# Potential of Biomass for Biofertilizer production: A Review

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**Abstract:** *The world's waste generation has drastically increased because of population hikes and industrialization. One of the major masses is biomass not being utilized entirely beyond landfilling and incineration of wastes. The conversion of bio-waste into bioproducts and bioenergy has been accomplished by various countries infinite ways. One of the effective ways of employing bio-waste as a source of biofertilizer production and the nutrients from waste can be utilized for growth. In ancient days of farming, many natural fertilizers are used. Because of the growing population and to meet the demand of victuals rapidly, the practice of inorganic fertilizer in the farming field become a trend. The long-term use of inorganic fertilizers causes various environmental mess and ill benefits to living beings. To conserve the soil from damage and to maintain its fertility the use of biofertilizers is a significant tradition to be followed. Organic waste has major nutrient sources like nitrogen, phosphorous, and potassium which meet the nutrient demand of plants and enhances their growth. Possible management of bio-waste and manufacturing of organic fertilizer with minor impacts on the soil is the objective to be heed for sustainable farming. The article reviewed the eminent use of biofertilizers which are produced from organic waste as the sole source and also discussed the efficient ways of bio-waste conversion to numerous bio valuable products.*

***Keywords*:** Sustainable farming, Biofertilizer, Biomass, Organic Waste, Nutrition recovery, Beneficial Soil Microorganisms.

## 1. Introduction

The expeditious growth of the human population leads to an increase in mass production of victuals resulting in high and rapid agricultural practices [1] and high utility of natural resources heads to vandalization of the eco sources. To meet the demand and for rapid results, the execution like chemical fertilizers, etc. are followed. The motive of fertilizer is to increase the nutritive value of soil and promotes plant growth [2]. In case of fulfilling the needs in a shorter time, the utilization of inorganic fertilizers becomes more custom. The benefits of inorganic fertilizers include minimal duration, efficiency, cost-effectiveness, more yield etc are some of the major intentions for high-level usage. The prolonged use of chemical fertilizers may also cause impacts like degradation of soil, an increase in the pH of the soil, groundwater contamination, suppression of microbial growth and plant growth, and algal blooms in water bodies. To reduce the pollutants caused by synthetic fertilizers and to retain or increase the naturality of the soil the alternative trend is to be wielded.

The application of various raw materials accords to organic waste which is a major hassle in the environment. The world annually generates 2.01 billion tonnes of municipal solid waste, about that 33percent of waste that are considered not safe for the environment. The waste generated per person per day in the world averages 0.74 kilograms but ranges widely, from 0.11 to 4.54 kilograms [3]. The generation of waste will be twofold in the year 2050 and threefold in the year 2100 [4]. Organic waste sources including Agro waste, fruit waste, kitchen waste, food waste, animal waste etc. are biologically processed and reused in various forms into bioproducts and bioenergy like biogas, biofertilizer, biofuel, electricity etc. To avoid these hard impacts generated by man-made fertilizers, the handling of biofertilizers became a trend in agricultural practices. The waste helps in the regeneration of nutrients for food production and also meets the organic purpose of agriculture. These fertilizers will not cause any adverse effect on the environment and resume the soil system [5].

Biofertilizers or microbial inoculants are a developing trend in agriculture that also reduces the inheritance use of inorganic fertilizer. These fertilizers can fix nitrogen and retain mineral sources like phosphorus. They can also ameliorate the growth of plants, and develop drought and salt tolerance [6]. The advantages of biofertilizers include eco-friendly, cost-effective, renewable sources readily available to plants, and supporting growth [7]. The genuine usage of biofertilizers may pave structured utility in future around all farmlands. This review details the importance and necessity of the utilization of organic waste for the efficient development of biofertilizers. The production of biofertilizers from waste like agricultural waste, municipal waste, food waste etc is explained. The advantages and limitations of inorganic fertilizers and the mechanism of the utilization of organic fertilizers are focused on. The major sources that crops needed are delineated which aid in the mass production of biofertilizers from organic waste. This review work gives cognizance to the employment of biomass in a beneficial way and the significant role of biofertilizers in the present environment.

## 2. History of Fertilizers

To study the effect of synthetic fertilizers it is necessary to know the history of fertilizers and their employment in fertile lands. Manure had been used as fertilizer far back 8000 years [8]. This was established by testing the crops which evince nitrogen in a large amount. In the 19th century, bird excrement was used as fertilizer. Later many scientists were considering various methods for better agriculture practices. One of the iconic scientists was Justus von Liebig deemed as the 'Father of fertilizer' detailed about the major nutrients like nitrogen, phosphorus and potassium and also underpinned the modern fertilizers supported for plant growth. In the year 1842, Sir John Lawes, a pioneer unlocked his fertilizer factory and may a way of producing and patenting synthetic fertilizer using phosphate rock and sulfuric acid. The 20th century was developed with various analytical methods for soil along with synthetic fertilizers [9].

## 3. Necessity of Fertilizer

Once the crops are harvested the soil loses its wealthy elements. In the case of further cultivation, the soil is enriched by using fertilizers. Plants majorly need 17 essential nutrients for their growth. About 14 of the nutrients provided by the soil rest were obtained from the atmosphere and water. The key nutrient is Nitrogen which builds up the protein in living cells. The second most nutrient is phosphorous involves energy storage. Potassium, a third compound supports yield and resists the plants from disease. These nutrients enrich the soil which helps in the development of crops and feeds living beings. The International Fertilizer Association (IFA) evaluated that globally 85% of the soils are lacking nitrogen. 73% of the soils are deficient in phosphorus, whereas 55% are shortfalls in potassium [10]. Fertilizers are generally categorized into three types **Figure 1**. Mineral and Organic fertilizers are commonly used in cultivation whereas industrial fertilizers are modern development that was developed by chemical and their reaction.


**Figure 1. Classification of Fertilizers**

## 4. Vital Supplements for Plant Growth

The major nutrients include nitrogen, phosphorous and potassium. Other than these major nutrients micronutrients include calcium, magnesium, sulfur, iron, zinc, and manganese. These nutrients obtainable from the soil are diminished after crop rotation. Hence various sources of nutrients in the form of fertilizer are provided.

## 4.1 Nitrogen (N)

The Availability of nitrogen in the soil is found to be in three forms: i) Organic nitrogen elements ii) Ammonium ions iii) Nitrate ions. About 95 to 99 % of organic nitrogen is in the forms of plants, animal leftovers, bacteria and organic matters majorly found in the soil. In the presence of microorganisms, organic nitrogen can be transformed and made available for plants. Some of the nitrogen readily support the growth in the form of soluble urea [11]. The sources of nitrogen for plants include minerals and atmospheric nitrogen. The nitrogen-containing minerals support only a small amount of nutrients for growth. Atmospheric nitrogen is not directly utilized by plants but through the nitrogen cycle plants utilize them. The symbiotic bacteria called *Rhizobium* live in the nodules of leguminous plants. They fix the atmospheric nitrogen in plants and help in their growth. Many microorganisms like *Bradyrhizobium, Azorhizobium* etc biologically fix the nitrogen source or convert the sources into accessible for plants. The plants acquire dark green due to the existence of nitrogen. Nitrogen is the major nutrient component in amino acid building and genetic material synthesis. It is the foremost compound in chlorophyll that helps in the energy synthesizing process. Deficiency in nitrogen leads to a condition called general starvation like improper growth and pale-coloured leaves **Figure 2**.

## 4.2 Phosphorous (P)

In soil, the amount of total phosphorous is around 0.6%. Based on the pH of the soil the plants absorb phosphorous in the form of orthophosphate ions. Phosphorous in the soil is generally classified as organic and inorganic phosphorus. The sources of organic phosphorus include manures, microbial tissues and plant residues. Inorganic phosphorous are apatite, iron phosphate and aluminium phosphate [11]. Soil phosphorous is classified as primary and secondary minerals. Apatite like a primary mineral is stable and resistant to weathering. Calcium and iron-like secondary minerals are released gradually. The soluble form of phosphate combines with clay and other phosphate forms which results in a less available phosphate fixation process. Due to the fixation process, the plants initially absorb a very low amount of phosphates and unabsorbed remains in the soil. The insoluble form of phosphates is solubilized by organisms like *Pseudomonas, Bacillus, Rhizobium, Penicillium* etc. which can be used by plants for nutrient uptake. Mineralization by microbes is also carried out for nutrient availability. Soils under high rainfall and high temperature will have a high fixing capacity of phosphorous. This soil also contains a high amount of oxides which highly influence the fixation of phosphorous. The nutrient is essential for the enhancement of root, stem, stalk, fruit and seeds. It is a key nutrient in storing and converting sunlight to ATP molecules and is also present in genetic material. It helps in the fixation of nitrogen, especially in leguminous plants. Phosphorous enhances the early root development, seed development and winter hardiness in plants [12]. The deficiency in phosphorous leads to discolouration of leaves to purplish is observed. Deficiency factors include cold climate, pH change, dry soil, and poor soil health. Because of the accumulation of sugars that assist the production of anthocyanin pigment discolouration occurs **Figure 2**.

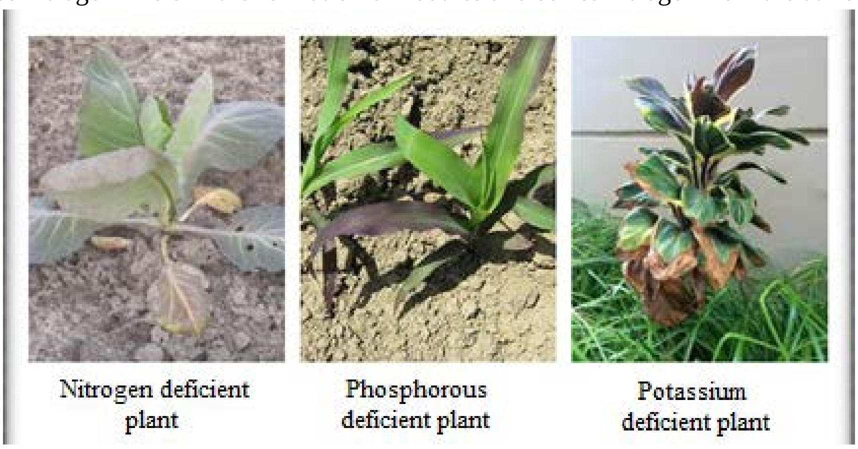


**Figure 2. Major Nutrient Deficiency in Plants**

## 4.3 Potassium (K)

The potassium in the soil appears in the form of inorganic minerals which cannot be readily treated using chemicals. Four forms of potassium are seen: i) Potassium in mineral form ii) Potassium in non-exchangeable form iii) Potassium in an exchangeable form on colloid surface iv) Soluble Potassium ions [13]. They slowly release the component into the soil and firmly fixed to the clay layers. Some plants gain their nutrient with help of soil microorganisms. These organisms create an acid environment and attract potassium directly from rock particles. In soil, potassium is present in cationic form and cycle attached with ion exchange and mineral weathering. Potassium produces enzymes that regulate the synthesis of proteins and starch and also help in translocation. The nutrient enhances the root, stem and leaves and acts as disease resistant. It strengthens cell walls and acts as a catalyst for iron uptake. Deficiency of potassium cause yellow scorching, or chlorosis in the leaf margin. In severe conditions, the leaf completely fell resulting in premature defoliation **Figure 2**.

## 4.4 Secondary Nutrients for Plant Growth

Calcium is the secondary nutrient available in the form of rocks, minerals etc. They are found in insoluble form until weathering or soil microorganisms convert into soluble forms. Calcium is absorbed into the soil as exchangeable ions. Major effects of calcium include acting as a bonding agent in soil and acting as a nutrient filler. The availability of calcium varies based on the pH [14]. Calcium helps nitrogen fixers in the formation of nodules and seizes nitrogen from the atmosphere for fixation. It transports nutrients inside the plants and produces growth-regulating enzymes. Contributes majorly to cell wall formation and neutralizes toxic substances in the plants. In acid and sandy soil, the nutrient is leached due to water. Deficiency symptoms include spotting on leaves, diminutive growth, necrotic leaf margins, and death of the end part of the bud and roots.

Magnesium is present in the earth's crust as minerals. Due to the weathering process, the minerals become available to plants. Based on the pH of the soil the nutrient is utilized by the plants. Magnesium helps in the uptake of phosphorous in plants and vice versa [11]. The major component in chlorophyll is magnesium helps in photosynthesis. This nutrient produces various growth enzymes, supports respiration and is essential for phosphorous metabolism. The deficiency symptoms in plants are interveinal chlorosis, reddish to purple spots seen on leaves, curvy and thin leaves, and loss of chlorophyll leads to inhibition of growth.

Sulfur prevails in the form of elemental sulfates, mineral sulfates and sulphide gas [15]. These organic sulfur are oxidized or mineralized by soil microbes to an inorganic form were plants can utilize. The inorganic form is uptaken up by plants and utilized for vitamins and protein. It is significant in photosynthesis and hardiness in winter. Symptoms of deficiency include discolouration in plants, and reduced growth, especially in buds, branches, and pigmented young leaves.

### 4.5 Micronutrients

- Boron (B) is found in an anionic form in the soil. They support cells structurally and functionally. The deficiency is majorly seen in grown plants.
- Copper (Cu) activates various enzymes and enhances protein and vitamin production.
- Plants take up Iron (Fe) in the form of cation and support nitrogen fixation, lignin formation and energy transfer.
- Manganese (Mn) plays an important function in the photosynthesis, germination and maturation of plants.
- Plants utilize Zinc (Zn) in the form of cation and limiting sources in the soil.
- Molybdenum (Mo) major component in the production of enzyme nitrate reductase found in legume plants [11].

## 5. The Genesis Of Synthetic Fertilizers

If the naturally available nutrients are not utilized by the plants or in insufficient quantity synthetic fertilizers are used as an alternative approach in the agriculture field. Chemical fertilizers are produced from non-renewable sources and the resulted products are mixed with water and used. The atmospheric nitrogen is abundant and not readily utilized whereas soil contains a limited amount of sources which can be utilized by the plants. The atmospheric nitrogen for utilization is either directly fixed by the soil microorganisms or by a lightning strike. Synthetically Nitrogen fertilizers are produced by the Haber-Bosch method which combines nitrogen and hydrogen from the atmosphere under high temperature and pressure. The end product was obtained to be anhydrous ammonia ($NH_3$) [16]. Hygroscopic Ammonium nitrate is widely used as fertilizer and coated with clay particles. Urea, ammonium sulphates, sodium nitrate, and calcium nitrate are other varied nitrogen sources widely used. The use of fertilizer enhances the organic acid level and reduces the level of starch in plants [17]. It causes changes in the phenology of root and shoot ratio [18].

Synthetic Phosphate fertilizers are produced from rock phosphate in combination with phosphoric acid resulting in triple superphosphate. Diammonium phosphate is widely used as fertilizer in farmlands. Other derivatives like calcium dihydrogen phosphate, Ammonium phosphate, and Ammonium hydrogen phosphate are also used in farmlands. A very small amount of phosphate source is utilized by the plants whereas the remaining phosphates are bound to the soil. The bounded nutrients are lost because of crop rotations, leaching and other processes.

Potassium fertilizers are in both liquid form and solid form as granules. Potassium is commercially produced as muriate of potash and sulphate of potash. Potassium sulfate is extracted from mineral langbeinite or potassium chloride along with sulphuric acid at high temperatures and magnesium salts are added [16].

## 6. Hazards of Synthetic Fertilizers

Synthetic fertilizers are commonly produced from non-renewable sources which exhaust in consecutive years. These fertilizers can interpret the nutrition content of plants and may diminish them [19]. Minor nutrients like vitamins and minerals are not completely present and also available in the diminished stage. The soil becomes acidic because of fertilizer's acidic tendency. Many fertilizers consist of potent elements cadmium, lead, arsenic, nickel etc which are considered carcinogenic metals. In common, fertilizers contaminate the water bodies and reduce the content of beneficial microorganisms in the soil. It also contaminates the underground water which leads to underutilization. Ammonium nitrate easily reacts with metals, acids, alkalines etc. while decomposing. The fumes from decomposition are toxic and cause ill effects to live beings. Excess nitrogen contributes to the release of greenhouse gases like carbon dioxide, and nitrous oxide into the atmosphere. The potassium fertilizer showed radioactivity around the mining lands [20]. Rock phosphate contains cadmium compound which contaminates the soil and water bodies found hazardous to human health. Excess amounts of potassium fertilizer produce toxic substances in soil and air leading to damage to plants. It breaks down the available organic sources from the soil. Generally, synthetic fertilizers will not support the growth of microorganisms. Microorganisms play a major role in the nutrient release and organic compound production. The application of synthetic materials will diminish the natural enriching processes. One of the major disadvantages is eutrophication. The accumulation of nutrients in water bodies tends to increase algal growth and aquatic plant growth. In recent decades the eutrophication process increased because of humans and their actions.

## 7. Biofertilizers

Biofertilizers are living or dormant cell inoculants which are efficient in nutrient fixation for the growth of crops [21]. Organic farming ensures food safety and enriches the biodiversity of soil [22]. The major and significant merit includes a prolonged shelf life that leads to no adverse effect on the ecosystem [23]. Organic fertilizers enrich the soil by carrying out various biogeochemical cycles like nitrogen, phosphorous etc. Because of the microbial inoculants, many growth-regulating substances are released to maintain the micro and macronutrients through the degradation process [24]. About 60 to 90% of applied fertilizer is lost and the remaining 10 to 40% is utilized by the plants. Hence the biofertilizers manage the nutrients, yield and healthy environment [25]. Initially, organisms like *Rhizobium, Azatobacter, Azospirillum and Blue-green Algae* have used as biofertilizers.

### 7.1 History of Biofertilizer

Through compost production, the application of biofertilizers is developed into commercial use. Nitragin is the pioneer biofertilizer produced by Nobbe and Hilther in 1895 and followed the discovery of *Azotobacte*r and *Blue-green Algae* used in biofertilizers [26]. In the late 1940s, industrial-scale production of microbial inoculants was started in Malaysia. Late 1950 *Arbuscular fungi* inoculants were used because of the effective uptake of phosphorous sources. In the late 1970 use of *Bradyrhizobium* for legumes are produced. The liquid form of fertilizer was first introduced in the year 1991 by Dr Teuro Higa. Generally, Biofertilizers are produced with a carrier consisting of effectual microorganisms [6]. The milestones in the biofertilizer history are shown in **Figure 3**.

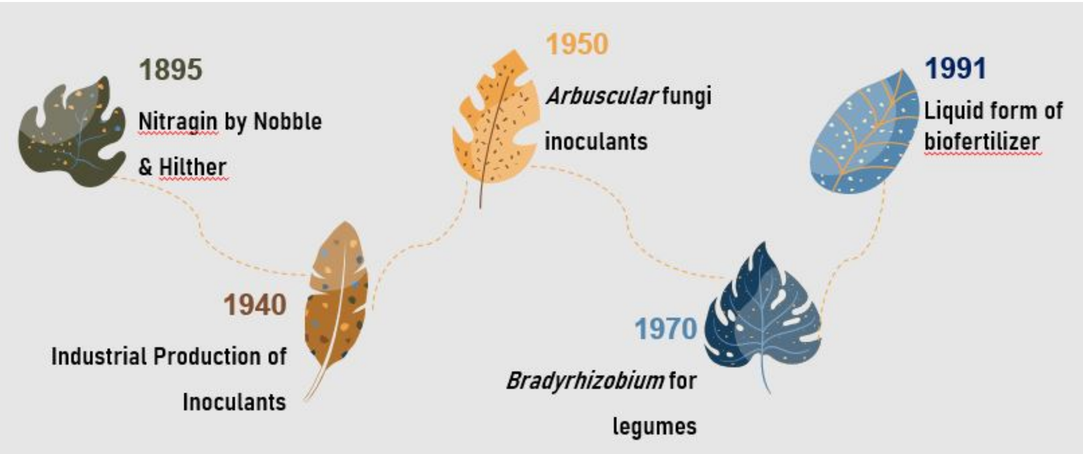


**Figure 3 Highlights of the Production of Biofertilizer**

### 7.2 Criteria for Biofertilizer Production

Growth characteristics, type of organism, formulation and conditions of inoculants need to be considered during biofertilizer production. The major steps in large-scale production to be considered like choosing active organisms, isolation and selection of particular microbes, the proliferation method selection, carriers, and phenotypes to be considered [27]. Based on the need and purpose the organism used for biofertilizer production should be actively selected. The isolated organisms are grown before in Petri dishes than in mass production. Optimum parameters enhance the multiplication of a particular organism and are finalized after phenotype testing. At different environmental characteristics, large-scale fertilizers are analysed and production is carried out. The carriers lug a sufficient quantity of microorganisms and keep them in viable condition. The carriers should be easy to sterilize and should not be a hazard to the microorganism. The remarkable characteristics like water holding capacity, adhesion to plant materials, and cost-effectiveness are analysed before the selection of carriers. The fertilizers are applied by the seed inoculation method and soil inoculation method. For seed inoculation, the carrier should be in powder form and firmly attached to the seed surface and carriers like gum Arabic, sucrose, and vegetable oil is used. For the soil inoculation method, the granular type carriers are used alongside seeds. The materials like peat soil, charcoal, lignite, coal, vermiculate, polyacrylamide etc are used. The carrier material is subjected to mining, drying, milling, neutralization, and sterilization for the production of biofertilizers. Liquid fertilizers consist of dormant organisms which become active after being applied to the soil.

## 8. Benefits of Soil Microbiome

Soil microorganisms generate various nutrients by decaying organic matter. The organisms utilize carbon and other nutrients for their survival and release surplus nutrients into the soil. These nutrients are utilized by plants for their growth. The symbiotic bacteria fix nitrogen in legume plants from the atmosphere. Arbuscular mycorrhizal fungi help in the uptake of the phosphorous source from the soil to plants. About 80% of plants have a symbiotic association with soil microbes. Many microorganisms degrade the pesticides and release various effective nutrients which enhance soil fertility. The soil food web supports the reduction of plant pathogens [28]. Based on the nature of soil microbes in soil fertility, biofertilizers are been produced.

## 9. Production of Biofertilizers

The efficient strain is selected and grown along with seed or soil. The starter culture is added with a carrier for the preparation of bio-inoculant. For large-scale production, culture fermenters are used. The production steps include strain selection, seed pelleting, inoculant carriers, packaging, storage and inoculation into the field. The inoculants are coated on seeds either by direct coating using gum arable or sugary syrup or slurry method. Then calcium chloride is after seed coating. In the case of *Rhizobia,* the soil is inoculated with seed pellets for enhanced effectiveness. The inoculants are the starter culture and carrier material used in the field. Peat is the most widely used carrier used in bioinoculant preparation. The standard scale of 40-60% of moisture content is maintained in the final product. The final package is properly labelled with appropriate details and certified by the Bureau of Indian Standards (BIS) [29]. The biofertilizer is applied either by seed inoculation method or by soil inoculation method. The selection of microorganisms is based on the beneficial and symbiotic relationship with the plants. The organisms beneficial to plant growth are known as plant growth-promoting bacteria which are used are tabulated in **Table 1**. The production technologies used are anaerobic digestion, aerobic composting, chemical hydrolysis, the solid-state fermentation, and In situ degradation of waste, residues are employed [30].

**Table 1 Biofertilizer groups based on their nature and function**

| Nature of fertilizer | Example |
|---|---|
| Nitrogen (N2) fixing Biofertilizers | |
| Free-living nitrogen-fixing | *Azatobacter*, *Anabaena*, *Beijerinkia*, *Clostridium*, *Klebsiella* and *Nostoc* |
| Symbiotic nitrogen-fixing | *Rhizobium*, *Anabaena sp*, *Azospirillum*, and *Frankia.* |
| Associative symbiotic | *Azospirilum* |

| | |
|---|---|
| **Phosphate solubilizing Biofertilizers** | |
| Phosphate solubilizing Bacteria | *Bacillus megaterium, Bacillus subtilis, Pseudomonas striata, Penicillium sp.*, and *Aspergillus sp.* |
| Phosphate solubilizing Fungi | *Arbuscular mycorrhiza - Glomus sp., Acaulospora sp., Scutellospora sp.*, and *Sclerocystis sp.* |
| **Phosphate Mobilizing Biofertilizers** | |
| Phosphate mobilizing Fungi | *Glomus sp, Gigaspora sp, Acaulospora sp. Scutellospora sp. & Sclerocystis sp.* |
| Ectomycorrhiza | *Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.* |
| Orchid mycorrhiza | *Rhizoctonia solani* |
| **Biofertilizers for Micronutrients** | |
| Silicate and zinc solubilizers Biofertilizers for micronutrients | *Bacillus sp.* |
| **Potassium Biofertilizers** | |
| Potassium solubilizers | *Bacillus mucilaginous* |
| **Plant growth-promoting Biofertilizer** | |
| Plant-growth-promoting Rhizobacteria | *Pseudomonas fluroscence* |

Plant growth-promoting bacteria are used as biofertilizers which are accompanied by biodegradable substances applied to the plants and the soil surface. These fertilizers colonize the plant through the rhizosphere and intracellular spaces which enhance the growth and yield [6]. The direct mechanism of Plant growth-promoting Rhizobia biofertilizers includes the production of plant hormones (*Auxins, Cytokinins, Gibberellins, Ethylene, or Abscisic acid*), Nitrogen fixation, Phosphate solubilization, Sequestering iron and indirect mechanism includes antibiotic and lytic enzyme production, Hydrogen Cyanide production, competition, Induced resistance are seen [31]. Biofertilizers act as a cohesive nutrient management system which has a very low impact on the environment [32]. Fungi are also used as biofertilizers because of their mycorrhizal association. According to the report from Teff rhizosphere soil, the phosphate solubilizing fungi include *Trichosporon beigelii, Rhodotorula aurantiaca A, Kluyveromyces walti, Saccharomycopsis schoenii Cryptococcus luteolus, Zygoascus hellenicus, Penicillium purpurogenum var. rubrisclerotium, Neosartorya fisheri var. fischeri*, and *Candida Montana* posses the property of phosphorous solubilizing [33]. Yeast has been used as a biofertilizer because of their safety and biological properties. Brewer's yeast is also widely used as a biofertilizer because it enhances the nitrogen and phosphorous availability to roots and shoots of tomato and sugarcane plants [34].

Cyanobacteria (Blue-green algae) are used as biofertilizers which fix nitrogen from the atmosphere. They also produce other compounds like growth-regulating hormones, vitamins and many bioactive components, organic acids etc. They also increase water-retaining capacity, tolerance to pesticides, and soil fertility [35].

## 10. Biomass for Fertilizer Production

Most of the landfilled biomass is incinerated without recognizing the valuable nutrients present in it. Globally municipal solid waste generation is about 1.3 billion Mg/ year. It will be expected to be doubled in the next few years [36]. Waste management paves way for the recovery of nutrients and manufacturing of new chemicals. Many of the biomass is being utilized as raw materials for the production of various sources like bioactive compounds, vitamins, proteins etc. The fertilizer production can be done in various methods like composting, vermicomposting, anaerobic digestion, thermal methods etc. Either the biomass nutrients are recovered and directly applied on farmlands or the nutrients are utilized for the enhancement of plant growth-promoting bacteria.

### 10.1 Agriculture Waste

During agriculture production, the waste generated is termed agricultural waste including forest residues, plant waste and animal manures etc. This waste contains lignocellulose components including cellulose, hemicellulose, and lignin. In older days wood ash is used as an alkali fertilizer which is commonly used in acidic soils [37]. Wood ash contains nitrogen and phosphorous source and cost-effective than other fertilizers for crop growth. The utilized biowaste is enriched with micronutrients like copper, and zinc to produce a fertilizer which enriches soil fertility [38]. About 60-80% of animal manure is widely spread in the environment without any utilization and the rest were used in fertilizer production [39]. It is the source of various micro and macronutrients, beneficial microorganisms and so on used for fertility. Poultry litter are most generated waste which is processed by biological and thermal methods.

### 10.2 Food Waste

Yearly 1.3 billion Mg of food waste is dumped into the environment [1]. This waste includes household and restaurant waste, spent coffee crops cultivation residues like husk, bran, beets etc. and consists of various nutrient sources like starch, cellulose, proteins, lipids, lignin moisture etc [40]. Food waste fertilizers are majorly produced by anaerobic digestion, aerobic composting, thermal process, reverse osmosis, chemical hydrolysis etc. Animal waste like skin, bones, fat etc is used in fertilizer and wastewater treatment. Fish waste has nutrients like nitrogen, phosphorous, and calcium used as an alternative source for inorganic fertilizer [41]. Food waste greatly supports the manufacturing of biobased products and is of significant importance. In much recent research, liquid biofertilizers are produced using a variety of fruits as a nutrient source for the growth of plant growth-promoting bacteria.

### 10.3 Sewage Sludge

After the removal of toxic substances, the sludge can be used as a nutrient source for agriculture. Sludge can be treated by biological, chemical and thermal methods and used for valuable product production. A major drawback in the usage of sludge is the presence of toxic metals and pathogenic microorganisms which can be removed by thermal processing. Household waste and kitchen waste consist of degradable and non-degradable materials. These wastes are generally classified as solid waste, semi-solid waste, and liquid waste. Along with other waste, this waste can be processed for valorisation. The waste should be categorized and processed with various techniques. In the generation of new fertilizers, it should be concerned with the maintenance of nutrients, crop fertility and soil fertility. The dosage, optimal conditions for usage etc need to be formulated. In the case of large-scale production, the fertilizer industries should not meet any practical issues and pollute the environment through the byproducts. These are the considerations that have to remain during the regulation of new biofertilizers.

## 11. Benefits of Biofertilizer Employment

Biofertilizers help in the solubilisation and utilization of various nutrients in the plants. The atmospheric nitrogen is utilized directly for plant growth. The organisms potentially reduce the emission of greenhouse gases and help efficiently in climate change [42]. It increases the physicochemical properties like structure, texture, pH, humus, and fertility of the soil. The soil is enriched with beneficial microorganisms and produces hormones, auxins, vitamins and other growth-promoting substances for crop growth. In some cases, the beneficial organisms and their products act as natural pesticides and inhibit the growth of pathogens in the soil. The growth rate of plants is found to be certain high during the employment of biofertilizers. The use of biofertilizers is low cost-efficient, eco-friendly, and does not create pollution to the environment.

## 12. Conclusion

The environmental impacts of the use of inorganic fertilizers created alternative practices for sustainable agriculture. Biofertilizers are microbial inoculants which naturally maintain soil fertility by producing various nutrient sources for the development of the crop and are economically more valuable than other fertilizers. The major nutrient sources like nitrogen, phosphorous, and potassium are produced by non-renewable sources. But biofertilizers are produced from renewable sources, especially biomass. Biomass consists of various valuable sources which are not completely identified and are being incinerated for disposal. The nutritive sources are examined and cost-effective fertilizers are generated and also used as a nutritive growth medium for the plant growth-promoting bacteria and other beneficial organisms. The major advantage is it enriches the soil and crops and reduces the effects caused while using inorganic fertilizers. Biomass management by analyzing the nutrient source is a significant factor in the commercial production of biofertilizers.

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