseudomonas*, *Penicillium*, and *Aspergillus*. PSB are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. P-solubilization ability of rhizosphere microorganisms is one of the most important traits associated with plant phosphate nutrition. It is generally accepted that the mechanism of mineral phosphate solubilization by PSB strains is associated with the release of low molecular weight organic acids, through which their hydroxyl and carboxyl groups chelate the cations bound to phosphate, thereby converting it into soluble forms.

Plants rely on microorganisms to mobilize organically and inorganically bound phosphorus in which the plant can then readily utilize. Application of phosphorus mobilizing microorganisms to soils can therefore be a promising approach for improving phosphorus fertilization efficiency in agriculture. Mycorrhizal fungi use as phosphorus mobilizing biofertilizers and they form a bridge between the roots and the soil, gathering nutrients including phosphorus from the soil and giving them to the roots.

Potassium solubilizing biofertilizers

Potassium is another vital nutrient and considered as a key parameter of soil fertility and plant growth. About 98% of soil potassium is bound within phyllosilicates structure. This is the layer of silicate minerals found in silt and clay fractions of the soil. The remaining 2% of potassium exists in soil solution or on exchange sites to become available for the plants. Some rhizobacteria are able to solubilize insoluble potassium bearing phyllosilicates. Some *Bacillus* spp. and *Aspergillus niger* are used as Potassium solubilizing biofertilizers.

Biofertilizers for secondary macronutrients: zinc solubilizers

Zinc becomes mostly unavailable to crops because of its low levels of mobility and solubility and its tendency to get adsorbed by soil making it unavailable to the plants. Microbes can help in improving zinc uptake by plants in different ways. There are biofertilizers that consist of efficient strain of zinc solubilizing bacteria such as *Mycorhiza*, *Pseudomonas* spp., and Bacillus spp. They can mobilize zinc to be readily available for the plants in well-maintained soils. These fertilizers enhance the uptake of zinc in plants leading to maintain the nutrient proportion and also improves soil nutrient content. Further, microorganisms found in the soil can be used as biofertilizers to provide micronutrients like Zn, Fe, Cu, etc.

Plant growth promoting biofertilizers

Plant Growth- promoting rhizobacteria include a wide variety of soil bacteria, which when grown in association with a host plant, results in simulation of the host plant due to increased mobility, uptake, and enrichment of nutrients in the plant. These bacteria vary in their mechanism of plant growth promotion but generally influence growth via nutrient uptake enhancement, plant growth hormone production or production of a variety of antimicrobial compounds that act in different ways. Examples for plant growth promoting biofertilizers are *pseudomonas* spp., *Agrobacterium*, *Rhizobium*, *Enterobacter*, *Streptomyces*, and *Xanthomonas*.

Compost biofertilizers

Biofertilizers are also used for enrichment of your compost and for enhancement of the bacterial processes that break down the compost waste. Suitable biofertilizers for compost use are cellulolytic fungal cultures and *Azotobacter* cultures. Biocompost is an eco-friendly organic fertilizer which is prepared from sugar industry waste material that is decomposed and enriched with various plants and human-friendly bacteria and fungi. Biocompost consists of nitrogen, phosphate-solubilizing bacteria and various beneficial fungi like the decomposing fungus *Trichoderma viridae*, which protects plants from various soil-borne diseases and also helps to increase the soil fertility, resulting in a good quality product for farmers.

Production and bioformulation of biofertilizers

Microorganism to be inoculated as biofertilizer need to be isolate and identified from soil or plant roots. Then the relevant microorganism is multiplied on artificial media to harvest on a large scale in a bioreactor. The carrier is a medium that can carry the microorganisms in sufficient quantities and keep them viable under specified conditions, easy to supply to the farmers.

Biofertilizers are generally prepared as carrier-based inoculants of effective microorganisms. These carriers provide support to the microbial culture and help in the survival capacity of microorganism. The choice of suitable carrier material ensures the longer viability and efficiency of the bioinoculant. Various carrier materials such as clay, compost, coconut shell powder, peat, talc, perlite, zeolite, vermiculite, perlite, rice bran, wheat bran, polyacrylamide, charcoal, sawdust, and organic manure are used for production of biofertilizers.

Liquid biofertilizers are broth cultures containing dormant form of desired microorganisms along with required nutrients, minerals and organic oils, allowing them to tolerate adverse conditions. Liquid bioformulations are easy to produce and can be applied directly on seeds, increasing the adherence of bacteria to plant roots. However, the survival of microorganisms in liquid biofertilizers decreases with time because it does not provide protection to microorganisms against environmental conditions and thus bioformulation is prone to contamination during transportation or storage.

Biofertilizer technology is projected towards the development of novel carriers that can be environment friendly and can provide suitable environment for microbial survival. Encapsulated bioformulations is one of those carriers using technique which involves the use of natural polymer-based carrier (Cellulose, chitosan, sodium alginate, starch, lignin, agarose) or synthetic polymer-based carrier (polystyrene, polyacrylamides, and polyurethane, polyvinyl acetate, polyvinylpyrrolidone, polyethylene glycol and polyethersulfone) for encapsulation of bacteria into a biodegradable matrix.

How to apply biofertilizers?

Seed treatment, root dipping, and soil application are the main methods that is used to introduce biofertilizers to plants. Seed treatment is the most common method adopted for all types of inoculants. The seed treatment is effective and economic. In this method, seeds are uniformly wetted with liquid biofertilizers or mixed with carrier-based biofertilizers followed by shade dry

for 20-30 minutes. The seed treatment can be done with any of two or more bacteria. Then the biofertilizer treated seeds will be introduced to the fields.
Root dipping method is used for application of biofertilizers on paddy transplanting and vegetable crops. The required quantity of biofertilizer has to be mixed with 5–10 liters and the roots of seedlings has to be dipped for a minimum of half an hour before transplantation.
Traditional main field application method is also used with some biofertilizers. Biofertilizer is used for main field application in during leveling of soil or to the plant crowing fields.

Limitations of biofertilizers

Although the biofertilizer technology is a low cost, eco-friendly technology, several constraints limit the application or implementation of the technology. Biofertilizers are live microorganisms which die in case of high temperature and require cold storage facilities. The shelf-life of biofertilizers is limited to 6–12 months in powder form. Some biofertilizers are crop specific as well as location specific and, therefore, their efficacy does not remain the same at different locations due to differences in agro-climatic conditions. Soil characteristics like high nitrate, low organic matter, less available phosphate, high soil acidity or alkalinity, high temperature as well as presence of high levels of agro- chemicals or low levels of micro-nutrients contribute to failure of inoculants or adversely affect their efficacy.
Lack of qualified technical personnel in production units and production of poor-quality inoculants without understanding the basic microbiological techniques. Finally, lack of awareness among farmers regarding the benefits of biofertilizers is a major issue in promoting this eco-friendly biofertilizers.

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