REVIEW ARTICLE

Use of biofertilizers in modern agriculture

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The fertilizer production in our country is less than the required amount. To fill this gap, alternate sources of nutrients have to be looked for. Organic wastes and biofertilizers are the alternate sources to meet the nutrient requirement of crops and mitigating nutrient deficiencies. Further, knowing the harmful effect of using only the chemical fertilizers on soil health, use of chemical fertilizer along with compost and biofertilizers is required which will help to maintain soil health and productivity. With the introduction of green revolution technologies, the modern agriculture is getting more and more dependent upon the steady supply of synthetic inputs (mainly fertilizers). Adverse effects are being noticed due to the excessive and imbalanced use of these synthetic inputs. This situation leads to identifying harmless inputs like biofertilizers whom use in crop cultivation will help in safeguarding the soil health and also the quality of crop products.

Key Words: *Biofertilizers; Rhizobiu; Phosphate solubilizing bacteria; Potassium mobilizing bacteria; Silicon solubilizing bacteria*

INTRODUCTION

Biofertilizers are the products containing one or more species of microorganisms which have the capacity to mobilize nutritionally important elements from non-usable to usable form through biological processes such as nitrogen fixation, phosphate solubilization, excretion of plant growth promoting substances or cellulose and lignin biodegradation in soil, compost and other environments. These microorganisms, which may include bacteria, fungi or algae, carry out a variety of biological processes that are significant for enhancing soil fertility and plant growth. One of the most significant advantages of biofertilizers is that they are completely harmless to the environment. Unlike chemical fertilizers, which can cause pollution and long-term soil degradation, biofertilizers are natural, non-toxic and sustainable. They contribute to a reduction in the need for synthetic fertilizers, which in turn lowers the risk of groundwater contamination, soil acidification and the depletion of essential soil microorganisms. Moreover, biofertilizers are low-cost renewable agricultural inputs. By improving the availability of nutrients in the soil, biofertilizers support healthier plant growth, higher crop yields and better-quality produce. They play a significant role in improving nutrient availability in plants. They are recognized as a components of integrated plant nutrient supply system [1].

A crop nutrient management plan is a tool that can increase the efficiency of all the nutrient. Nitrogen promotes the vegetative growth and increase protein content in the crop. Phosphorus enhances the activity of rhizobia, increase the formation of root nodules, stimulates early root development, helps in fixing more atmospheric nitrogen and aids in grain formation when applied to legumes. It also improves the crop quality and resistance to disease. Potassium also plays a major role in the transport of water and nutrients for whole of the plant in the xylem. In general, sulphur is required for the synthesis of vitamins and promotes nodulation in legumes. Sulphur is known to play an inevitable and imperative role in sulphur containing amino acids i.e., cysteine, cystine and methionine, vitamin and protein synthesis. The need of nitrogen, phosphorus, potassium and sulphur are determined by the crop [2]. Biofertilizers help in the maintenance or adjustment of plant nutrient supply to an optimum level for sustaining desired crop productivity and soil fertility.

In sandy soils of semi-arid regions, drought stress and lack of nutrients (mainly nitrogen and phosphorus) are considered as the main production constraints. Therefore, guar is expected to fit very well in this region as an important drought tolerant cash crop and soil-building crop, with respect to available nitrogen through nitrogen fixation to maintain soil fertility and sustainable productivity [3].

LITERATURE REVIEW

Liquid biofertilizers are liquid formulations have the dormant form of desirable micro-organisms and their nutrients together with the substances that encourage formation of resting spores or cysts for longer shelf life and tolerance to unfavorable conditions. The dormant form of reaching the soil, germinate to create the fresh batch of active cells. These cells developed and multiply by utilizing the carbon source in the soil or from root exudates. A lot of work done on carrier-based biofertilizers in the context of organic food production. In view of the advantages of liquid biofertilizers over carrier based formulations, research has now been started on the production and testing of liquid biofertilizers. Consequently, liquid biofertilizers are specifically formulated solution that contains beneficial micro-organism which improves nutrient uptake by converting it in soluble form, increase soil fertility, produces plant growth promoting substances and plant hormones thereby reduces chemical fertilizer usage up to 20%-30% [4]. Fungi, bacteria and *Cyanobacteria* are the main source of bioferlizers. Fungi are non-green microorganisms; aside from making phosphorus available in the soil for plant uptake, they help to aggregate the soil structure. *Cyanobacteria* are symbiotically associated with *Azolla* and also known as blue-green algae. Species of blue green algae are Nostoc and *Anabaena*. Examples of fungal biofertilizers are *Mycorrhiza*, *Fusarium* species and *Penicillum* species. Examples of bacterial biofertilizers are *Azotobacter*, *Azospirillum*, *Clostridium*, *Rhizobium* etc. A combination of biological and chemical sources of nitrogen are cheaper and impressive way of increasing production under limited resources [5]. Biofertlizers are applied as grain treatment or applied in the soil. Biofertilizers in liquid formulation are easy to handle and applied at 3-5 ml/kg grain just before sowing. Soil applied biofertiizers are mixed in compost or farm yard manure and kept it for overnight and then incorporated in soil just before sowing. Now a days in addition to Nitrogen (N), Phosphorus (P) and Potassium (K) fixing biofertilizer, liquid bifertilizers for sulphur, zinc and manganese are also available. These liquid biofertilizers are easy to handle and cost effective [6]. In India, biofertilizers are available for almost all crops. Hence, total consumption of biofertilizer is expected to increase too many fold in coming years. Various Agricultural State Universities and non-Government Organizations are engaged in mass production of biofertilizers [7-9]. Largest producing states are Madhya Pradesh, Maharashtra, Karnataka and Tamilnadu. The biofertilizer demand in India is several thousand tones, but no sufficient production facilities are available.

Characteristics of liquid biofertilizers

Dormant microorganisms: In their dormant state, these microorganisms can survive in the liquid formulation and remain viable until they are introduced

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into the soil. Upon reaching the soil, they reawaken, germinate and multiply, utilizing available carbon sources from the soil or root exudates to become active.

Extended shelf life: Liquid biofertilizers typically have a shelf life of 12 to 24 months, which is significantly longer than that of traditional carrier-based biofertilizers. This extended shelf life is due to the dormant state of the microorganisms and the formulation's stability.

Temperature tolerance: They can withstand higher temperatures up to 45°C without losing their efficacy, which is not the case for many carrier-based products.

Low contamination risk: The liquid format minimizes the chances of contamination compared to carrier-based biofertilizers.

High population density: Liquid biofertilizers can maintain high populations of beneficial microorganisms, often exceeding 10^9 cells per unit, ensuring effective inoculation and impact.

Reduced dosage: The required dosage for liquid biofertilizers is about ten times less than that of carrier-based inoculants, making them more efficient and cost-effective.

Quick quality control: The liquid formulation simplifies quality control procedures, making it easier to ensure product consistency and effectiveness.

Seed treatment

Nitrogenous biofertilizers: Apply at 200 gm/10 kg seeds.

Phosphatic biofertilizers: Apply at 200 gm/10 kg seeds.

Liquid biofertilizer: Dip seeds in a solution of 3 ml of liquid biofertilizer per liter of water.

Soil treatment

4 kg each of the recommended biofertilizers are mixed in 200 kg of compost and kept overnight. This mixture is incorporated in the soil at the time of sowing or planting.

DISCUSSION

Challenges of biofertilizers development and use

Biofertilizers represent a biological approach aimed at the sustainable intensification of agriculture, offering an eco-friendly alternative to synthetic fertilizers. Despite their potential benefits, several challenges hinder their widespread application and effectiveness in boosting agricultural yields.

Variable performance under field conditions: Biofertilizers are highly sensitive to both biotic and abiotic stresses. While they may demonstrate promising results in laboratory and greenhouse settings, their performance often varies significantly in actual field conditions. Crops are grown in diverse environments with varying temperatures, rainfall, soil types, soil biodiversity and crop varieties. These environmental variations can lead to inconsistencies in the efficacy of biofertilizers, making it challenging to ensure reliable results across different settings.

Slower action compared to synthetic fertilizers: Biofertilizers generally act more slowly than synthetic fertilizers. The inoculum in biofertilizers needs time to establish itself, build up its population and effectively colonize plant roots. This delayed action can impact their adoption among farmers who may be accustomed to the immediate results provided by synthetic alternatives.

Need for field-specific research: To address these challenges, it is essential to select potential biofertilizer isolates based on their performance under various field conditions. This involves testing them across multiple crops, soil types and environmental conditions to identify those that offer consistent benefits. Biofertilizers should ideally complement rather than completely replace synthetic fertilizers, helping to reduce their usage and associated environmental impacts.

Shelf life and storage issues: Biofertilizers contain live microbial cells, which pose challenges related to shelf life and storage. Typically, they have a short shelf life of around six months when stored at 20°C-25°C. This necessitates careful handling, transportation and storage to maintain their viability, which can increase product costs and limit availability, especially in remote rural areas.

Regulatory and standardization barriers: The development and commercialization of biofertilizers face regulatory hurdles, including difficulties in product registration and patenting. One major issue is the lack of standardized legal and regulatory definitions for terms such as "plant biofertilizer" or "plant biostimulant". This absence of a globally coordinated regulatory framework creates inconsistencies and barriers to market entry, complicating the commercialization process [10-12].

Future prospects of biofertilizers

There is a growing demand for agricultural goods produced in a sustainable manner; therefore, the use of eco-friendly inputs for food production, such as biofertilizers, will have a significant increase in the coming years. The global market of biofertilizers is expected to increase from 2.3 billion US dollar in 2020 to 3.9 billion in 2025. The increase in the market value will be supported by government agencies and industry to create awareness among farmers and consumers about the benefits of the use of biofertilizers, in concordance with the development sustainable goal 12 proposed by FAO: "ensure sustainable consumption and production patterns. The role of metagenomics to have a better understanding of microbial communities associated with rhizosphere is a growing field of research and it will continue to increase. Plant rhizosphere is colonized by a large number of microorganisms and this results in a huge number of microbial genes that interact with plant genes. However, more elaborated research has to be conducted, such as meta transcriptomic and meta proteomics and their relation with plant growth. The results of the omics must be translated into the field to have better agronomic practices and new biofertilizer formulations.

CONCLUSION

In conclusion, the increasing reliance on chemical fertilizers in modern agriculture has raised significant concerns regarding soil health, environmental impact and the long-term sustainability of farming practices. To reduce this, the integration of biofertilizers, which are eco-friendly and renewable, offers a potential solution. Biofertilizers, derived from naturally occurring microorganisms, contribute to maintaining soil fertility, promoting healthier crop growth and reducing the negative environmental effects linked to synthetic fertilizers. Despite challenges such as variability in field performance, slower nutrient release and regulatory hurdles exist, the potential of biofertilizers remains positive. The growth will be supported by ongoing research and technological advancements that aim to improve the efficiency and reliability of biofertilizers. By harnessing the benefits of biofertilizers and overcoming existing challenges, they can play a pivotal role in sustainable crop production, soil health preservation and environmental protection, making them an indispensable component of future agricultural strategies.

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