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Biofertilizers: Its Role in Soil Fertility and Sustainable Agriculture

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The current trend of application of chemical fertilizer has resulted in environmental pollution and made the cost of agricultural activities increase tremendously. Conventional agriculture plays a significant role in fulfilling the demands of food for an ever-increasing population, which has also led to growing dependence on chemical-based fertilizers and pesticides. Chemical fertilizers are substances composed of known quantities of nitrogen, phosphorus, and potassium which are industrially manipulated. The exploitation of these very chemical fertilizers causes air and groundwater pollution by eutrophication of water bodies. The use of synthetic fertilizer in agriculture results in the deterioration of soil conditions and the environment. In this context, recent efforts have been made more towards the production of 'nutrient-rich high-quality food' in a sustainable manner to ensure bio-safety. Biofertilizers contain microorganisms that promote the adequate supply of nutrients to the host plants and are one of the important components of organic farming that enhances plant growth and yield improving soil health and fertility. The problems created due to the utilization of chemical fertilizers such as increased salinity and chemical residues can be reduced with the application of biofertilizers ensuring a healthy atmosphere for plants. Biofertilizers play a vital role in maintaining long-term soil fertility and sustainability in agriculture (figure 1). Sustainable agriculture encouraging alternate means of soil fertilization relies on organic inputs to improve nutrient supply and conserve the field management is very much of important and it is huge a challenge to meet the food demands of the human population considering environmental safety factors. Organic farming can be considered as one of such strategies that not only ensure food safety but also add to the biodiversity of soil. In this regard, biofertilizers are one such part of organic farming and alternative fertilizer which is nothing but the preparation containing microorganisms that help crops to uptake nutrients more efficiently and are critical components of nutrient management. However, in nature, beneficiary microorganisms may not present at optimal levels in the fields to get the required benefit. Therefore, artificial cultures of selected microorganisms hold a promising role in developing the microbial fauna in the soil environment.

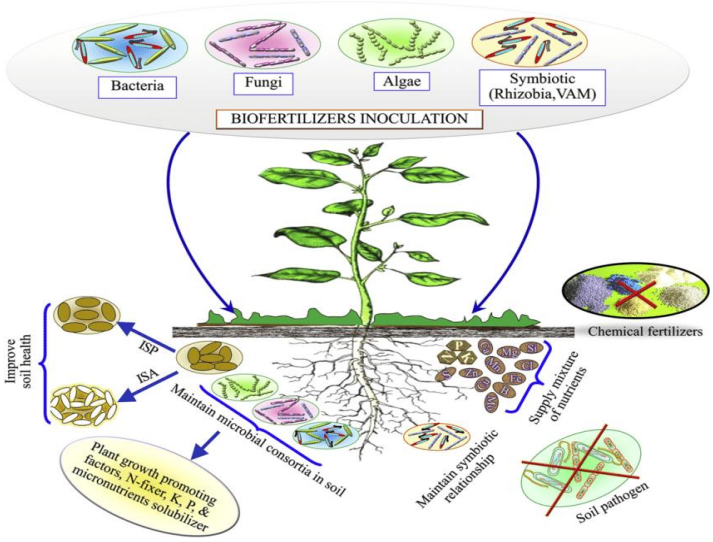

Fig. 1 Diagrammatic representation of biofertilizers and its influence on plant growth-performance and soil health where VAM = Vesicular-arbuscular mycorrhiza, ISP=Increase soil porosity and ISA = Increase soil aggregation (Mahmud *et.al.*, 2021)

Biofertilizers

Biofertilizers are the biologically active products or microbial inoculants of bacteria, algae, and fungi, which may help biological nitrogen fixation for the benefit of plants (Vessey, 2003). They contain living microorganisms that colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. They also include organic fertilizers (manures, etc.), which are rendered in an available

form due to the interaction of microorganisms or due to the interaction of microorganisms or due to their association with plants accelerating certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants. They add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth-promoting substances. Since they play several roles, a preferred scientific term for such beneficial bacteria is "plant-growth promoting rhizobacteria" (PGPR).

Need for Biofertilizers

Green revolution technologies have emerged, the modern agriculture is getting more and more dependent upon the steady supply of synthetic inputs mainly fertilizers. It is well well-known fact that the efficiency of phosphate fertilizers is very low (15-20%) because of their fixation nature in acidic and alkaline soils and unfortunately, both soil types are predominantly found in India accounting for more than 34% acidity affected and more than seven million hectares of productive land are salinity/alkaline affected (Singh, 2015).

In short, some concerns are listed below:

(i) Availability and cost.

- Demand is much higher than the availability.
- Unaffordable by small and marginal farmers due to the increased costs of artificial inputs.

(ii) Adverse effect of chemical fertilizers in soil and environment.

- Excessive and imbalanced use has adversely affected the soil causing a reduction in microbial flora of soil, a decrease in organic carbon, increasing acidity and alkalinity, and hardening of soil.
- Over usage of N-fertilizer contaminates water bodies thus affecting fish fauna causing health hazards for human beings and animals.
- Their production adds pollution.

To overcome these, it is suggested that efforts should be made to exploit all the available resources of nutrients under the theme of integrated nutrient management. Under this approach, the best available option lies in the complimentary use of biofertilizers, and organic manures in a suitable combination of chemical fertilizers.

Types of biofertilizers

Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. They can be grouped in different ways based on their nature and function as shown below in Table 1.

Benefits of biofertilizers in soil fertility and agriculture

Biofertilizers are known to play several vital roles in soil fertility, crop productivity, and production in agriculture as they are eco-friendly. Some of the important functions or roles of biofertilizers in agriculture are:

1. The natural habitat of the soil is maintained increasing crop yield by 20-30% replacing chemical nitrogen and phosphorus by 25%, and stimulating plant growth.
2. They are best at minimizing the use of chemical fertilizers not exceeding 40-50 kg N/ha under ideal agronomic and pest-free conditions.
3. They can add 20-200 kg N/ha year *(eg. Rhizobium sp.* 50-100 kg N/ha year, *Azospirillum, Azotobacter:* 20-40 kg N/ha /yr; Azolla: 40-80 kg N/ha; BGA: 20-30 kg N/ha) under optimum soil conditions and thereby increases 15-25 percent of total crop yield.
4. Some biofertilizers *(eg, Rhizobium, BGA, Azotobacter* sp) stimulate the production of growth-promoting substances like vitamin-B complex, Indole acetic acid (IAA), and Gibberellic acids, etc. Thus, activates soil biologically.
5. Phosphate mobilizing or phosphorus solubilizing biofertilizers convert insoluble soil phosphate into soluble forms by secreting several organic acids and under optimum conditions they can solubilize/mobilize about 30-50 kg P_2O_5/ha due to which crop yield may increase by 10 to 20%.
6. They act as antagonists and suppress the incidence of soil-borne plant pathogens and thus, help in the bio-control of diseases.
7. Blue-green algae like *Nostoc, Anabaena, and Scytonema* are often employed in the reclamation of alkaline soils.

8. *Azolla-Anabaena* grows profusely as a floating plant in flooded rice fields and can fix 100-150 kg N/ha /year in approximately 40-60 tons of biomass produced.

Conclusion

While our agriculture system is facing various environmental stresses, it is very important to realize the useful aspects of biofertilizers and implement modern agricultural practices. It has a great role in increasing agricultural production. They are extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements by supplying organic nutrients through microorganism and their by-products. Thus, it improves the soil health status and provides different growth-promoting hormones and phytohormones to the plant

The long-term use of biofertilizers is economical, and eco-friendly without leaving any residual effects as in chemical fertilizer, renewable energy sources, and more efficient, productive, and affordable by small and marginal farmers. Hence use of biofertilizers is a proper option for sustainable agriculture.

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Table 1: Types of biofertilizers

For Nitrogen	
	Rhizobium for legume crops
	Azotobacter for nonlegume crops like wheat, cotton, maize, mustard, potato, and other vegetable crops. Azospirillum for crops like sorghum, millets, maize, sugarcane and wheat
	Acetobacter for sugarcane only
	BGA and Azolla for lowland paddy
For Phosphorous	
	Phosphate solubilizing bacteria for all crops to be applied with Rhizobium, Azotobacter, Azospirillum, and Acetobacter
For enriched compost	
	Cellulolytic fungal culture
	Phosphate solubilizing bacteria and Azotobacter culture

Sl No.	Groups	Examples
N_2 fixing biofertilizers		
1.	Free-living	*Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc,*
2.	Symbiotic	*Rhizobium, Frankia, Anabaena azollae*
3.	Associative Symbiotic	*Azospirillum*
Phosphate Solubilizing biofertilizers		
1.	Bacteria	*Bacillus megaterium* var. *phosphaticum, Bacillus subtilis, Bacillus circulans, Pseudomonas striata*
2.	Fungi	*Penicillium sp, Aspergillus awamori*
Phosphate Mobilizing biofertilizers		
1.	Arbuscular mycorrhiza	*Glomus sp.,Gigaspora sp.,Acaulospora sp., Scutellospora sp.* & *Sclerocystis sp.*
2.	Ectomycorrhiza	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
3.	Ericoid mycorrhizae	*Pezizella ericae*
4.	Orchid mycorrhizae	*Rhizoctonia solani*

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