BIOFERTILIZERS IN SUSTAINABLE AGRICULTURE- A REVIEW

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Abstract:
Biofertilizers are defined as preparation of living cells or efficient microorganism which helps to uptake the nutrients for the growth of plants. Sustainable agriculture is the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species. The worldwide increase in human population every year raises a major threat to the food security of the people as the land for agriculture is restricted and even drastic reduction with time. Therefore, it is essential that agricultural productivity should be enhanced significantly within the next few decades to meet the large demand of food by emerging population. For long time chemical fertilizers are used to fulfill the soil requirement of nutrients, but large amount of these chemical fertilizers are dangerous for environment, beneficial microbes, animals and human beings. Therefore, environment friendly and cost effective biofertilizers are used. The exploitation of beneficial microbes as a biofertilizer has become paramount importance in agriculture sector for their potential role in food safety and sustainable crop production. The eco-friendly approaches inspire a wide range of application of plant growth promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, cyanobacteria and many other useful microscopic organisms led to improved nutrient uptake, plant growth and plant tolerance to abiotic and biotic stress. The present review highlighted the different type of microbes associated with biofertilizers, physiological bases of biofertlizers and their activity towards sustainable agriculture in reducing problems associated with the use of chemicals fertilizers.

Index Terms: Biofertilizer, Chemical fertilizers, Sustainable agriculture, PGPR, Eco-friendly.

I. INTRODUCTION

Conventional agriculture plays a significant role in meeting the food demands of a growing human population, which has also led to an increasing dependence on chemical fertilizers and pesticides. Chemical fertilizers are industrially manipulated, substances composed of known quantities of nitrogen, phosphorus and potassium, and their exploitation causes air and ground water pollution by eutrophication of water bodies. In this regard, recent efforts have been channelized more towards the production of 'nutrient rich high quality food' in sustainable process to ensure bio-safety.

Biofertilizers are defined as preparation of living cells or efficient microorganism which helps to uptake the nutrients for the growth of plants **(Abdullah *et. al.,* 2012).** Biofertilizers are used to improve the soil fertility using the biological wastes. The biological waste don't contain toxic materials, hence the living microorganism present in the soil are able to enrich the fertility of the land**.** Thus Biofertilizers can increase the output and improve the quality of the soil. It is well known that the continued use and overuse of petrochemical based fertilizers and toxic pesticides have caused a detrimental effect to the soils, water supplies, foods, animals and even people**.**

As the term biofertilizer implies, it is eco-friendly to environment and farmers. The biofertilizer and biological waste are used to replace the usage of chemical fertilizers as it does not contain any toxic substance and makes the soil enriched. Use of such natural products like biofertilizers in crop cultivation will help in safeguarding the soil health and also the quality of crop products. And these products are also being used in different food industry to produce quality product. There are many groups of the microorganism which are beneficial for the plants but the major contribution are of the following three which considered as important for plants growth: arbuscular mycorrhizal fungi. Plant growth promoting rhizobacteria (PGPR), and nitrogen fixing bacteria. Biofertilizers keep the soil environment rich in all kinds of micro- and macro-nutrients via nitrogen fixation, phosphate and potassium solubalisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil. When biofertilizers are applied as seed or soil inoculants, they multiply and participate in nutrient cycling and benefit crop productivity. In general, 60% to 90% of the total applied fertilizer is lost and the remaining 10% to 40% is taken up by plants. In this regard, microbial inoculants have paramount significance in integrated nutrient management systems to sustain agricultural productivity and healthy environment.

II. DIFFERENCE BETWEEN BIOFERTILIZER AND ORGANIC FERTILIZER

Bio-fertilizer itself explains fertilizer that contains biological means, living organisms that synthesize the atmospheric plant nutrient in the soil or in the plant body, or create such an atmosphere in the soil or in the medium (in which the organisms are kept) which are helpful for the plants. The biofertilizers may be in solid or liquid medium and micro organisms are in huge numbers, (e.g. 10^8cells /g). All these means that the nutrients made available to the plants by the help of microorganisms present in bio-fertilizers. Bio-fertilizers are element specific. Organic manure is the manure prepared from the animal and plant wastes after properly decomposing the raw material. It may contain all necessary plant nutrients in small quantities which are required in large quantities and these may be the medium for bio-fertilizers (Anonymous, 2012a).

III. DIFFERENT TYPES OF BIOFERTILIZERS

Biofertilizer can be grouped in different ways based on their nature and function.

TYPES OF BIOFERTILIZERS ON THE BASIS OF THE PHYSICAL NATURE AND CARRIER MATERIALS

Based on the physical nature and carrier materials used, various types of biofertilizers are manufactured by different producers. These are carrier-based inoculants, agar-based inoculants, broth cultures and dried cultures. New developments in biofertilizer production like (i) freeze-dried inoculants (e.g. BAIF, IARI, India), (ii) Rhizobium-paste (e.g. KALO Inc. USA), (iii) granular inoculant (e.g. Soil implant of Nitragin, USA), (iv) pelleting (e.g. Pelinoc of Nitragin), (v) polyacrylamide-entrapped rhizobia (e.g. Agrosoke) and (vi) pre-coated seeds (e.g. Prillcote of New Zealand), appear to be more promising for inoculation success in tropical legumes.

Carrier-Based Biofertilizers

At present, biofertilizers are supplied as carrier-based microbial inoculants which are added to the soil to enrich the soil fertility. 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. The use of ideal carrier material is necessary in the production of good quality biofertilizer.

A good carrier should have the following qualities:

- Highly absorptive (water-holding capacity) and easy to process;
- Non-toxic to microorganisms;
- Easy to sterilize effectively;
- Available in adequate amounts and low-cost;
- Provide good adhesion to seeds;
- Has good buffering capacity;
- High organic matter content and water-holding capacity of more than 50%.

Liquid Biofertilizers

The strength of biofertilizers is determined by two basic parameters: number of cells and efficiency of the microorganisms to fix nitrogen or solubilize phosphates.

Liquid biofertilizers are liquid formulations containing the dormant form of desired microorganisms and their nutrients along with the substances that encourage formation of resting spores or cysts for longer shelf-life and tolerance to adverse conditions. The dormant forms, on reaching the soil, germinate to produce a fresh batch of active cells. These cells grow and multiply by utilizing the carbon source in the soil or from root exudates.

As an alternative to conventional carrier–based biofertilizers, liquid formulation technology, which has more advantages than the carrier-based inoculants, has been developed in the Department of Agricultural Microbiology, TNAU, Coimbatore. The advantages of liquid biofertilizers over conventional carrier-based biofertilizers are listed below:

- Longer shelf life, 12-24 months;
- No contamination;
- No loss of properties due to storage up to 45º C;
- Greater potential to fight with native populations;
- High populations can be maintained at more than 10^9 cells/ml up to 12 to 24 months;
- Easy identification by typical fermented smell;
- Cost saving on carrier material, pulverization, neutralization, sterilization, packing and transport;
- Quality control protocols are easy and quick;
- Better survival on seeds and soil;
- No need of running biofertilizer production units throughout the year;
- Very much easy to use by the farmer;
- Dosages are 10 times less than those of carrier-based powder biofertilizers;
- High commercial revenues;
- High export potential;
- Very high enzymatic activity, since contamination is nil.

TYPES OF BIOFERTILIZERS ON THE BASIS OF FUNCTION

Biofertilizer can be grouped in different ways based on their nature and function **(Table 1).** Biofertilizers are broadly classified into two main groups:

1. Biological nitrogen fixing biofertilizers

2. Phosphate solubilising (mobilising) biofertilizers

Biological nitrogen fixing biofertilizers consist of micro-organisms which have the ability to fix biological molecular nitrogen (N2) either symbiotically or asymbiotically in the plants.

Phosphate solubilising biofertilizers are capable of solubilising or mobilising the fixed insoluble phosphates of the soil

However, Biofertilizers are divided into five main categories. These five types are again divided in sub-types as follows:

i. Nitrogen fixers:

Symbiotic: Rhizobium, Frankia, Anabaena azollae.

Free living: Azotobacter, Clostridium, Blue green algae, Azolla, Acetobacter, Nostoc, Anabaena.

Associative symbiotic: Azospirillum.

ii. Phosphate supplier:
Phosphatesolubiliser:
Bacteria: Bacillus megaterium, Phosphaticum, Bacillus circulans, Pseudomonas striata, Pseudomonas sp..
Fungi: Penicillium sp, Aspergillus awamori.
iii. Phosphate absorber biofertilisers:
Arbuscular mycorrhiza: Glomus sp., Gigaspora sp., Acaulospora sp., Scutellospora sp. and Sclerocystis sp., Ectomycorrhiza: Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp. Orchid mycorrhiza: Rhizoctonia solani.
iv. Sulphur supplier:
Thiobacillus novellus, Aspergillus.
v. Micronutrients supplier:
Silicate and Zinc solubilisers: Bacillus sp.

Table 1: Main types of biofertilizers on the basis of function

Sl. No.	Group of Bio-fertilizers	Microorganisms
1.	Nitrogen fixing Bio fertilizer	Rhizobium, Azotobacter, Azospirillum, Bradyrhizobium.
2.	Phosphorous solublizing Bio fertilizer	Bacillus, Aspergillus and Pseudomonas.
3.	Phosphate mobilizing Bio fertilizer	Mycorrhiza
4.	Plant growth promoting Bio fertilizer	Pseudomonas sp.

The beneficial soil micro-organisms sustain crop production either as biofertilizers or symbiont. They perform nutrient solubilisation which facilitate nutrient availability and thereby uptake. It improves the plant growth by advancing the root architecture. Their activity provides several useful traits to plants such as increased root hairs, nodules and nitrate reductase activity. Efficient strains of Azotobacter, Azospirillum, Phosphobacter and Rhizobacter can provide significant amount of available nitrogen through nitrogen cycling. The biofertilizers produced plant hormones, which include indole acetic acid (IAA), gibberellins (GA) and cytokinins(CK). Biofertilizers improve photosynthesis performance to confer plant tolerance to stress and increase resistance to pathogens thereby resulting in crop improvement (**Fig. 1**).

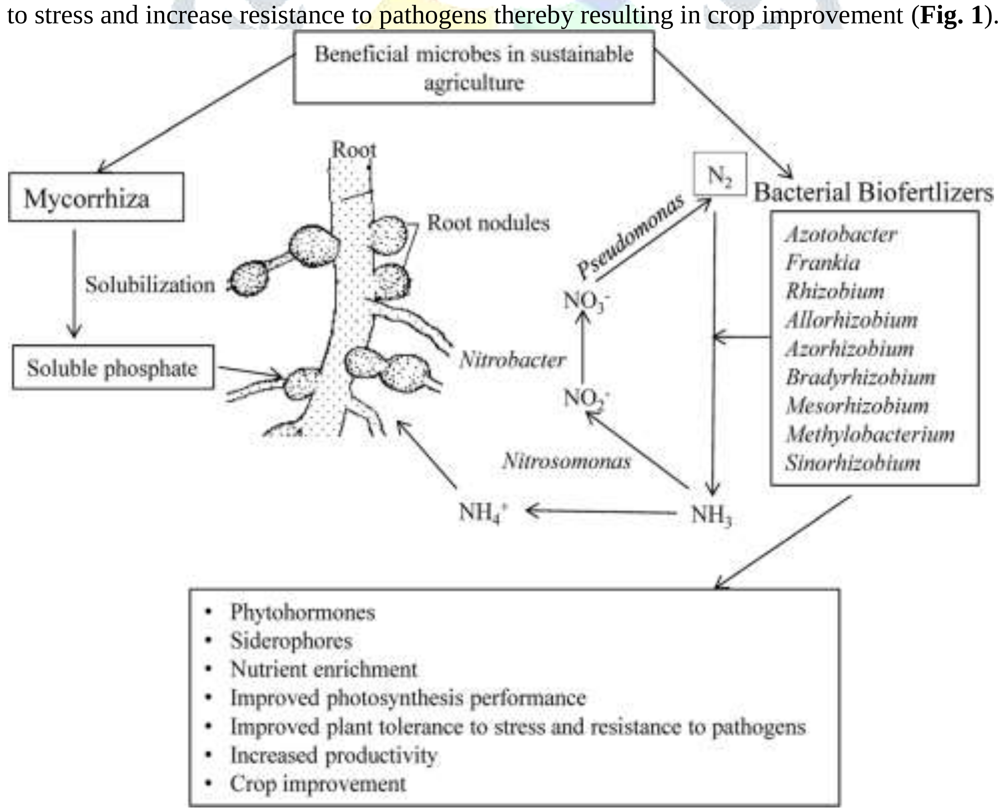

Fig. 1: Potential use of soil microbes in sustainable crop production Source: Bhardwaj et al. Microbial Cell Factories 2014, 13:66 http://www.microbialcellfactories.com/content/13/1/66

IV. WORKING PRINCIPLE OF BIOFERTILIZERS

Bacteria, fungi and other microbes an important and unequally distributed micro-organism present everywhere in the world with different amount of concentration present in more concentration near the root and perform very important works. The Bacteria which are present near the roots (rhizosphere) have the capability to promote plant growth accordingly are called as plant growth promoting microbes, the bacteria which play its role as a plant growth promoter are called as plant promoting bacteria or (PGPB). Today many of the PGPB are available on commercial scale as a bio fertilizers PGPB have very important role in the fertility of soil and plant growth. Its paly role in two way a) PGPBs supply important hormones like auxins, cytokinin, gibberellin, which play role in plant growth directly, PGPBs help in providing the essential elements like nitrogen by nitrogen fixation, phosphorous by method of phosphorous solubilization, potassium intake, which is called as direct way. b) Helping the genes against the pathogens in many ways which are called as indirect way.

V. ADVANTAGES AND LIMITATIONS OF BIOFERTILIZERS

The relevance of bio fertilizer increasing rapidly since chemical fertilizers (i) utilizes petroleum (nitrogenous fertilizers), (ii) are costly, (iii) are short in supply, and (iv) damage the environment.

In contrast, biofertilizers are (i) low cost inputs, (ii) lead to soil enrichment and (iii) compatible with long term sustainability. Further, (iv) they are eco-friendly and pose no danger to the environment. However, the acceptability of biofertilizers has been rather low chiefly because they do not produce quick and spectacular responses. In addition, the amount of nutrients provided by them is not enough to adequately meet the total needs of crops for high yields. Therefore, a pragmatic approach more likely to succeed will be to develop a rational and effective combination of biofertilizers and conventional fertilizers for optimum crop yield.

VI. CONCLUSION

Environmental stresses are becoming a major problem and productivity is declining at an unprecedented rate. Our dependence on chemical fertilisers and pesticides has encouraged the thriving of industries that are producing life-threatening chemicals and which are not only hazardous for human consumption but can also disturb the ecological balance. At last of my review I concluded that today microbial based fertilizers are very significant for the improvements of crop. There are two means due to which we have to use the bio fertilizers. First one that they provide the unavoidable amount of yield and nutrition to human food, they are very safe to use for environment, plants, animals and human and highly eco-friendly. Second one is that they ensure the sustainable growth of agriculture by providing the nutrition to plant in it rhizosphere such as N, P, and K and other minerals and vitamins. Different types microbes are used for this purpose like PGPB and fungi which work exceptional well.

Acknowledgement:

The author is very grateful to P.G. department of Microbiology of Acharya Prafulla Chandra College, New Barrackpore, Kolkata and Dr. Prajna Mondal (Head of the department of Microbiology, Acharya Prafulla Chandra college, New Barrackpore) and also to my family and friends for their constant help and encouragement.

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