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BIOFERTILIZERS: A MINI-REVIEW

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ABSTRACT

Biofertilizers are products containing living cells of different microorganisms, which have the ability to increase the mobility of nutritionally important elements from non-usable to usable forms through biological processes.[1], [2] Biofertilizers are extensively used for increasing the yield and growth of agricultural crops and various medicinal plants. They are used in farming and agroforestry. They are environment friendly and also good to hold nutrients into the soil after the yield of the crop, thus keeping the soil usable for the next cultivation.

KEYWORDS: Agroforestry, biofertilizers, farming, microorganisms, yield.

INTRODUCTION

The world agricultural sector is now facing a great challenge with the increasing human population. It has been estimated that the human population will rise to 9.5 billion by the year 2050, requiring a large number of food supplies.[3] Due to the changes in global climate, and the increased rate of different abiotic and biotic stresses, the production rate of several crops has declined dramatically.[4] Also, the soil fertility and different Physico-chemical parameters and overall, the natural health of the soil is gradually degrading with the use of chemical fertilizers. Chemical fertilizers have a negative impact on the environment and different health-related problems in the population. Hence, it is very much urgent to develop eco-friendly and sustainable technologies, which can minimise the use of chemical fertilizers.[5]

Furthermore, overall soil quality, microbial and biological population of the soil as well as the availability of different nutrients, and environmental parameters are the primary factors for improving crop yield for attaining the targeted goal of food security.[6] In order to restore the natural health of the soil and its fertility for enhancing the rate of food production, different organic fertilizers, such as beneficial microbial biofertilizers have been used vastly in agricultural fields. They have played the role as a stimulator for the overall growth and development of plants.[7-11] Biofertilizer can be defined as a preparation containing living cells of a specific group of microorganisms that improves the soil fertility and promotes the growth of plants by adding and converting different major nutrients (such as nitrogen, and phosphorus) from unavailable to available forms through biological nitrogen fixation and phosphorus solubilization.[12] Different beneficial aspects of biofertilizers are improving nutrient availability, synthesis of various phytohormones, and also protecting the plants by developing various strategies against abiotic and biotic stresses.[13-14] Soil fertility depletion in nitrogen and phosphorus has occurred as agriculture is affected by major biophysical constraints.[15] In this condition, soil fertility can be restored by the use of microbial-based bio-fertilizers which are considered an alternative solution.

Chemical fertilizers have not only been found to be lesser effective in improving the yield of various plants compared to those biofertilizers but also chemical fertilizers may be responsible for some kinds of pathological conditions in plants and humans or animals who consume those plants. Heavy metals contained in chemical fertilizers may accumulate in living bodies on long term consumption of plants and plant products derived from plants grown using chemical fertilizers. Heavy metals are toxic to the living system and they easily accumulate in the soft organs and therein generate free radicals which in turn cause free radical-mediated damages leading to oxidative stress.[16-18] Using biofertilizers completely eliminates this disaster associated with chemical fertilizers. Also, biofertilizers when used for cultivating medicinal plants give better

qualitative and quantitative yields. Chemical and organic fertilizers may cause contamination of the medicinal phytocompounds with the various chemicals and metals present in the chemical and organic fertilizers. This risk of contamination is also completely eliminated by using biofertilizers. Chemicals of chemical fertilizers may get washed down in rainwater to nearby water bodies and thereby affect the health of the fishes being cultivated there and the toxic chemicals and heavy metals may also enter our food chain through those consumable fishes cultivated in those water bodies.[19, 20]

BACTERIAS AS BIOFERTILIZERS

Studies reveal that the use of biofertilizers like mycorrhiza and *Thiobacillus* altered and improved drought tolerance, antioxidant enzymes' content, soluble protein content, and grain yield in Medicinal Pumpkin (*Cucurbita pepo* convar. *pepo* var. *Styriaca*).[21] These microorganisms which are associated with soil and plant naturally play a significant role in maintaining the balance of an ecosystem. These microorganisms not only add to the fertility of the soil but also contribute to the biogeochemical cycle.[22] The main mechanisms by which biofertilizers are reported to acquire nutrients in the soil are

1. Nitrogen fixation
2. Phosphorus solubilization and mineralization
3. Potassium solubilization
4. Sulphur oxidation
5. Micronutrient's chelation and solubilisation

Atmospheric nitrogen cannot be utilized by plants until and unless the nitrogen is fixed biologically. This is utilized in enhancing soil fertility by using microorganisms that help in the process of nitrogen fixation and making it available for plants. Rhizobia are the most popular nitrogen-fixing bacteria which are used in farming as biofertilizers. Rhizobia are the bacteria of the family Rhizobiaceae [i.e., *Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium,* and *Sinorhizobium (Ensifer*).[23] The amount of nitrogen fixed is dependent on the availability of oxygen and also on the species of the plant.[24] Rhizobium forms nodules in the roots of leguminous plants mostly and fix atmospheric nitrogen. *Rhizobium, Sinorhizobium (Ensifer*), and *Bradyrhizobium* are the rhizobia which are commonly used as biofertilizers in agriculture.[25] Endophytic nitrogen-fixing bacteria have been isolated from *Aloe barbadensis* and those nitrogen-fixing bacteria are considered to be beneficial for helping the plant to survive in drought conditions and add to the draught resistant property of the plant.[26] Other than symbiotic nitrogen-fixing bacteria, other heterotrophic free-living diazotrophic microorganisms such as *Azospirillum* sp., *Azotobacter* sp., and cyanobacteria have been recognised which can fix atmospheric Nitrogen in the rhizosphere and bulk soil. Those free-living bacteria are mostly found in non-leguminous plants. These free-living nitrogen-fixing bacteria have been reported to increase the yield of crops like wheat, rice, and corn. These free-living bacteria are also known to fix nitrogen for plants like sunflower, oak, carrot, sugarcane, tomato, pepper, sugar beet, eggplant, cotton etc.[27]

Phosphorous is another important mineral for plant growth and development. Most of the phosphate that remains in soil occurs in insoluble form and hence remains unavailable for the plants. Microbes present in soil can solubilize inorganic phosphate by forming various compounds which can be easily taken up by the plants and used. One of the most common ways is by excretion of organic acids, hydroxyl ions and CO_2. This in turn dissolves the insoluble phosphate. Other microbes may release chelating compounds which are known to capture and mobilize cations (Ca^{2+}, Al^{3+}, and Fe^{3+}) from different insoluble phosphates. This releases the associated phosphates. *Pseudomonas, Bacillus, Rhizobium, Enterobacter, Penicillium*, and *Aspergillus* are the most widely studied Phosphate-solubilizing microbes (PSM).[28]

Various other groups of soil bacteria e.g., *Bacillus, Rhizobium, Acidithiobacillus, Paenibacillus, Pseudomonas*, and *Burkholderia*) and fungi (*Aspergillus, Cladosporium, Macrophomina, Sclerotinia, Trichoderma, Glomus*, and *Penicillium* are reported can solubilize potassium mineral and make it available for the plants. Potassium is an important mineral for plants and is an essential element for maintaining basic plant physiology. The bacteria present in soil or added as biofertilizers are known to either release organic acids which solubilize the potassium in the soil and make it available for the plants. They also often are found to release potassium by chelation and exchange reaction by organic acids that the microbes produce.[28]

Certain bacteria are known to oxidize and release sulphur in soil and make the sulphur available for plants to easily absorb and utilize. Sulphur is an essential mineral for plant growth. A variety of archaea and bacteria such as the genera *Xanthobacter, Alcaligenes, Bacillus, Pseudomonas, Streptomyces*, and *Thiobacillus* when added to soil are known to oxidize sulphur in the soil.[29,30]

Micronutrients like iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), boron (B), molybdenum (Mo), chlorine (Cl), nickel (Ni), cobalt (Co), and silicon (Si) are significantly essential for plant growth, development and yield. Deficiency or excess of any of these micronutrients may lead to retarded growth and ill yield of plants. Certain microbes when added to soil are reported to produce siderophores which in turn bind to ferric ions which occur in an insoluble form. The binding of siderophores with the ferric ions converts them to certain soluble iron compounds that the plants can easily take up. Three prime classes of fungal siderophores (i.e., rhodotorulic acid, ferrichrome, and fusarinines) and four classes of bacterial siderophores (i.e., phenol-

catecholates, hydroxamates, carboxylate, and pyoverdines) have been reported.[31] These siderophores also solubilize minerals like Al^{3+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Mn^{2+}, Ni^{2+}, and Pb^{2+} in the soil and make them available for the plants.[31] Certain bacterias which solubilize silica are termed silicate solubilizing bacteria. They solubilize silica in soil and make them available for plants to absorb. Bacterias from the genera *Burkholderia, Aeromonas, Rhizobium, Enterobacter*, and *Bacillus* have been reported to be solubilizing silica in soil.[32]

FUNGI AS BIOFERTILIZERS

Root associated fungi have been recognized and are in extensive use as biofertilizers, they mobilize the nutrients in the soil and make them available for the plants to absorb and utilize. The most common and most well-studied root-associated fungi are the arbuscular mycorrhizal fungi (AMF). These fungi remain associated with the root and form a symbiotic relationship with more than 80% of land plant species. These help in the intake of water and minerals like P, N, S, Cu, and Zn by the plants.[33] AMF with their radical mycelium is known to penetrate soil pores and reach deep into the soil and thus are beneficial for making fewer mobile nutrients like phosphorus and nitrogen in the form of ammonium for the plants.[34] Alhough the reliability is still under investigation, several global companies have produced and commercialized AMF as biofertilizers. The prime target markets of those global companies is Asia Pacific regions such as India and China.[35] Besides AMF, other endophytic fungi are also been studied for using them as biofertilizers to enhance the yield of certain crop plants and medicinal plant species.[36]

A variety of fungi such as the genera *Fusarium, Aspergillus*, and *Penicillium* when added to soil are known to oxidize sulphur in the soil.[29,30]

VERMICOMPOST AND BIOFERTILIZERS

Vermicompost is also very widely used and is popular which is known to increase plant yield and help in the growth and development of different types of plants. These compost produced by earthworms is rich in nutrients essential for the growth of plants. Different species of worms including red wigglers, earthworms or white worms,[37] tiger worms (*Eisenia fetida*) are mostly used for vermicomposting.[38] Worms are reared on various waste medium and the compost yielded are used for improving plant growth and development. These worms when added to the soil, have been found to be highly beneficial in degrading various organic contents in the soil and breaking down the complex organic substances into simpler forms which are thus made easily available for the growing plants and are also easy for the plants to absorb and use those nutrients. Compost produced by vermicomposting has also been found to be enhancing the yield of various plants significantly when used in combination with inorganic fertilizer and bacteria (biofertilizer).[38] Using Vermicompost also conditions the soil for future cultivation and is very popularly used by small scale farming businesses. Studies report the use of Vermicompost as a part of integrated nutrient management in combination with bacterial biofertilizers has a good impact on the growth and yield of *Aloe barbadensis*.[39]

NANOBIOFERTILIZERS

In modern days, nanoparticle-based formulations of biofertilizers have been developed. Typical features of nanoparticles make them efficient plant growth promoters and plant developers. Biofertilizer (which are nutrients and plant growth promoter bacteria) are coated in nanoscale polymers. This technique is called nanoencapsulation and the formulation is termed a "Nano-biofertilizer". Certain metal oxides, ceramics, silicates, magnetic materials, semiconductor quantum dots, lipids, polymers, dendrimers and emulsions are used as nanoparticles. The nanomaterials (chitosan, zeolite and polymers) used for coating in the production of nano-biofertilizers help in the slow and constant release of nutrients to plants.[40] The application of nano-biofertilizer has been reported to result in a threefold increase in nutrient use efficiency in plants. Nano-biofertilizers are cost-effective and eco-friendly, they increase the stability of the biofertilizers used in the formulation, and promote plant growth and development, nutrient availability and utilization.[42] Nano-biofertilizers are thus the future of biofertilizers and are considered emerging eco-friendly approaches for sustainable agriculture.[41]

CONCLUSION

Biofertilizers are beneficial for the environment. The use of biofertilizers enhances the quality of the soil by proving nutrients and a natural ambience for the rhizosphere. Biofertilizers also enhance yield and are beneficial for the quality and quantity of yield. Biofertilizers work best in combination with other types of fertilizers. Also, biofertilizers help in breaking down organic fertilizers in the soil and also add antibiotics to the soil. One important thing that should always be considered and taken care of while promoting the use of biofertilizers is that they can only be used as supplements and not as substitutes for other kinds of fertilizers. Unfortunately, biofertilizers despite of their immense benefits in cultivation are not yet enough popular among the farmers and cultivators. It is because they lack enough knowledge about using biofertilizers and have doubts regarding the methods of using biofertilizers. Programmes should be planned by the government and implemented by giving instructions and guidance by experts to farmers for encouraging the use of biofertilizers. This will reduce the use and dependence on chemical fertilizers. On the other hand, switching to biofertilizers in combination with other types of fertilizers will sustain the quality of the farm products. Also, the quality and quantity of medicinal plants are known to improve with the proper use of biofertilizers.

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CONFLICTS OF INTEREST

Declared none.

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