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RECENT ADVANCEMENTS IN USE OF BIOFERTILIZERS FOR SUSTAINABLE AGRICULTURE

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Introduction

The Food and Agriculture Organization (FAO) of the United Nations estimates that by 2050, the global population will reach at least 9.8 billion people (Harold and Reetz, 2016). To ensure global food security, it is essential to double current agricultural production levels (FAO, 2018). Achieving this goal will require either highly fertile soils or the application of significant amounts of fertilizer to nutrient-poor soils. Traditionally, the primary nutrients needed by plants—nitrogen, phosphorus, and potassium (NPK)—have been supplied through chemical fertilizers to meet global food needs.

Nitrogen plays a vital role in photosynthesis and the enzymatic processes that produce proteins. Plants redistribute nitrogen within their systems, moving it from areas with high concentrations to areas where it is less abundant. Phosphorus is equally important, as it supports fruit production, stem growth, and root development. Without adequate phosphorus, plants are likely to become weak, prone to wilting, discoloration, and poor fruit yield.

Fertilizers are widely used by farmers as a key method to enhance crop productivity. However, excessive use of fertilizers, particularly in horticulture where fertilizer costs represent less than 10% of variable crop costs, has been associated with several negative consequences. These include groundwater pollution, increased pest populations, and a higher incidence of plant diseases. Biofertilizers, which are applied as seed or soil treatments, offer an alternative approach. These are mixtures of living organisms or dormant cells of beneficial bacterial strains that enhance nutrient uptake in crops by interacting with the root zone, or rhizosphere. Biofertilizers increase the population of beneficial bacteria in the soil, thereby improving the availability of primary nutrients for plant absorption.

Unlike inorganic and organic fertilizers, biofertilizers do not directly supply nutrients to plants. Instead, they promote the growth of specific microorganisms—such as fungi, bacteria, algae, and actinomycetes—that aid in nutrient availability. These microorganisms are highly effective in providing the essential elements found in chemical fertilizers, particularly nitrogen (N), phosphorus (P), and potassium (K). Although these elements are present in sufficient quantities in the soil (NPK) or atmosphere (N), they are not always in a form that plants can easily absorb.

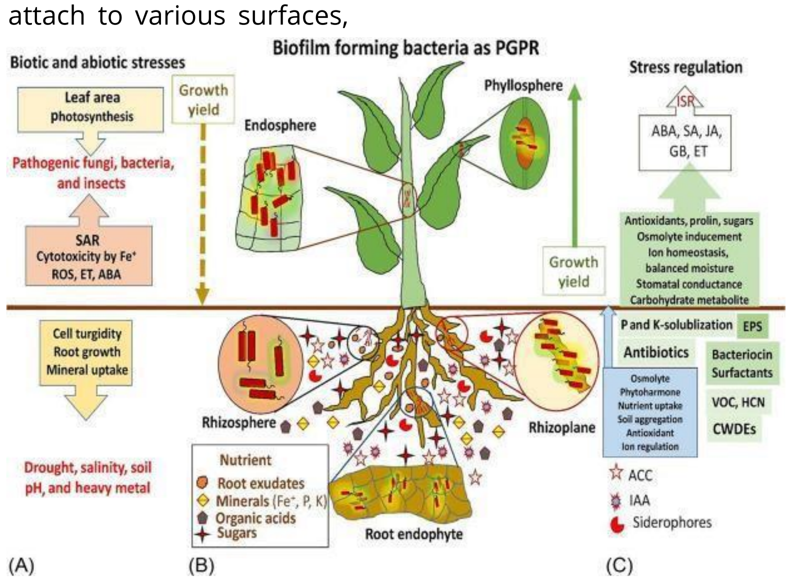
In the context of modern agriculture, the use of biofertilizers is becoming increasingly important as a sustainable alternative. Researchers have been driven to develop biofertilizers as a way to reduce or replace chemical fertilizers, due to the high costs associated with chemical formulations and the challenges of meeting global demand. However, creating biofertilizers that meet the standards of long-term storage, ease of use, and effectiveness comparable to chemical fertilizers is a significant challenge. For biofertilizers to gain widespread acceptance, they must produce results that are on par with those of chemical fertilizers. Without this, it will be difficult to convince low-income farmers to make the switch. Despite these challenges, biofertilizers offer distinct advantages over chemical fertilizers. They can complement other nutrients and growth factors, and they release nutrients gradually, according to the crop's needs. As such, biofertilizers hold great potential for enhancing sustainable agricultural practices while reducing dependency on chemical fertilizers.

Advances in use of biofertilizers in fruit crops

1. Biofilm bio fertilizers:

Recent advancements have been made in utilizing biofilms for the production of biofertilizers. According to Junaid and Khan (2018), biofilms consist of microbial communities that attach to various surfaces, whether living or non-living, and include biological elements that maintain the structural integrity and sustainability of the biofilm. Within these communities, microbes communicate and collaborate through a process known as quorum sensing.

The development of biofilm-based biofertilizers primarily aims to bolster the native microbial population's resistance to diseases and environmental inhibitors, while addressing challenges associated with soil's biotic and abiotic factors. These biofilms enable the exchange of genetic material and organic resources among microbial species. Biofilms composed of multiple strains are particularly robust and sustainable, leading to improved nutrient uptake and increased resilience to environmental stresses. Recent studies indicate that biofilm biofertilizers, especially those enhanced with additional organic resources, can significantly improve plant growth metrics, including fruit count, weight, and overall yield. This is likely due to the steady supply of essential nutrients provided to the plants.



Source : Quddus *et al.* (2021). Recent Advances in Biofertilizer.

2. Nanobiofertilizers

The integration of nanotechnology with biofertilizers, referred to as nano-biofertilizers, significantly enhances crop productivity. This combination improves plant nutrient absorption and soil moisture retention. Unlike traditional fertilizers, nano-biofertilizers effectively tackle issues such as temperature fluctuations, pH variations, limited shelf life, fewer microbial strains, and short-term effectiveness. They allow for broader coverage with smaller amounts of fertilizer, leading to better crop growth and yields. Additionally, their superior field performance and cost-effectiveness benefit farmers. Nano-biofertilizers are also environmentally friendly, boosting soil fertility by enhancing the activity of native microbial populations and optimizing the use of essential nutrients such as potassium, nitrogen, and phosphorus.

3. Lyophilisation and encapsulation techniques

A novel technique known as encapsulation has been developed, allowing biofertilizers to be released into the environment in a controlled manner. This technique is often used to cultivate microbial species with specific compositions and structural characteristics. A more advanced area within this field is microencapsulation, which focuses on enclosing active molecules within a protective shell or capsule. This approach not only extends the shelf life of biofertilizers but also enhances crop yields by providing protection against environmental stressors and ensuring a slow release into the soil.

One method for storing and preserving microorganisms is lyophilization, commonly referred to as freeze-drying. This technique is widely used in laboratory settings for formulating microorganisms. Lyophilization allows bacteria to survive for extended periods, making it possible to directly apply these lyophilized microbial organisms in the field, either on their own or combined with an appropriate carrier material.

4. Nanoencapsulation technology

Nanoencapsulation technology is used to encapsulate biofertilizers at the nanoscale, utilizing various nanomaterials such as chitosan, polymers, and zeolite. This technique offers several advantages in agriculture. Primarily, it enhances the stability of biofertilizers and allows for controlled release, ensuring that plants receive a consistent supply of nutrients. This controlled diffusion optimizes nutrient absorption, stabilizes the soil-plant system, and ultimately increases plant yield.

Furthermore, nanoencapsulated biofertilizers can collaborate with arbuscular mycorrhizal fungi (AMF) inoculants or microbial species to improve soil health by facilitating processes such as phosphorus solubilization, nitrogen fixation, phytohormone production, and chelating agent synthesis by plant growth-promoting rhizobacteria (PGPR). The application of nanoencapsulation technology improves the efficacy of biofertilizers through enhanced stability, controlled release, interaction with soil microbiota, and increased agricultural productivity.

Conclusion

In summary, the recent advancements in biofertilizer technology mark a significant step toward embracing sustainable agricultural practices. These innovations provide a more eco-friendly approach by reducing dependency on chemical inputs and minimizing environmental impact. Biofertilizers offer effective solutions to challenges such as soil degradation, nutrient loss, and climate change through specialized formulations and advanced technologies. Integrating biofertilizers into modern farming represents a shift towards more holistic and regenerative practices. By harnessing the potential of beneficial microorganisms, farmers can boost crop yields, support ecological balance, and enhance soil fertility. This shift not only ensures food security but also builds resilience against unpredictable environmental conditions. Moving forward, increased research, investment, and education are necessary to optimize the effectiveness and widespread adoption of biofertilizers. Collaboration among scientists, policymakers, and farmers is crucial for overcoming challenges and realizing the full potential of this sustainable solution.

With coordinated efforts, biofertilizers can play a vital role in creating an agricultural system that nourishes both people and the planet.

"Grow green, go bio: Sow the future with eco-friendly fertilizers!"

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