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Preparation, Process, and Significance of Bio-fertilizers

Mahima Rani[1], Ajay Singh[2,*]

Abstract

The application of chemical fertilizers (such as calcium nitrate, urea, ammonium sulfate, diammonium phosphate, etc.) is crucial to the world's food production because it acts as a fast food for plants, accelerating their growth and efficiency. However, because of the excessive and unbalanced use of these synthetic inputs, negative effects are being observed. Beneficial microorganisms found in biofertilizers provide a sustainable substitute for chemical fertilizers, tackling the mounting worries about non-renewable resource depletion and environmental degradation. Biofertilizers play an important role in enhancing soil fertility, promoting plant growth, and ensuring agricultural sustainability. Various types of biofertilizers have distinct mechanisms of action and work with a variety of crops and soil types. Overall, this review compiles the body of knowledge currently available on biofertilizers, offering insightful information to academics and agricultural professionals who want to make the most of biofertilizers' potential to advance sustainable agriculture and guarantee global food security. Bio fertilisers provide not only major nutrients like nitrogen, phosphorous, potassium but also other nutrients like Zinc, Magnesium, Manganese, Be, Se etc through biological action Some Green methods have played important role in the synthesis of such fertilizers. The idea of "green technology" prompted scientists to devise a novel approach for utilizing the environment continuously without compromising its stability. Utilizing environmentally friendly and biodegradable technology in agriculture in conjunction with the natural world as a substitute for chemical fertilizers is one way to address this issue of sustainability .

Keywords: **Bio fertilizer, Nutrient, Micro organism, Agriculture, Sustainability**

INTRODUCTION

The current situation is one of population growth and rising demand for nutritious foods. The production of food is difficult due to issues such as depletion of arable land, high throughput, lack of agricultural inputs, climate variability, and loss of soil fertility [1]. Demand for wholesome food puts a strain on agriculture's sustainability. To ensure agriculture grows sustainably, the "green revolution" is crucial. It focuses on using environmentally friendly methods to lessen the number of dangerous artifacts in the environment. The idea of "green technology" prompted scientists to devise a novel approach for utilizing the environment continuously without compromising its stability. Utilizing environmentally friendly and biodegradable technology in agriculture in conjunction with the natural world as a substitute for chemical fertilizers is one way to address this issue and preserve sustainability [2]. An essential part of the lithosphere that both directly and indirectly supports life is soil. It can be divided into

***Author for Correspondence**
Ajay Singh
E-mail: ajay21singh@yahoo.com

[1]Scholar- M.Sc. Industrial Chemistry, School of Applied and Life Sciences, Uttaranchal University Dehradun, Uttarakhand, India
[2]Professor, Department of Chemistry, School of Applied and Life Sciences, Uttaranchal University Dehradun, Uttarakhand, India

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three layers: the parent layer, the subsoil layer, and the top layer. Since the top layer contains organic matter, water, air, and micro- and macro-inorganic nutrients, it promotes plant growth. To make the soil fertile, certain amounts of each component are present. Additionally, microorganisms in the soil contribute to its fertility and supply available nutrients that plants cannot directly use. Because of the presence of microbes, the top layer of the soil participates in the cycling of nutrients [3].

One essential macronutrient for plants is nitrogen. It aids in the synthesis of RNA and DNA, cytokines, chlorophyll, osmoregulation, and other processes. Nitrates, ammonium, and urea are the forms in which plants get nitrogen. Through biological nitrogen fixation, thundering, organic matter decay, and artificial fertilizer application, it enters the soil [4]. Another macronutrient that plants need in significant amounts is phosphorus. It serves a variety of purposes, including aiding in the growth of legumes and the quantity and mass of nodules; it is a component of membranes in the form of phospholipids; and it improves crop yield and quality. Nuts and fruits are also found to require phosphorus as a necessary component. Phosphates are the form of phosphorus that plants can use. Fertilizers provide phosphorus to plants. Following nitrogen and phosphorus, potassium is a macronutrient that plants need in large quantities. It performs a variety of tasks, including assisting with water uptake, root growth, turgor maintenance, stomatal and transpiration regulation, and ultimately aiding in plant growth and yield [5]. Additionally, it aids in the synthesis, aggregation, and enzyme catalysis of certain vitamins, including thiamine and riboflavin. Potassium is essential for the healthy operation of guard cells, for carrying out the processes of photosynthesis and protein synthesis, and for enhancing the quality of fruit. Additionally, potassium contributes to resistance against bacterial and fungal infections [4]. Potassium ions are taken up by plants and are added to the soil by fertilizers or organic matter that decomposes naturally [6]. Nutrients are vital for plants to have in both macro- and micro-quantities for continued growth and production.

The "Green Revolution" produced high-yielding cultivars that require ongoing nutrient supplies, irrigation water, insecticides, and pesticides. The prolonged cultivation of these cultivars in a monoculture led to soil acidification, nutrient deficiencies, and salt buildup from excessive irrigation, leaching, and contamination of the atmosphere and subterranean water. The overuse of synthetic fertilizers weakens plants' roots and makes them more vulnerable to disease [7]. An environmentally friendly solution is urgently needed to address these issues and maintain agricultural productivity. This environmentally friendly alternative is a biofertilizer that is made with helpful microorganisms. Throughout the world, one of the primary economic sectors is agriculture. An estimate of the number of workers employed in agriculture is one-third [6] to produce an increasing amount of food grains to feed the world's expanding population. The use of artificial fertilizers, irrigation, insecticides, and pesticides has been crucial to the "Green Revolution" of the past century [9]. Although food grain production has significantly improved as a result, a recession has ultimately occurred. The primary negative impact of the Green Revolution is the decrease in crop yield in developing nations as a result of unfertile soil. The primary cause of this is fertilizers, which are widely used to boost crop yield to feed the world's expanding population. Chemical fertilizers cause soil infertility, genetic diversity loss, gas emissions such as nitrous oxide, and chemical leaching, among other detrimental effects on the environment [7]. Furthermore, petrochemical discharge and heavy metal contamination from industrial effluents pose a serious threat to soil fertility. Therefore, an alternate approach to these issues is required [8]. Figure 1

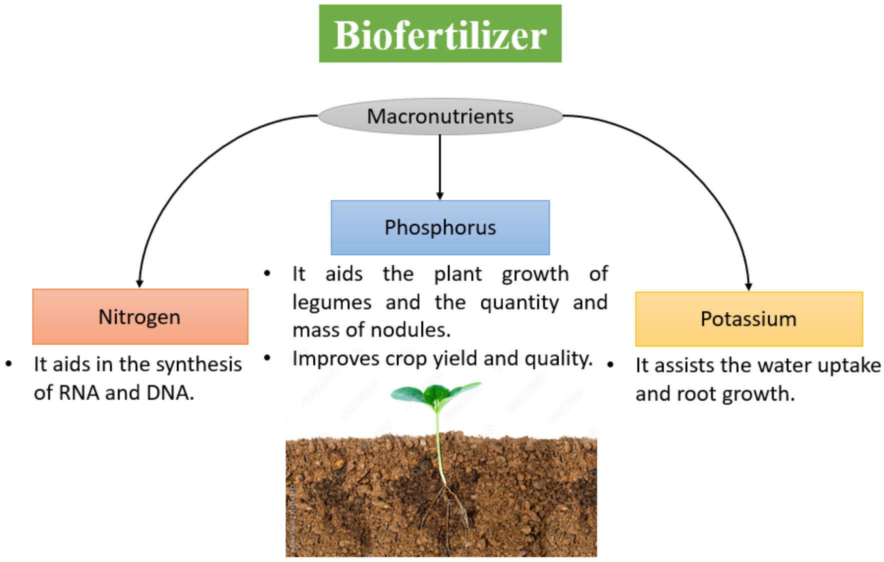

Figure 1. Process of Bio-fertiliser.

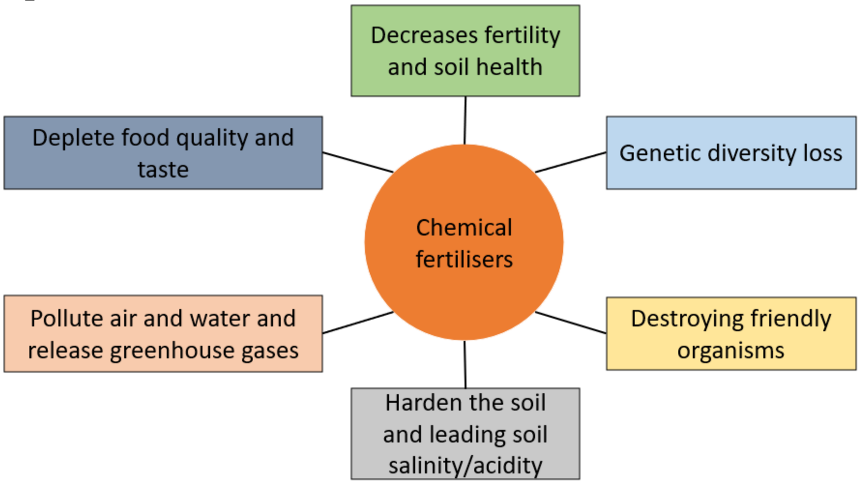

Figure 2. Disadvantages of chemical fertilizers.

Farmers were compelled by the demands of an expanding population to plant an increasing number of crops on the same plot of land each year. Farmers rely on chemical fertilizers to meet the demands of an ever-growing population, but this has led to eutrophication, acidification of the soil, barrenness of the soil, and weakening of the plant root system [7]. This has accelerated the transition from conventional farming, which is associated with stereotypes, to environmentally friendly organic agriculture, which uses soil microbes and organic fractions as biofertilizers [9,10]. These nutrient-rich biofertilizers have several benefits over chemical fertilizers, including being more affordable, safe for food, and contributing to soil biodiversity [5].figure 2

These days, a variety of microbes are employed as chemical fertilizer substitutes [2]. By fixing nitrogen, releasing plant growth regulators, solubilizing and mobilizing phosphates, zinc, and potassium, and other ways, using microbes as an alternative to chemical fertilizer improves plant growth. Additionally, biofertilizers aid plants in surviving in harsh environments [11,12]. Because of their ability to promote growth, these microorganisms are commonly referred to as plant growth-promoting bacteria (PGPB) and have been used in medicine since the 1950s. However, a few of its drawbacks, such as vitality, efficiency, adaptability, and consistency, have made it difficult for it to be used widely in the commercial sector. Numerous strategies have been used since then to enhance and get around these limitations [13].

By fixing nitrogen, solubilizing phosphate, releasing bound potassium, secreting substances that promote plant growth, producing antibiotics, and mineralizing soil's inorganic and organic matter, these microbes enrich the soil with macro- and micronutrients [3,5]. Using biofertilizer is a durable, eco-friendly substitute that increases product flavor, taste, and aroma while preventing eutrophication and maintaining soil fertility by reducing acidification [14]. It aids in the management of various plant diseases, including parasitic nematodes, Rhizoctonia- and pythium-induced root rot, and chili fusarium wilt [6]. It improves the soil's ability to retain water and aids in binding soil particles together to stop soil erosion and desertification.

DEFINITION OF BIOFERTILIZER

Microbial inoculants that promote plant growth and preserve the sustainability of the environment are known as biofertilizers [15,16]. Biologically active bacterial and fungal strains are the main components of biofertilizers; they aid in the increase, addition, conservation, and conversion of nutrients from unusable to useable forms [17]. It contributes to biodiversity by enriching the soil with beneficial bacteria and fungi. Microorganisms such as phosphate-solubilizing organisms, nitrogen-fixing organisms, symbiotically associated arbuscular mycorrhiza fungi (AMF), and decomposers of soil organic stock are examples of biofertilizers [17]. By releasing antibiotics to protect against harmful microbes and secreting substances to support plant growth and development, they increase yields [3]. Biofertilizer is the cornerstone of integrated nutrient management because it contributes to the nutrient cycle and maintains a sustainable and healthy environment.

Table 1. General differences between biofertilizer and chemical fertilizer.

Chemical fertiliser	Biofertilizer
They are traditionally used on a large scale to obtain more crop yield.	they are renewable nutritional resources mostly nitrogen-fixing microbes.
Overuse of chemical fertilizers causes pollution of soil.	They enrich the soil with nutrients.
They are in the form of chemicals.	They are free-living or symbiotic bacteria, cyanobacteria, or fungi.
They are not part of sustainable agriculture.	They are part of organic farming, better and sustainable agriculture.

TYPES OF BIOFERTILIZER

Based on common microorganisms (bacteria, fungi, and algae) that are used as microbial inoculants, biofertilizers can be categorized into several classes and microorganisms can fix the atmospheric nitrogen, solubilize insoluble phosphates and produce growth-promoting substances for plants e.g., vitamins and hormones. Nitrogen fixers, some anaerobes, such as Bacillus, Klebsiella, Rhodos pseudomonas, and some species of the anaerobic genus Clostridium, fix nitrogen under anaerobic conditions, nitrogen-fixing organisms, such as Azotobacter, clostridium, Azotococcus and Cyanobacteria, fix nitrogen under aerobic conditions and can be utilized for nitrogen-deficient soil. Legume plants have nodules in their roots where bacteria from the *Rhizobium* genus fix nitrogen from the atmosphere. *Azotobacter* is an aerobic, nonsymbiotic, free-living, photoautotrophic bacteria. They release substances such as acetic acid, gibberellins, vitamin B complex, naphthalene, and others that promote root growth and enhance plant nutrient uptake while inhibiting some root pathogens. Cyanobacteria (blue-green algae) are prokaryotic organisms and they play an important role in enriching soil by fixing atmospheric nitrogen and supplying vitamin B complex and growth-promoting substance which in turn helps the plants to grow vigorously. Phosphate solubilizing bacteria, Inorganic phosphates can be directly or indirectly solubilized by a wide range of soil microorganisms through their metabolic activity. They produce a variety of organic acids, such as lactic acid, citric acid, fumaric acid, succinic acid, and others, as well as hormones that promote plant growth. These organic acids support the soil's phosphate solubilization activity. They dissolve soil phosphate and make it available for crops. Pseudomonas fluorescens, Bacillus megatherium var. phosphaticum, Acrobacter acrogens, Nitrobacter spp., Escherichia freundii, Serratia spp., Pseudomonas striata, Bacillus polymyxa are the bacteria that have phosphate solubilizing ability. Mycorrhiza is created when certain fungi that inhabit plant roots symbiotically interact with plant roots. This indicates that the fungi are growing on the plant roots. For vegetables, flowers, trees, fodder crops, etc., there are specialized fungi. Mycorrhizas are employed as both biocides and biofertilizers. They take up nutrients from the soil and transfer them to the plant, including manganese, phosphorus, iron, sulfur, and zinc. They also exhibit greater resistance to elevated soil temperatures. It also produces plant growth-promoting substances and it also exhibits the ability to mobilize the phosphorus. Commonly mycorrhizas are of two types: Ectomycorrhiza and Endomycorrhiza. Plant growth-promoting rhizobacteria, a group of bacteria that colonize roots and are beneficial for plant growth through suppression of plant disease, improved nutrient acquisition, and phytohormone production. Species of pseudomonas and bacillus cause crops to have greater amounts of fine roots which have the effect of increasing the absorptive surface of plant roots for uptake of water and nutrients [18,19,20].

PREPARATION OF BIOFERTILIZERS

The microbes found in biofertilizers are responsible for the increased nutrient supply that results from the breakdown of organic matter, the fixation of atmospheric nitrogen, the mineralization of salts, and the solubilization of bound phosphorus. This process enhances crop plant growth and productivity [17]. In liquid form, biofertilizer is also used in conjunction with microorganisms and their nutrients to protect cells, form cysts, and enable dormant spores to withstand unfavorable environmental conditions [10]. Together with organic manures, modern biofertilizers contain microorganisms that are helpful to plants while establishing a sustainable ecosystem. Making and utilizing biofertilizers, which use the natural and inherent microbes found in plants and soil, is both economical and environmentally friendly [5]. Plants produce growth hormones such as auxin, cytokinin, gibberellic acid, and ethylene in response to the microbes present in biofertilizers. These hormones aid in both general and reproductive growth and increase plant productivity. In this context, particular attention is paid to rhizobacteria that exhibit profound plant growth-promoting (PGPR) activity [15,16]. There are three ways in which the microbes in biofertilizers contribute to plant growth and productivity: indirectly by acting as bioprotectants and suppressing plant diseases, by enhancing the fertilizer's ability to absorb nutrients, and by secreting phytohormones known as biostimulants [12]. Figure 3

Waste resulting from diverse agricultural activities is referred to as agro-waste. These include plant stalks, hulls, leaves, and vegetable matter. Agro-waste is normally produced by farming activities. Agro-waste from farming operations is frequently worthless and is disposed of. Agro-waste buildup can be hazardous to one's health, safety, environment, and aesthetics. As a result, this poses a challenge that needs to be safely resolved. Reviews of the literature indicate (Table 2) that agro-wastes contain both soluble and insoluble chemical components, such as sugar, amino acids, and organic acids, as well as insoluble components like cellulose and lignin. Fats, oil waxes, resins, pigment, protein, and minerals are additional components. The main source of organic matter in soil is agro-waste, such as decomposing plant parts. Thus, the least expensive resource available to farmers for enhancing soil fertility is agro-waste. Recently, many studies and research have been focused on developing and commercializing agro-waste-based biofertilizers [21, 22].tav

Advantages of using biofertilizer

- They are affordable and environmentally friendly. • Using them enriches the soil, and over time, the soil's quality rises.
- The results they produce over time are remarkable, even though they do not show results right away.
- These fertilizers increase the amount of phosphorous in the soil by solubilizing and releasing unavailable phosphorous. They also capture atmospheric nitrogen and provide it directly to the plants.
- Because biofertilizers release hormones that promote growth, they enhance root proliferation.

- For the benefit of the plants, microorganisms change complex nutrients into simpler ones.
- Microorganisms included in biofertilizers help the host plants receive an appropriate amount of nutrients, support healthy development, and maintain physiologic regulation.
- They contribute to a higher crop yield by 10-20%

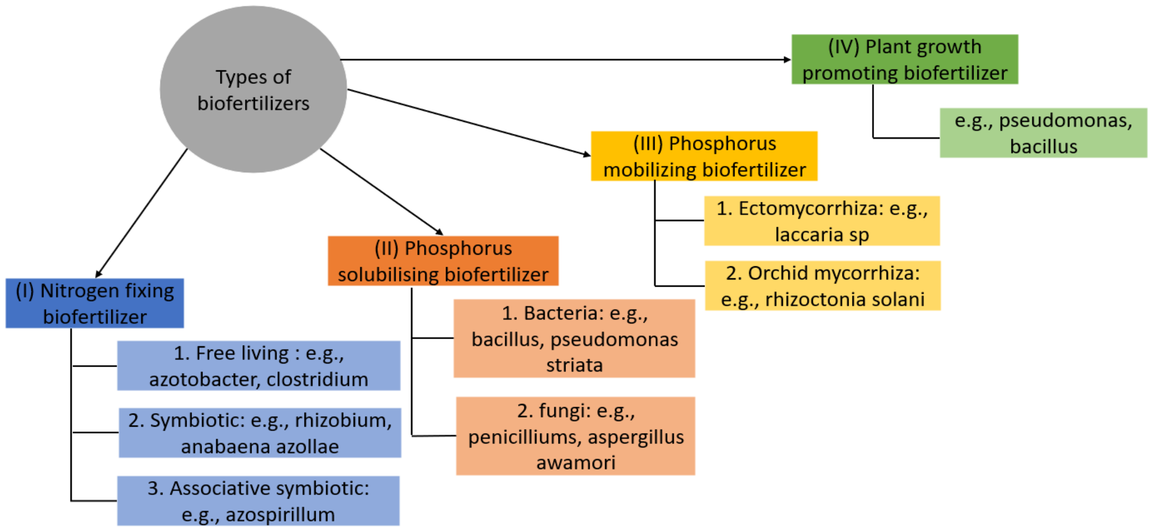

Figure 3. Types of Biofertilizers.

Table 2. Chemical composition of various agro-waste and enzymes and microorganisms found in them.

Argo-waste (substrate)	Chemical composition	Enzymes produced from waste with SSF	Microorganisms	Microorganisms for Protein production with SSF	Organic acids produced with SSF	References
Banana peels and fruit waste	Starch	Pectinase, α- and β-amylase, cellulases, fibrinolytic enzyme	Moniliella, Penicillium sp., Penicillium viridicatum, Bacillus subtilis, Bacillus haloduran	Rhizopus oryzae, Saccharomyces cerevisiae, Trichoderma reesei	Citric acid, gallic acid and succinic acid	[26,27,28]
Orange peels and pulp	Soluble sugar	β-fructofuranosidase, Pectinase	Aspergillus tamarii, Moniliella, Penicillium sp., Penicillium viridicatum, Bacillus cereus	Aspergillus niger Chaetomium sp. Trichoderma reesei	Citric acid and succinic acid	[23,29]
Pineapple waste	Soluble sugar	Laccase	Rheinheimera sp.	Aspergillus niger, Saccharomyces cerevisiae, Trichoderma viride	Acetic acid, butyric acid, citric acid, and succinic acid	[23,30]
Papaya peels	Soluble sugar	-	-	-	Acetic acid	[31,24]
Wheat and rice waste (straw and bran)	Lignocellulose	α-amylase, α-Galactosidase, glucoamylase and pectinase	Aspergillus niger, Penicillium chrysogenum, Moniliella, Penicillium sp.,	Rhizopus oryzae, Aspergillus flavus, Aspergillus ochraceus,	Citric acid, butyric acid, and succinic acid	[32,25]

			Penicillium.	Penicillium citrinum		

CONCLUSION

As key elements of organic farming, biofertilizers fix atmospheric nitrogen and mobilize fixed macro and micronutrients in the soil into forms that plants can use. This helps to maintain long-term soil fertility and sustainability. Ten million tons of plant nutrients are currently missing between crop removal and chemical fertilizer supply. Excessive reliance on chemical fertilizers is not feasible in the long run due to the cost, both in domestic resources and foreign exchange, involved in setting up fertilizer plants and maintaining the production, given the environmental impact and cost of chemical fertilizers. In this situation, farmers would have a practical choice to boost productivity per unit area by using bio-fertilizers.

Overall process of bio-fertiliser is also economical and agricultural waste along with food waste material can be used for the development of Bio-fertiliser, such developed bio-fertilisers have attracted the attention of farmers and other uses for getting green crops or vegetables. The challenge of feeding the ever-growing global population can be tackled through the use of biofertilizers. To successfully incorporate biofertilizers into modern agricultural practices, it is crucial to understand their beneficial qualities. The use of biofertilizers enriched with beneficial microorganisms significantly boosts crop yield. These potential biological fertilizers are environmentally friendly and affordable inputs for farmers, essential for soil sustainability, productivity, and environmental protection. By utilizing organic and biological fertilizers, a low-input system can help achieve farming sustainability.

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