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Role of Bio-fertilizers in Organic Agriculture

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Organic farming has emerged as priority area globally in view of growing demand for safe and healthy food along with the environmental concerns associated with indiscriminate use of agrochemicals. Bio-fertilizers are the preparations containing live or latent cells of efficient strains for nitrogen fixing, phosphate solubilising or cellulolytic micro-organisms, and act as one of the essential components of organic farming. Bio-fertilizers may be used as seed or soil application; with objective of increasing the number of micro-organisms and accelerate the microbial processes which augment nutrients availability for crop plants.

Need and potential role of bio-fertilizers in agriculture

Indiscriminate use of synthetic fertilizers has led to the pollution and contamination of soil and water basins, destroyed beneficial insects and micro-organisms, made the crops more prone to diseases, and reduced soil fertility. Due to increasing cost, fertilizers are becoming unaffordable by small and marginal farmers, thus further reduce soil fertility because of widened gap between nutrient removal and addition. These issues are raising concern about environmental hazards and intensify the threats to sustainable agriculture. The incorporation of bio-fertilizers in agriculture plays major role in improving soil fertility and crop yield by increasing availability and efficiency of plant nutrients. In low land rice cultivation, application of BGA+*Azospirillum* proved significantly beneficial for improving LAI and all yield attributing parameters. In addition, their application in soil improves soil biota and minimizes the dependency on sole use of chemical fertilizers. Therefore, the inoculations with PSB and other useful microbes in these soils become mandatory to restore and maintain the effective microbial populations for solubilisation of chemically fixed phosphorus and increased the availability of macro and micronutrients to harvest good sustainable yield.

Types of bio-fertilizers

Bio-fertilizers play a significant role in improving soil fertility by fixing atmospheric nitrogen as free living or in association with plant roots; solubilise insoluble soil phosphates; mobilize fixed macro and micro nutrients or convert into available forms; and also produces plant growth substances in soil. On the basic of various functions performed, bio-fertilizers can be classified into following groups:

A. Nitrogen fixers

Rhizobium: It belongs to family Rhizobiaceae and has ability to fix 50-100 kg ha^{-1} atmospheric nitrogen in symbiotic association with legumes and certain non-legumes like Parasponia. It is useful for pulse legumes (chickpea, red-gram, pea, lentil, black gram etc.), oil-seed legumes (soybean and groundnut); and forage legumes (berseem and lucerne). Successful nodulation of leguminous crops by *Rhizobium* largely depends on availability of compatible strain for a particular crop.

Azospirillum: These heterotrophs belongs to family Spirilaceae and fix atmospheric nitrogen via associative symbiosis with many plants, particularly those having the C4-dicarboxylic path way of photosynthesis (Hatch and Slack pathway), because they fix nitrogen on salts of organic acids such as malic and aspartic acid. In addition to their nitrogen fixing ability (20-

40 kg ha^{-1}), they also produce growth regulating substances. Although there are many species under this genus, but, inoculation mainly with *A. lipoferum* and *A. brasilense* have been proved beneficial worldwide.

***Azotobacter*:** These N fixers are aerobic, free living, heterotrophic in nature, and belong to family Azotobacteriaceae. Azotobacters can fix N in neutral or alkaline soils and *A. chroococcum* is the most commonly found species in arable soils.

***Blue green algae* (*Cyanobacteria*):** These phototrophs can fix 20-30 kg N ha^{-1} in submerged rice fields and produce growth hormones like auxin, indole acetic acid and gibberllic acid. As they are abundant in paddy field, so also referred as "paddy organisms". BGA fixes N via symbiotic association with fungi, liverworts, ferns and flowering plants, but the most common symbiotic association has been found with free floating aquatic fern, the Azolla. Azolla contains 4-5% N on dry basis and 0.2-0.4% on wet basis, thus can be the potential source of organic manure and nitrogen in rice production. The benefit of using Azolla as biofertilizer for rice crop is due to its quick decomposition in soil and easy availability of its nitrogen to rice plants. India has recently introduced some species of Azolla for their large biomass production including *A. caroliniana*, *A. microphylla*, *A. filiculoides* and *A. mexicana*.

B. Phosphate solubiliser

The bacterial genera such as *Pseudomonas*, *Bacillus*, *Rhizobium*, *Achromobacter*, *Agrobacterium*, *Microccocus*, *Aereobacter*, *Flavobacterium* and *Erwinia* have the ability to solubilize insoluble inorganic phosphate compounds like tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate. There are considerable populations of phosphate solubilising bacteria in soil and in plant rhizosphere depending on substrate availability and soil conditions. Among the wide microbial diversity, the soil bacteria belonging to genera *Pseudomonas* and *Bacillus;* and Fungi are most common for phosphate solubilisation.

C. Phosphate absorbers (Mycorrhiza)

The term mycorrhiza denotes "fungus roots" and is a symbiotic association between host plants and certain group of fungi at root system. In this association, fungal partner is benefited for its carbon requirements from the photosynthates of the host; and the host is benefited with essential nutrients (especially phosphorus, calcium, copper, zinc etc.) with the help of fine absorbing hyphae of the fungus which increased the absorption.

D. Zinc solubiliser

The zinc can be solubilised by various microorganisms including *Bacillus subtilis*, *Thiobacillus thioxidans* and *Saccharomyces* sp. etc. The research studies have reported that Zn solubilising bacteria can be used as bio-fertilizer; or in soils where native zinc is higher; or in conjunction with insoluble cheaper zinc compounds like zinc oxide, zinc carbonate and zinc sulphide instead of costly zinc sulphate.

Major limitations in large scale production of bio fertilizers

1. Lack of regulation and standards for bio-fertilizer
2. Inadequate awareness among the farming community about bio-inoculants
3. Bio-fertilizers are environmental and crop/cultivar specific, thus unable to show expected positive results
4. Lack of trained man power and cost required for production of quality bio-fertilizer
5. Lack of storage and transportation facilities to avoid contamination
6. Extreme climatic conditions (especially prolonged hot and dry summer) often make the results of bio-fertilizers inconsistent
7. Lack/poor availability of suitable carrier materials for bio-fertilizer formulation

Future prospects and recommendations

For a comprehensive development and utilization of bio-fertilizers, there are several issues and recommendations, which need to be taken care by the Government in future research:

1. Necessary legislation for monitoring the quality and hazardous effects of bio-fertilizers, if any

2. Government may subsidize or provide loans for small scale production units of bio-fertilizers
3. Development of culture collections or gene bank facility for microorganisms in the country
4. A strong extension and training program may be initiated for motivating the farmers and other concerned personnel to exploit full potential of the bio-fertilizer technology
5. Short term diploma programs may also be initiated at agricultural universities or proposed Microbiology Research Centres/Labs to develop bio-fertilizer for their local conditions
6. The potential of bio-fertilizers to supply micronutrients and for biofortification of food crop also is to be explored in future research
7. Culture of less used bio-fertilizers, such as phosphate solubilizer and phosphate mobilizers should be improved under laboratory conditions that will enable to test their performance in field and promote their application in agriculture.

Conclusion

Currently there is a gap of ten million tonnes of plant nutrients between removal by crops and supply through chemical fertilizers. In context of cost and environmental impact of chemical fertilizers, excessive reliance on chemical fertilizers is not an acceptable strategy for sustaining the crop production in long run. Thus, bio-fertilizers would be the viable option for farmers because besides N-fixation, bio-fertilizers or bio-manures also contribute in mobilization or solubilisation of macro or micro nutrients (P, K, S, Zn, Fe, Mn etc.) and play vital role in maintaining long term soil fertility and ecosystem sustainability.