S.S. Sandhu
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BIOFERTILIZER TECHNOLOGY

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CONTENTS

CHAPTER 1

ANALYSIS OF THE BIOFERTILIZER TECHNOLOGY: A REVIEW STUDY

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ABSTRACT:

Biofertilizer technology is a sustainable and environmentally friendly method of increasing soil fertility and crop output. This study delves into the ideas, kinds, application techniques, and function of biofertilizer technology in encouraging sustainable agriculture. This study intends to give insights into the relevance and potential of biofertilizer technology in contemporary agriculture via a thorough evaluation of scientific papers and research results. Biofertilizers, a subset of biological products, play an important role in increasing soil fertility and crop output. They use the power of helpful microorganisms like nitrogen-fixing bacteria and mycorrhizal fungus to boost plant nutrition availability. Nitrogen-fixing, phosphate-solubilizing, and plant growth-promoting rhizobacteria are examples of biofertilizers that provide diverse solutions for a variety of crop demands and soil conditions. Methods of administration like as seed inoculation, soil application, and foliar spray provide for more flexibility in incorporating biofertilizers into agricultural techniques.

KEYWORDS:

Agriculture, Biofertilizer, Crop Productivity, Sustainable Farming, Soil Fertility, Technology.

INTRODUCTION

Humanity's many achievements, we owe our existence to six inches of top soil and the fact that it rains. Sustainable agriculture is defined as the efficient production of safe, high-quality agricultural products. goods in a manner that preserves and enhances the natural environment, as well as the social and economic environment preserves the health and safety of farmers, their workers, and local communities The well-being of all farmed species. It is critical for a sustainable agricultural system to employ renewable inputs herbicides, water, and so forth that benefit the plant while causing no or little environmental impact Reduced usage of chemical fertilizers and pesticides is one option. Fertilizers made from chemicals. are being utilized in greater quantities to boost crop production in high producing types of agricultural plants. Chemical fertilizers are industrially engineered compounds that include known amounts of nitrogen, phosphorous, and potassium, and their usage pollutes the air and groundwater by eutrophicating water bodies [1], [2].

Chemical fertilizers, on the other hand, pollute water bodies and groundwater in addition to being stored in agricultural plants. Modern agriculture is growing more reliant on a regular supply of synthetic inputs, mostly chemical fertilizers, which are fossil fuel (coal+ petroleum) products. The excessive and unbalanced usage of these synthetic inputs is causing adverse impacts. The soils are now biologically dead. As a result of this predicament, innocuous inputs such as biofertilizers and biopesticides have been identified. Environmentalists all around the globe are urging the market and society to shift to organic farming and biofertilizers. Organic farming strives to be a more ecologically sustainable kind of agricultural production by integrating best environmental practices and stressing biodiversity conservation and natural resource preservation. It also stresses high animal welfare standards, as well as the avoidance of synthetic chemical inputs like fertilizers and pesticides, as well as genetically modified organisms (GMOs) [3], [4].

Organic farming is one such method that not only assures food safety but also contributes to soil biodiversity. Organic farming is the cultivation of unpolluted crops using manures, biofertilizers, and biopesticides to supply op The term "fertilizer" refers to a "fertilizing material or carrier" that contains one or more of the essential element's nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, chlorine, sodium, cobalt, vanadium, and silicon. As a result, fertilizers are employed to increase the fertility of the ground.

The word "biofertiliser" has been defined in several ways during the last 20 years, owing to a better knowledge of the interactions that occur between rhizosphere microorganisms and plants. When applied to soils, seeds, or plant surfaces, biofertilizers are described as "substances containing living microorganisms that colonize the rhizosphere or the interior of the plants and promote growth by increasing the supply or availability of primary nutrients to the target crops. Vessey defines biofertiliser as a substance containing living microorganisms that, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant". Biofertilizer was described in 2005 as "a product containing living microorganisms that exert direct or indirect beneficial effects on plant growth and crop yield via various mechanisms." As microorganisms were utilized to combat plant diseases, the term was expanded. However, microorganisms that stimulate plant development by controlling dangerous organisms, such as biofungicides, bionematocides, bioinsecticides, or any other product with comparable action that benefits plant health, are classified as biopesticides rather than biofertilizers [5], [6].

Biofertilizers may convert nutritionally significant components from non-usable to usable form. These microbes need organic matter to develop and function in soil, and they supply important nutrients to plants. Biofertilizer microorganisms replenish the soil's natural nutrient cycle and increase soil organic matter. Healthy plants may be cultivated while improving soil sustainability and health with the application of biofertilizers. Thus, the word biofertilizer refers to a product that contains carrier-based live microorganisms that are agriculturally helpful in terms of nitrogen fixation, phosphorus solubilization, or nutrient mobilization, in order to boost soil and/or crop yield. Although biofertilizers for nitrogen and phosphorus are already available, attempts are being made to develop organisms that can solubilize or mobilize additional minerals or nutrients. K-biofertilizers and Zn-biofertilizers have also recently been created, however these products have yet to be marketed.

Biofertilizers are live or biologically active products or microbial inoculants of bacteria, algae, and fungus (individually or in combination) that may enrich soil with nitrogen, phosphorus, organic matter, and so on. Biofertilizers are a substance that improves soil nutrient quality by using microorganisms that form symbiotic interactions with plants. Biofetilizers are low-cost renewable plant nutrition sources that augment chemical fertilizers. Plant nutrients such as nitrogen and phosphorus are generated by biofertilizers via their activities in the soil or rhizosphere and made accessible to plants on the soil. The use of biofertilizers is becoming more popular due to the need of maintaining soil health, reducing environmental pollution, and reducing chemical consumption. Biofertilizers are an essential component of integrated nutrient management because they provide a low-cost, renewable source of plant nutrients that may augment or replace chemical fertilizers in sustainable agriculture. When administered via seed or soil, they are preparations containing live cells or latent cells of effective strains of microorganisms that aid in nutrient absorption in agricultural plants through interactions in the rhizosphere. They speed up some microbial activities in the soil, increasing the availability of nutrients in a form that plants can readily absorb timal nutrients to crop plants while controlling pests and diseases [7], [8].

DISCUSSION

A "fertilizer" is a "fertilizing material or carrier" containing one or more of the necessary elements like nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, chlorine, sodium, cobalt, vanadium, and silicon. As a consequence, fertilizers are used to improve the fertility of the soil. Due to a greater understanding of the interactions that occur between rhizosphere microorganisms and plants during the past 20 years, the term "biofertiliser" has been defined in a variety of ways. Biofertilizers, which are applied to soils, seeds, or plant surfaces, are defined as "substances containing living microorganisms that colonize the rhizosphere or the interior of the plants and promote growth by increasing the supply or availability of primary nutrients to the target crops." Biofertilizer, according to Vessey, is "a substance containing living microorganisms that, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant." In 2005, the term "biofertilizer" was defined as "a product containing living microorganisms that exert direct or indirect beneficial effects on plant growth and crop yield via various mechanisms." The word was broadened when microorganisms were used to address plant ailments. Microorganisms that promote plant growth by controlling harmful organisms, such as biofungicides, bionematocides, bioinsecticides, or any other product with a similar effect that enhances plant health, are categorized as biopesticides rather than biofertilizers.

Biofertilizers have the ability to transform nutritionally important components from non-usable to usable form. These microorganisms need organic matter to grow and operate in soil, and they provide essential nutrients to plants. Microorganisms in biofertilizers renew the soil's natural nutrition cycle and enhance soil organic matter. With the use of biofertilizers, healthy plants may be grown while also enhancing soil sustainability and health. Thus, a biofertilizer is a product that comprises carrier-based (solid or liquid) living microorganisms that are agriculturally beneficial in terms of nitrogen fixation, phosphorus solubilization, or nutrient mobilization in order to increase soil and/or crop output. Although nitrogen and phosphorus biofertilizers are currently available, efforts are being undertaken to produce organisms that can solubilize or mobilize other minerals or nutrients. K-biofertilizers and Zn-biofertilizers have also recently been developed, however they have yet to be commercialized.

Biofertilizers are living or biologically active products or microbial inoculants of bacteria, algae, and fungi (individually or in combination) that may enrich soil with nitrogen, phosphorus, organic matter, and other nutrients. Biofertilizers are substances that increase soil nutrient quality by using microorganisms that interact symbiotically with plants. Biofertilizers are low-cost renewable sources of plant nourishment that supplement artificial fertilizers. Plant nutrients such as nitrogen and phosphorus are produced by biofertilizers via their activities in the soil or rhizosphere and made available to plants growing in the soil. Because of the need to preserve soil health, reduce environmental contamination, and reduce chemical use, the use of biofertilizers is becoming increasingly widespread. Biofertilizers are an important part of integrated nutrient management because they provide a low-cost, renewable source of plant nutrients that may supplement or replace chemical fertilizers in sustainable agriculture. They are preparations comprising live cells or latent cells of efficient strains of microorganisms that help in nutrient absorption in agricultural plants via interactions in the rhizosphere when delivered by seed or soil. They increase the availability of nutrients in a form that plants can easily absorb by speeding up certain microbial processes in the soil. Scientists can make plants generate pesticide chemicals that target and kill certain pests by putting genetic material into plants. In certain situations, combining a gene with a specific Bt protein might result in the production of these plant-incorporated protectants, or plant pesticides [9], [10].

The use of biopesticides has the potential to provide significant advantages to agricultural and public health programs. The following are the benefits linked with biopesticides that have sparked interest in them:

1) They are less toxic and inherently less harmful, resulting in a lower environmental load.
2) They are designed to affect only one specific pest or, in some cases, a few target organisms.
3) They are often effective in very small quantities and often decompose quickly, resulting in lower exposures and largely avoiding pollution problems.
4) Biopesticides may make a significant contribution to Integrated Pest Management (IPM) programs.
5) They are less hazardous to people and the environment.

However, in order to employ biological insecticides effectively, you must first have a thorough understanding of pest control.A microbial green revolution has been developing in recent years. Biofertilizers offer benefits over chemical fertilizers in terms of both cost and environmental friendliness. With rising agricultural demand, it is critical for scientists and society to boost agricultural output via the use of different fertilizers, insecticides, and pesticides. However, due to the extensive usage of these chemicals, the soil has suffered as a result of the loss of important minerals. As a result, it has become critical to employ a different cure for the development of diverse biofertilizers in order to solve this difficulty. They are the most economical. The following are the primary reasons to investigate biofertilizers: The demand exceeds the supply by a wide margin. It is anticipated that by 2017, in order to meet the planned output of 321 million tonnes of food grain, the required nutrients would be 28.8 million tonnes, but their availability will be only 21.6 million tonnes, resulting in a 7.2 million tonnes shortfall.

1. Depletion of feedstock/fossil fuels (energy crisis) and rising fertilizer costs.
2. Small and marginal farmers are finding it more difficult to finance this.
3. Depleting soil fertility when the gap between nutrient absorption and supply widens.
4. Growing worry about potential environmental threats.
5. The challenge to sustainable agriculture is growing. Aside from the factors stated above, the long-term usage of biofertilizers is more inexpensive, eco-friendly, efficient, productive, and accessible to marginal and small farmers than chemical fertilizers.

Bio-fertilizers, also known as microbial inoculants, offer significant promise as an additional, renewable, and ecologically friendly source of plant nutrients, and are an essential component of the Integrated Plant Nutrient System (IPNS). Biofertilizers are ready-to-use live formulations of beneficial microorganisms that, when applied to seeds, roots, or soil, mobilize the availability of nutrients through their biological activity in particular, and help build up the microflora and, as a result, soil health in general, benefiting crops. Biofertilizers are intended to increase soil N and P fertility. They give chemicals that promote growth. Biofertilizers supply nutrients by natural processes such as atmospheric nitrogen fixation, phosphorus solubilization, and plant growth stimulation through the manufacture of growth-promoting chemicals. They may be classified in several ways depending on their nature and purpose. This group symbiotically fixes nitrogen. Nitrogen biofertilizers aid in nitrogen level correction in the soil. Because plants need a particular quantity of nitrogen in the soil to develop, nitrogen is a limiting element for plant growth. Because various biofertilizers work best in different soils, the choice of nitrogen biofertilizer to utilize is determined by the farmed crop. Azotobacter or Azospirillum are employed for non-legume crops, Acetobacter for sugarcane and blue-green algae, and Azolla for lowland rice fields. Biofertilizers are also used to enrich your compost and to improve the bacterial activities that break down compost material. Cellulolytic fungus cultures, as well as Phosphotika and Azotobacter cultures, are suitable biofertilizers for compost application. Vermi Compost is a 100% pure eco-friendly organic fertilizer that contains nitrogen, phosphorous, potassium, organic carbon, sulphur, hormones, vitamins, enzymes, and antibiotics to assist boost produce quality and quantity. The soil is losing fertility and becoming saline as a result of the continued use of chemical fertilizers. Natural farming is the only way to solve such difficulties, and Vermi compost is the greatest option.

Biocompost is another environmentally friendly organic fertilizer made from sugar industry waste that has been degraded and enhanced with diverse plants as well as human-friendly bacteria and fungus. Biocompost is made up of nitrogen, phosphate-solubilizing bacteria, and helpful fungi such as the decomposing fungus Trichoderma viridae, which protects plants from soil-borne illnesses and also helps to boost soil fertility, resulting in a high-quality product for farmers. To recap, biofertilizers are biologically active products or microbial inoculants of bacteria, algae, and fungus (individually or in combination) that may enhance biological nitrogen fixation for the benefit of plants. Organic fertilizers (manure, for example) that are made accessible by the interaction of microorganisms or their relationship with plants are also considered biofertilizers.

Biofertilizers therefore include the following: (i) symbiotic nitrogen fixers, Rhizobium spp.; (ii) non-symbiotic, free-living nitrogen fixers (Azotobacter, Azospirillum, etc.); (iii) algal biofertilizers (blue-green algae or blue-green algae in association with Azolla); (iv) phosphate-solubilising bacteria; (v) mycorrhizae; (vi) organic fertilizers.

The following are the numerous biofertilizers:

Nitrogen-fixing biofertilizers Nitrogen-fixing bacteria work in two ways: symbiotically and as free-living (non-symbiotic) bacteria, as well as associative symbiotic bacteria.

Nitrogen-Fixing Bacteria

They live freely in the soil and fix nitrogen. Some of them are saprotrophic, meaning they feed on organic waste, such as *Azotobacter*, *Bacillus polymyxa, Clostridium, and Beijerinckia*. They are further subdivided into aerobic and anaerobic variants. Nitrogen fixation is also seen in photoautotrophic bacteria such as *Rhizobium, Rhodopseudomonas, Rhodospirillum, and Chromatium*. Soil inoculation with these microorganisms increases production while reducing nitrogen fertilizer use. Azotobacter, for example, found in cotton, maize, jowar, and rice crops not only boosts output but also reduces nitrogen fertilizer use by 10-25 kg/ha. Its inoculant is sold under the brand name Azotobactrin. Rhizobia are soil bacteria that colonize legume roots and symbiotically fix atmospheric nitrogen. Rhizobia's shape and physiology will differ from free-living environments to the bacteroid of nodules. In terms of fixed nitrogen, they are the most effective biofertilizer. A cross-inoculation group consists of seven taxa that are extremely specialized in the formation of nodules in legumes.

Azotobacter is a genus of free-living heterotrophic nitrogen-fixing bacteria found in alkaline and neutral soils. Its aerobic nature makes it suitable for non-leguminous crops such as rice, millets, cotton, tomato, cabbage, and other monocotyledonous crops. Azotobacter also generates chemicals that promote growth. Azotobacter thrives in soils with a high organic matter concentration. Rice, maize, cotton, sugarcane, pearl millet, vegetable, and certain plantation crops have all shown resistance to Azotobacter. Rhizobia (Sg. rhizobium) are a kind of symbiotic nitrogen-fixing bacteria. On the roots of legume plants, they produce nodules. Rhizobium species that develop associations with the roots of various legumes include *R.*

leguminosarum, R. lupini, R. trifolii, R. meliloti, and *R. phaseoli*. Except for a strain of cowpea Rhizobium, these bacteria, also known as rhizobia, may live freely in soil but cannot fix nitrogen. Only until they are present within the root nodules do they gain the potential to fix nitrogen. Bacteria (bacteroids) are grouped in nodule cells and are surrounded by the host cell membrane, which is coated with a pink-red pigment called leghemoglobin.

Rhizobium cultures specific for various crops are now being grown in the laboratory. Frankia, a nitrogen-fixing mycelial bacterium (actinomycete), is symbiotically linked with the root nodules of various non-legume plants, including *Casuarina, alnus* (Alder), *Myrica*, *Rubus*, and others. A few plants' leaves (e.g., Ardisia) develop specific interior chambers to accommodate symbiotic nitrogen-fixing bacteria, *Xanthomonas* and *Mycobacterium*. Such leaves provide a steady supply of nitrogen fertilizer to the soil. Nitrogen-fixing cyanobacteria (blue-green algae) collaborate with a variety of plants, including cycad roots, liverworts, Azolla (fern), and lichenized fungus. Azolla is an aquatic floating fern that grows in temperate climates that are appropriate for paddy production. The fern emerges over water as a green mat that becomes scarlet owing to anthocyanin colouring. Cyanobacteria, which lives as a symbiont with this fern in the lower cavities, fix atmospheric nitrogen. Azolla pinnata is a little free-floating fresh water fern that grows quickly, doubling every 5-7 days. Because it does not interfere with the development of rice plants, the fern may cohabit with them. Anabaena azollae lives in the fern's leaf cavities. It is a nitrogen fixer. A portion of the fixed nitrogen excreted in the cavities is accessible to the fern. The nitrogen is released by dying fern plants for use by rice plants. When a field dries out after harvest, the fern acts as green manure, decaying and nourishing the soil for the following crop.

CONCLUSION

Nitrogen-fixing, phosphate-solubilizing, and plant growth-promoting rhizobacteria, among others, provide adaptable solutions for a wide range of crop demands and soil conditions. Methods of administration like as seed inoculation, soil application, and foliar spray provide for more flexibility in incorporating biofertilizers into agricultural techniques. Biofertilizer technology is very beneficial to sustainable agriculture, which focuses on reducing environmental effect and guaranteeing long-term food security. Biofertilizers lessen dependency on chemical fertilizers, hence reducing soil deterioration and pollution. Biofertilizer technology is a light of hope for eco-conscious agriculture as we continue to explore novel and sustainable agricultural techniques. It underlines the significance of using nature's potential to improve soil health and agricultural production while protecting the environment for future generations.

REFERENCES:

[1] M. Ahamd *et al.*, “Effectiveness of multi-strain biofertilizer in combination with organic sources for improving the productivity of Chickpea in Drought Ecology”, *Asian J. Agric. Biol.*, 2017.

[2] M. Barman, S. Paul, A. G. Choudhury, P. Roy, en J. Sen, “Biofertilizer as Prospective Input for Sustainable Agriculture in India”, *Int. J. Curr. Microbiol. Appl. Sci.*, 2017, doi: 10.20546/ijcmas.2017.611.141.

[3] Y. Ma, Y. Yin, en Y. Liu, "Corrigendum to 'New insights into co-digestion of activated sludge and food waste: Biogas versus biofertilizer' [Bioresource Technology 241 (2017) 448–453] (S0960852417308222)(10.1016/j.biortech.2017.05.154)", *Bioresource Technology*. 2017. doi: 10.1016/j.biortech.2017.07.152.

[4] T. H. Nguyen, T. C. Phan, A. T. M. A. Choudhury, M. T. Rose, R. J. Deaker, en I. R. Kennedy, "Biogro: A plant growth-promoting biofertilizer validated by 15 years' research from laboratory selection to rice farmer's fields of the mekong delta", in *Agro-Environmental Sustainability*, 2017. doi: 10.1007/978-3-319-49724-2_11.

[5] S. Gothandapani, S. Sekar, en J. C. Padaria, "International Journal of Advanced Research in Biological Sciences Azotobacter chroococcum: Utilization and potential use for agricultural crop production: An overview", *Int. J. Adv. Res. Biol. Sci*, 2017.

[6] Nurjanani, "Teknologi Produksi Kentang Tropika melalui Pengelolaan Tanaman Terpadu Berbasis Sumberdaya Lokalo di Sulawesi Selatan", *J. Agrotan*, 2017.

[7] H. Suthar, K. Hingurao, J. Vaghashiya, en J. Parmar, "Fermentation: A Process for Biofertilizer Production", 2017. doi: 10.1007/978-981-10-6241-4_12.

[8] I. Dávila, E. Robles, I. Egüés, J. Labidi, en P. Gullón, "The Biorefinery Concept for the Industrial Valorization of Grape Processing By-Products", in *Handbook of Grape Processing By-Products: Sustainable Solutions*, 2017. doi: 10.1016/B978-0-12-809870-7.00002-8.

[9] Grandchamp et al. *et al.*, "crossm Sporulation in Bacillus subtilis", *J. Bacteriol.*, 2017.

[10] Y. F. C. Putra, "EFEK PEMBERIAN EKSTRAK KETEPENG CINA (Cassia alata l.) TERHADAP KADAR GLUKOSA DARAH PADA TIKUS WISTAR (Rattus norvegicus) DENGAN INDUKSI ALOKSAN", *Carbohydr. Polym.*, 2017.

CHAPTER 2

ANALYSIS AND DETERMINATION OF BIOFERTILIZERS

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ABSTRACT:

Biofertilizers are environmentally safe and sustainable alternatives to chemical fertilizers, and they play an important role in improving soil fertility and agricultural output. This research investigates different elements of biofertilizers, including their varieties, modes of action, application techniques, and importance in encouraging sustainable agriculture. This study intends to give insights into the potential and relevance of biofertilizers in current agricultural methods by conducting a thorough evaluation of scientific papers and research results. Biofertilizers, which include nitrogen-fixing, phosphate-solubilizing, and plant growth-promoting rhizobacteria, harness the power of beneficial microbes to improve soil fertility and nutrient availability to plants. Their mechanism of action includes forming symbiotic interactions with plants or directly aiding nutrient intake, resulting in increased agricultural yields. Biofertilizers' numerous application techniques, including as seed coating, soil application, and foliar spray, provide flexibility in incorporating these environmentally acceptable options into agricultural processes.

KEYWORDS:

Agriculture, Biofertilizers, Eco-friendly, Sustainable Farming, Soil Fertility, Agricultural Productivity.

INTRODUCTION

Act as an extended root system by establishing itself on the root system. They not only collect moisture from deeper and further away nits in the soil, but they also harvest different micronutrients and supply them to the host plants. VAM improves phosphorus nutrition by improving both its availability and mobility. VAM are obligatory symbionts that enhance Zn, Co, P, and H2O absorption. Its large-scale use is confined to perennial crops and transplanted crops. A single fungus, for example, Glomus, may create a mycorrhizal relationship with many plants. Biofertilizers are formulations created from naturally helpful microbes. They are safe for all plants, animals, and humans. They are not only ecologically benign, but they also assist to save chemical inputs since they are helpful to crops and natural nutrient cycles. To prepare a slurry, combine one packet of inoculant with 200 mL of rice kanji. The seeds for an acre are mixed in the slurry to provide a consistent coating of the inoculant over the seeds, and then shade-dried for 30 minutes. Shade-dried seeds should be planted within 24 hours. One box of the inoculant (200 g) is enough to treat 10 kg of seeds. Suspend 1 to 2 kg of nitrogen-fixing (*Azotobacter/Azospirillum*) and phosphate solubilizing biofertilizer in just enough water (5-10 L depending on the number of seedlings to be sown in one acre). Before transplanting, soak seedling roots in this mixture for 20-30 minutes. Make a bed of adequate size (2 m x 1.5 m x 0.15 m) in the field, fill it with 5 cm of water, and suspend 2 kg each of *Azospirillum* and phosphate-solubilizing biofertilizer, mixing well. Now soak the seedlings' roots in this bed for 8-12 hours (overnight) before transplanting [1], [2].

Biofertilizers have a bright future in terms of market growth, manufacturing, technology, equipment and instruments, and so on. They show promise in terms of minimizing soil quality issues while increasing crop output. Biofertilizers, as discussed in Part I of Module 1, are a complex product of living microbial inoculants that may fix atmospheric nitrogen, solubilize soil phosphorus, degrade organic material, and oxidize sulfur in the soil. Biofertilizers are cultures of beneficial soil microorganisms that have been artificially produced and may increase soil fertility and crop yield. They contribute nutrients by natural processes such as nitrogen fixation, phosphorus solubilization, and plant growth stimulation through the creation of growth-promoting chemicals. They are manufactured from biological waste and are chemical-free. Bacteria, fungus, and cynobacteria (blue-green algae) are the primary sources of biofertilizers. The new eco-friendly technology for producing biofertilizers will solve the inadequacies of the current chemical-based agricultural system. The use of technology has a good impact on both soil sustainability and plant development. By fixing atmospheric nitrogen, they help to nourish and eventually enhance soil fertility.

They boost the soil's phosphorus content by solubilizing and releasing unavailable phosphorous. They help to replenish depleted minerals in the soil. Plant root proliferation is improved by growth-promoting chemicals generated by biofertilizers. They help protect the plant from various soil-borne illnesses. To promote and apply additional biofertilizers, the following new technologies must be developed. Plant nutrients play an important role in crop production, and 16 critical plant nutrients must be accessible to crops in sufficient amounts to meet the yield objective. Many studies have also stressed the relevance of N, P, and K in improving plants' inherent capacity to tolerate stress from drought and cold, as well as pests and diseases. The important plant nutrients N, P, K, Ca, Mg, and S are referred to as macronutrients, whereas Fe, Zn, Cu, Mo, Mn, B, and Cl are referred to as micronutrients [3], [4].

It is required to examine a soil's potential to deliver the missing quantities of plant nutrients (total crop requirement-soil supply). This is also necessary in order to create a suitable biofertilizer formulation and provide nutrients that may increase soil health and plant fertility. Several writers have focused on the possible use of nitrogen from animal manures. Nonetheless, the endeavor to develop a supply alternative to animal dung requires further research. Granite powder has also been investigated as a potential source of slow-release potassium fertilizer. In general, adding nitrogen to high C:N ratio residues might increase microbial activity throughout the fermentation process. Plant growth is definitely affected by the quantity of microorganisms and the amount of macro- and micronutrients. One advantage of fertilizers is that they increase the availability of the microbial population. It is critical to have a greater initial population of suitable microorganisms in a ready biofertilizer shortly after fermentation. Using the idea of an effective microorganism (EM), as described by Higa and Wididana (1991), is one method for increasing the quantity of chosen microorganisms. Most organic fertilizers need field testing to ensure nutrient availability and effectiveness. This kind of experiment is necessary since the nutritional content of organic fertilizers varies greatly. The amount of chosen microorganisms in an active form per gram and their capacity to stimulate plant development and soil fertility directly influence the quality.

Water-in-oil emulsions seem to be an effective, if underused, way for storing and distributing microorganisms through liquid formulations. Once applied, the oil retains the water surrounding the organism and thereby inhibits water evaporation. This is especially advantageous for organisms that are susceptible to desiccation or when used for horticulture crops with irrigation systems. Water-in-oil emulsions allow for the addition of chemicals to the oil and/or aqueous phases, which may increase both cell viability and release kinetics. Cell sedimentation during storage, on the other hand, is a big concern. This issue is being addressed via research using nanomaterials. Using hydrophobic silica nanoparticles to thicken the oil phase may greatly minimize cell sedimentation and increase cell viability during storage [5], [6].

Implementation of a novel procedure based on the application of supercritical fluid qualities to encapsulate viral formulations aids in the preparation of bacterial inoculants. The PGSS (Particles from Gas Saturated Solutions) method operates at low temperatures and use carbon dioxide as a supercritical fluid. As a result, there should be no detrimental impacts on microbial viability, and the manufacturing cost should be relatively cheap. The technique produces virtually spherical particles that combine to create a free-flowing powder that can be suspended in water. The PGSS process's capabilities have previously been successfully shown for a variety of solids and liquids.

DISCUSSION

Another intriguing new technique is the use of spontaneous bacterial biofilm creation as a prospective carrier, not only for the development of specific bacterial or fungal-bacterial consortium inoculum. Biofilm manufacture has previously been achieved for a variety of industrial purposes (e.g., wastewater treatment, chemical compound synthesis). In that situation, two kinds of biofilms are used: biofilms that grow on inert supports (charcoal, resin, concrete, clay brick, and sand particles) and biofilms that arise as a consequence of aggregate formation. In the first situation, biofilms form all around the particles, and the biofilm particles expand in size over time, often to several millimeters in diameter. Granular biofilms are created by aggregation; granule development might take several weeks to many months. A mature biofilm develops in four stages: initial attachment, irreversible adhesion through EPS synthesis, early development, and maturity of biofilm architecture. The creation of EPS, which helps to connect the cell to the surface and protect it from the surrounding environment, is very important. Polysaccharides, proteins, nucleic acids, and phospholipids may all be found in EPS. The exopolysaccharide alginate is a typical EPS generated by bacterial cells in biofilms. Beneficial biofilms created in in vitro cultivation of both fungal and bacterial strains have been exploited as biofertilizers for non-target organisms.

Lentil species with high effectiveness. When compared to a typical rhizobium inoculant, a biofilmed inoculant containing a fungalrhizobia consortium dramatically improved N2 fixation in soybean. Wheat seedlings injected with biofilm-producing bacteria yielded more in moderately salty soils. Biofilms seem to assist microorganisms survive after inoculation, even under stressful conditions: this is an important factor for the success of PGPM inoculation in agricultural settings. When compared to rhizobial monocultures, biofilm inoculants allowed their rhizobia to survive at high salinity (400 mM NaCl) by 105-fold. Surprisingly, beneficial endophytes were shown to generate more acidity and plant growth hormones than mono- or mixed cultures with no biofilm development.

Technologies utilized to create living hybrid materials might open up a new area in the development of PGPM carriers. Silica has emerged as a suitable host for microbe encapsulation, with immobilization methods based on the immobilization of a population of bacteria distributed in a silica gel. Bacteria may be confined in either alginate microbeads covered with silica membranes or macrocavities formed inside the silica matrix. These compounds increase the mechanical characteristics of the alginate bead, as well as the cell leakage and vitality. Bio-nanotechnology might potentially open up new opportunities for the creation of carrier-based microbial inoculants. Nanotechnology makes use of nanoparticles, which are formed of inorganic or organic components and have one or more dimensions of 100 nm or less. The combination of entire cells with nanostructures results in hybrid systems with extensive applications in a variety of industries, including agriculture. Despite the fact that nanoscale structures are smaller than cells, macroscopic filters capable of absorbing Escherichia coli were created using radially oriented carbon nanotube walls. The same approach might therefore be used to collect and distribute bacterial cells from fermentation operations to the plant. The physical stability and large surface area of nanotubes, as well as the convenience and cost-effective manufacture of nanotube membranes, may thereby enhance their usage in biofertilizer production. Nanoformulations may improve the stability of biofertilizers and biostimulators in terms of desiccation, heat, and UV inactivation. The inclusion of hydrophobic silica nanoparticles ranging in size from 7 to 14 nm to the water-in-oil emulsion formulation of the biopesticide fungus *Lagenidium giganteum* decreased mycelium desiccation. The physical properties of the formulation were enhanced, and the microbe was still functional after 12 weeks of room temperature storage [7], [8].

In the case of biofertilizers, it has been maintained for over a decade that there are significant product- and market-related limits; yet, marketing organizations have been unable to adapt to the demands of the business environment. As previously noted, biofertilizers in powder form have various limits that might be greatly alleviated by product alteration from "powder form" to "liquid form," which offers huge better advantages, as explained below. Product innovation is another step forward in addressing farmers' issues, such as potash mobilizers like *Frateuria aurentia,* zinc and sulfur solubilizers like *Thiobacillus species*, and manganese solubilizer fungal cultures like *Penicillium citrinum*, which have been identified for commercial operations and are highly useful and economical for enhancing agricultural productivity.
In the European Union, there are no explicit laws governing biofertilizers. This is governed at the national level by each country. For example, the Polish Fertilizers and Fertilization Law of July 10th, 2007 classifies "growth stimulators" as plant conditioners. These are goods that "have a positive impact on plant growth or other metabolic processes of plants in ways other than plant nutrients" and "pose no threat to [human or animal] health or the environment after use in accordance with use and storage instructions."

This concept may be applied to biofertilizers, however no special restrictions are anticipated for this product category. Spain, the world's second biggest producer of conventional fruits and vegetables after Italy and one of Europe's top producers of organic crops, does not contain the phrase "biofertilizer" in its regulations. The most recent fertilizer-related legislative requirement stipulates the amount of microorganisms in organic amendments and compost but does not address plant beneficial microorganisms. Fertilizers are defined as "products used in agriculture or gardening that, because of their nutrient content, facilitate plant growth, increase performance, and improve crop quality, or that, by their specific action, amending, as appropriate, modify soil fertility or its physical, chemical, or biological properties and meet the requirements of Article 4.2 of this Royal Decree characteristics." This concept also includes fertilizers, specialist goods, and additives.

There is a small but rapidly expanding biofertilizers market. Among today's significant issues are soil degradation and contamination caused by the excessive and injudicious use of agrochemicals, as well as their harmful impacts on people, particularly agricultural workers and rural populations. Concerns about both health and the environment have prompted governments to seek ecologically friendly alternatives and shift away from 'risk reduction' and'safe usage' methods in sustainable agriculture production. Biofertilizers and biopesticides are a superior alternative for increasing 'Fertilizer Use Efficiency' and maintaining soil health. Biofertilizers are regarded as a significant component of Integrated Nutrient Management, with a secondary function for the greatest fertilizer users.

Rural markets are extremely "price sensitive," and biofertilizers, which are technical and new to farmers with many restraints, do not fall into the category of "zero elasticity of demand" and need more push due to a lack of pull. The pricing of a product is normally determined by the firm based on its marketing goals. It is critical to understand how biofertilizers are regarded by consumers in terms of value for money invested. Biofertilizers have generated demand, but farmers have yet to see them as providing economic rewards by reducing the amount of chemical fertilizers required. Biofertilizer makers will likely be unable to use "pricing strategies" unless farmers are persuaded of significant cost savings in production via decreased use of chemical fertilizers while achieving comparable output. There is an urgent need to advertise the product, both in terms of sales and use. Channel members, i.e., dealers/distributors, must be encouraged by providing real benefits/incentives tied to sales objectives, such as "free family tour, gifts, etc." Similarly, depending on customer characteristics/buying behavior, offers of discounts, premiums, competitions, purchasing allowances, and so on must be appealing to the consumer. In addition to merchants, progressive farmer village leaders may be chosen for the purpose of organizing demonstrations and should be adequately rewarded.

The POS (Point of Sales) literature must be made accessible to all dealers/distributors, and the goods must be displayed prominently. Broader exposure through radio and instructional film screenings must also be aggressively pursued. Free biofertilizer distribution at farmer gatherings must be avoided. Orientation and training programs for field sales force and dealers/distributors must also be developed. There is a need for a dedicated team of Extension Executives to promote biofertilizers by regular visits, creating strong relationships with farmers, and carrying out demonstrations with replication in neighboring villages. The primary research emphasis is and should be on the development of effective and sustainable biofertilizers for agricultural plants, with the goal of drastically reducing inorganic fertilizer use to prevent additional environmental concerns.

The rhizosphere, or narrow zone of soil around plant roots, may contain up to 1011 microbial cells per gram of root and over 30,000 prokaryotic species, which boost plant production in general. The collective genome of the rhizosphere microbial community enveloping the plant roots is larger than that of plants and is referred to as the microbiome, whose interactions determine crop health in natural agro-ecosystems by providing a variety of services to crop plants, including organic matter decomposition, nutrient acquisition, water absorption, nutrient recycling, weed control, and biocontrol. Using 454 sequencing (Roche) of 16S rRNA gene amplicons, the metagenomic investigation presents the individual, core rhizosphere, and endophytic microbiome activities in Arabidopsis thaliana. It has been claimed that tailor-made core microbiome transfer treatment in agriculture might be a promising strategy to manage plant diseases in various crops. Rhizosphere microbial communities have gained popularity as an alternative to chemical fertilizers in sustainable agriculture and biosafety programs [9], [10].

A primary emphasis in the future decades will be on safe and environmentally acceptable techniques of sustained agricultural production by using beneficial microbes. In general, these microorganisms are varied naturally occurring bacteria whose incorporation into the soil ecosystem improves soil physicochemical qualities, soil microbial biodiversity, soil health, plant growth and development, and agricultural yield. Plant growth-promoting rhizobacteria, N2-fixing cyanobacteria, mycorrhiza, plant disease suppressive beneficial bacteria, stress-tolerant endophytes, and biodegrading microorganisms are among the agriculturally valuable microbial communities. Biofertilizers are a supplement to soil and crop management practices such as crop rotation, organic adjustments, tillage maintenance, crop residue recycling, soil fertility renovation, and biocontrol of pathogens and insect pests, the operation of which can be extremely beneficial in ensuring the sustainability of various crop productions. Azotobacter, Azospirillum, Rhizobium, cyanobacteria, phosphorus- and potassium-solubilizing microorganisms, and mycorrhizae are some of the PGPRs that have been reported to grow in soil when no or little tillage is used. Efficient Azotobacter, Azospirillum, Phosphobacter, and Rhizobacter strains may deliver considerable amounts of nitrogen to Helianthus annus and improve plant height, number of leaves, stem diameter, percentage of seed filling, and seed dry weight.

CONCLUSION

Their mechanism of action entails forming symbiotic connections with plants or directly aiding nutrient absorption, resulting in increased agricultural yields. The numerous biofertilizer treatment techniques, including as seed coating, soil application, and foliar spray, provide flexibility in incorporating these eco-friendly options into agricultural processes. Biofertilizer technology is very beneficial to sustainable agriculture, which focuses on lowering chemical inputs and minimizing environmental effect. Biofertilizers improve soil health, lower greenhouse gas emissions, and aid in food security. Biofertilizers are a viable tool for increasing agricultural output while maintaining the environment as we negotiate the problems of contemporary agriculture and aim for more sustainable methods. Their significance is highlighted by their role in encouraging environmentally aware farming methods and guaranteeing a more sustainable agricultural future.

REFERENCES:

[1] T. Mahanty *et al.*, “Biofertilizers: a potential approach for sustainable agriculture development”, *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-016-8104-0.

[2] R. Chatterjee en S. Bandyopadhyay, “Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (Vigna unguiculata L. Walp.) in acid soil of eastern Himalayan region”, *J. Saudi Soc. Agric. Sci.*, 2017, doi: 10.1016/j.jssas.2015.11.001.

[3] Rinku V Patel *et al.*, “A Review: Scope of Utilizing Seaweed As A Biofertilizer In Agriculture.”, *Int. J. Adv. Res.*, 2017, doi: 10.21474/ijar01/4941.

[4] R. Klaic, F. Plotegher, C. Ribeiro, T. C. Zangirolami, en C. S. Farinas, “A novel combined mechanical-biological approach to improve rock phosphate solubilization”, *Int. J. Miner. Process.*, 2017, doi: 10.1016/j.minpro.2017.02.009.

[5] N. K. & Y. K. S. Rakesh Kumar, “Role of Biofertilizers in Agriculture”, *Popular KhetiVolume -5, Issue-4 (October-December), popularkheti.infoISSN: 2321-0001*, 2017.

[6] L. N. P. Patola, S. Supriyono, en P. Pardjanto, “Effect Use Biofertilizer And Differences Type Soil On Growth And Yield Arrowroot”, *Sains Tanah - J. Soil Sci. Agroclimatol.*, 2017, doi: 10.15608/stjssa.v14i1.600.

[7] S. Timmusk, L. Behers, J. Muthoni, A. Muraya, en A. C. Aronsson, “Perspectives and challenges of microbial application for crop improvement”, *Front. Plant Sci.*, 2017, doi: 10.3389/fpls.2017.00049.

[8] J. R. Lamont, O. Wilkins, M. Bywater-Ekegärd, en D. L. Smith, “From yogurt to yield: Potential applications of lactic acid bacteria in plant production”, *Soil Biology and Biochemistry*. 2017. doi: 10.1016/j.soilbio.2017.03.015.

[9] K. Bhavya, R. S. Reddy, S. Triveni, K. D. Chari, en Y. Nagaraju, “Study of Shelflife of Carrier Biofertilizers from Different Production Centers”, *Int. J. Curr. Microbiol. Appl. Sci.*, 2017, doi: 10.20546/ijcmas.2017.606.206.

[10] J. Pralhad Rathod, R. M. Gade, D. R. Rathod, en M. Dudhare, “A Review on Molecular Tools of Microalgal Genetic Transformation and their Application for Overexpression of Different Genes”, *Int. J. Curr. Microbiol. Appl. Sci.*, 2017, doi: 10.20546/ijcmas.2017.612.373.

CHAPTER 3

ANALYZING THE TRENDS IN BIOFERTILIZERS PRODUCTION

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ABSTRACT:

Trends in biofertilizer manufacturing are critical in contemporary agriculture as sustainable agricultural techniques gain traction. This study investigates the changing environment of biofertilizer manufacturing, including technical breakthroughs, the growth of microbial consortia, quality control methods, and their influence on sustainable agriculture. This study intends to give insights into the dynamic area of biofertilizer production and its key role in determining the future of eco-friendly farming via an in-depth review of current research and market developments. Biofertilizer manufacturing technological improvements, like as bioreactor technology and genetic engineering, have opened the road for efficient and large-scale production of microbial inoculants. The creation of unique microbial consortiums suited to individual crops and soil conditions improves the efficacy of biofertilizers by maximizing nutrient absorption and crop yields.

KEYWORDS:

Agriculture, Biofertilizers, Microbial Consortia, Production Trends, Quality Control, Sustainable Farming.

INTRODUCTION

Azotobacter is an essential part of the nitrogen cycle in nature since it has a range of metabolic roles. Apart from nitrogen fixation, Azotobacter may create vitamins such as thiamine and riboflavin, as well as plant hormones such as indole acetic acid (IAA), gibberellins (GA), and cytokinins (CK). *Azotobacter chroococcum* promotes plant development by improving seed germination and developing root architecture by suppressing pathogenic bacteria surrounding agricultural plant root systems. *A. chroococcum, A. vinelandii, A. beijerinckii, A. nigricans, A. armeniacus,* and *A. paspali* are all members of this genus. Wheat, oat, barley mustard, sesame, rice, linseeds, sunflower, castor, maize, sorghum, cotton, jute, sugar beets, tobacco, tea, coffee, rubber, and coconuts are among the crops that utilize it as a biofertilizer. Azospirillum is a free-living, motile, Gram-variable, aerobic bacteria that thrives in water and supports different aspects of plant growth and development [1], [2].

Azospirillum has been found to improve plant growth and agricultural production in both greenhouse and outdoor studies. Several *Azospirillum species*, including *A. lipoferum, A. brasilense, A. amazonense, A. halopraeferens, and A. irakense*, have been observed to increase agricultural yield. It was discovered that Azospirillum inoculation may alter root shape by creating plant growth-regulating chemicals through siderophore synthesis. It also increases the number of lateral roots and promotes the production of root hairs, providing increased root surface area for adequate nutrient absorption. This increases the plant's water status and assists the nutritional profile in the progression of plant growth and development. The combination of *Azospirillum brasilense* and *Rhizobium meliloti* with 2,4-D increased grain production and N, P, and K content in *Triticum aestivum*. For many years, Rhizobium has been employed as an effective nitrogen fixer. It contributes significantly to increased yields by transforming atmospheric nitrogen into useable forms. Rhizobium, which is resistant to a wide range of temperatures, generally penetrates root hairs, multiplies, and produces nodules. Rhizobium inoculants have been shown to dramatically raise grain yields of Bengal gram and lentil, as well as to improve the rhizospheres of pea, alfalfa and sugar beet, berseem, ground nut, and soybean in various locations and soil types. Rhizobium isolates isolated from wild rice have been shown to provide nitrogen to the rice plant, promoting growth and development. *Sinorhizobium meliloti* 1021, a *Rhizobiaceae species*, infects plants other than legumes, such as rice, to boost growth by increasing endogenous plant hormone levels and photosynthetic performance to impart plant tolerance to stress.

The IRC-6 rhizobium strain improved various beneficial features in groundnut, including increased number of pink-colored nodules, nitrate reductase activity, and leghaemoglobin concentration in 50 DAI (days after inoculation). Plants are protected by rhizobial symbiosis against infections and herbivores such as the Mexican bean beetle and the greenhouse whitefly *Trialeurodes vaporariorum*. Beneficial soil microorganisms help crop productivity by acting as biofertilizers or as symbionts. They carry out nutrient solubilization, which improves nutrient availability and hence absorption. This enhances plant development by increasing root architecture. Plants benefit from their activity in a variety of ways, including increased root hairs, nodules, and nitrate reductase activity, and effective strains of Azotobacter, Azospirillum, Phosphobacter, and Rhizobacter may give a large quantity of accessible nitrogen via nitrogen cycling. Plant hormones such as indole acetic acid (IAA), gibberellins (GA), and cytokinins (CK) are produced by biofertilizers. Biofertilizers boost photosynthetic performance to increase plant tolerance to stress and disease resistance, resulting in crop improvement [3], [4].

Beneficial microorganisms have the ability to digest phosphorus for their own needs, which then becomes accessible in adequate amounts in the soil in soluble form. It has been observed that Pseudomonas, Bacillus, Micrococcus, Flavobacterium, Fusarium, Sclerotium, Aspergillus, and Penicillium are involved in the solubilization process. Micrococcus sp. NII-0909 phosphate solubilizing bacterial strain displays polyvalent characteristics, including phosphate solubilization and siderophore synthesis. Similarly, two fungi isolated from decaying cassava peels, *Aspergillus fumigatus* and *A. niger*, have been discovered to convert cassava wastes to phosphate biofertilizers using the semi-solid fermentation process. *Burkholderia vietnamiensis*, a stress-tolerant bacterium, generates gluconic and 2-ketogluconic acids, which aid in phosphate solubilization. Siderophores and indolic compounds (ICs) are produced by Enterobacter and Burkholderia isolated from the rhizosphere of sunflower.

Potassium-solubilizing microorganisms (KSM) from the genera Aspergillus, Bacillus, and Clostridium are effective in potassium solubilization and mobilization in various crops. Mycorrhizal mutualistic symbiosis with plant roots meets plant nutritional requirement, resulting in increased plant growth and development as well as protection from pathogens and environmental stress. It results in phosphate absorption by the hyphae from the exterior to the inside cortical mycelia, which then transfers phosphate to the cortical root cells. Nitrogen-fixing cyanobacteria employed as biofertilizers include Aulosira, Tolypothrix, Scytonema, Nostoc, Anabaena, and Plectonema. In addition to the nitrogen, growth-promoting compounds, and vitamins released by these algae, *Cylindrospermum musicola* promotes root development and yield in rice plants. Interestingly, Anabaena sp. strain PCC7120's nitrogen-fixing capability was improved by genetic engineering. When compared to the wild-type strain, constitutive expression of the hetR gene controlled by a light-inducible promoter increased HetR protein production, resulting in greater nitrogenase activity in Anabaena sp. strain PCC7120. This, in turn, resulted in greater paddy growth when applied to the fields.

Through IAA, siderophore, and 1-aminocyclopropane-1-carboxylate deaminase (ACCD), P. fluorescens strain may protect canola and barley plants against the inhibitory effects of cadmium. It has been claimed that introducing microbes in the form of effective microbial agents (EMA) to several plant species such as cotton, ryegrass, tall fescue, and alfalfa may speed up rhizoremediation of petroleum-contaminated soil. PGPRs, as biological agents, have shown to be one of the chemical agent options for providing resistance to diverse pathogen assaults. They may confer resistance against infections by generating metabolites in addition to functioning as growth promoters. *Bacillus subtilis* GBO_3 can stimulate defense-related pathways, viz. salicylic acid (SA) and jasmonic acid (JA). Immunity against tomato mottle virus is provided by the use of PGPR isolates, namely *B. amyloliquefaciens* 937b and *B. pumilus* SE-34.

B. megaterium IISRBP, isolated from black pepper stem, inhibits *Phytophthor capsici*. *Bacillus subtilis* N11 and mature composts were shown to be effective in controlling Fusarium infection on banana roots. Similarly, *B. subtilis* (UFLA285) was discovered to confer resistance to *R. solani* as well as to stimulate foliar and root development in cotton plants. *Paenibacillus polymyxa* SQR-21 was found as a promising agent for the biocontrol of Fusarium wilt in watermelon in another intriguing investigation. Furthermore, it was discovered that using PGPRs to regulate spotted wilt viruses in tomato, cucumber mosaic virus in tomato and pepper, and banana bunchy top virus in banana was efficient. In rare situations, mycorrhizae, in conjunction with bacteria, may impart resistance to fungal infections and prevent the development of numerous root pathogens, including *R. solani, Pythium spp., F. oxysporum, A. obscura,* and *H. annosum*, by increasing the plant nutritional profile and hence productivity. *Glomus mosseae*, for example, is effective against *Fusarium oxysporum f. sp. basilica*, which causes root-rot disease in basil plants. With mycorrhizal colonization, Medicago tranculata also demonstrated upregulation of several defense-related genes.

DISCUSSION

The addition of arbuscular mycorrhizal fungi and Pseudomonas fluorescens to the soil has been found to prevent the development of root-rot disease and increase the yield of Phaseolus vulgaris L. Mechanism of action of several biofertilizers Mycorrhiza is the connection of fungus with higher plant roots. While it remains a mystery, it serves as a model system for understanding the mechanism underlying mycorrhizal-induced root cell growth stimulation. The genome sequencing of two EM fungus (ectomycorrhizae), *L. bicolor* 13 and *T. melanosporum* (black truffle) 14, has aided in the discovery of factors that govern mycorrhiza formation and function in the plant cell. In *L. bicolor*, fifteen genes that were up-regulated during symbiosis were identified as probable hexose transporters. Its genome lacks invertase genes, leaving it reliant on plants for glucose. *T. melanosporum*, on the other hand, has one invertase gene and, unlike *L. bicolor*, can directly utilise the host's sucrose. The upregulation of transporter genes during symbiosis suggested that beneficial chemicals such as amino acids, oligopeptides, and polyamines were transported from one creature to the other through the symbiotic interface. Nitrate and ammonium may be taken up by free-living mycelium from the soil. These chemicals then make their way to the mantle and Hartig net, after which they are conveyed to the plants. The fungus's cysteine-rich proteins (MISSP7) act as effectors and facilitators in the establishment of symbiotic interfaces. Many genes involved in auxin production and root morphogenesis were found to be up-regulated after mycorrhizal colonization. Furthermore, *G. versiforme* has inorganic phosphate (Pi) transporters on its hyphae, which aid in the direct absorption of phosphate from the soil, and a glutamine synthase gene was discovered in *G. intraradice*, which increases the possibility that nitrogen metabolized in the fungal hyphae can be transported to the plant later. Myc factors, which are identical to Rhizobium Nod factors, are thought to be released by mycorrhiza and Rhizobium and recognized by host roots for the activation of signal transduction pathways or the common symbiosis (SYM) pathway. There are several similarities between the mechanisms that prepare the plant for both AM and Rhizobium infection. With the initial encounter with fungal hyphae, the common SYM pathway prepares the host plant to undergo molecular and anatomical changes. Calcium is thought to be the center of secondary messengers through Ca2+ spiking in the nuclear area of root hairs thus far. According to microarray research, *Rhizobium leguminosarum* biovar viciae may activate a variety of genes in plants such as pea, alfalfa, and sugar beet. PGPRs create IAA, which stimulates the synthesis of nitric oxide (NO), which functions as a second messenger to activate a complex signaling network, resulting in increased root growth and development.

During entrance, the expression of ENOD11, as well as various defense-related and root-remodeling genes, increases. As a result, the creation of a pre-penetration apparatus (PPA) is possible. Although the biology of arbuscule formation is unclear, a gene called Vapyrin, when turned down, causes arbuscule growth to slow. Many additional genes are known to be involved in arbuscule production, including those encoding subtilisin protease, phosphate transporter, and two ABC transporters. Scientists are increasingly using nitrogen-fixation genes to build transgenic plants that can fix atmospheric nitrogen. The stimulation of nif genes in nitrogen-fixing bacteria occurs in the rhizosphere at low nitrogen and oxygen concentrations. Interestingly, sugarcane plantlets seeded with a natural strain of *G. diazotrophicus* displayed radioactive N_2 fixation when compared to a *G. diazotrophicus* mutant with a mutant nifD gene, demonstrating the importance of nif genes.

The consumption of carbon affects the effectiveness of nitrogen fixation. *Bacillus subtilis* (UFLA285) has been shown to differently stimulate 247 genes in cotton plants when compared to controls in which no PGPR was provided to the cotton plant. With UFLA285 activation, several disease-resistance genes that function through jasmonate/ethylene signaling as well as osmotic control via proline synthesis genes were differently expressed. Several genes encoding metallothionein-like protein type 1, a NOD26-like membrane integral protein, ZmNIP2-1, a thionin family protein, an oryzain gamma chain precursor, stress associated protein 1 (OsISAP1), probenazole-inducible protein PBZ1, and auxin- and ethylene-responsive genes were identified as differentially expressed. The expression of defense-related proteins PBZ1 and thionins has been reported to be suppressed in the rice-H. seropedicae relationship, indicating that plant defense responses are modulated during colonization.

Azospirillum has been hypothesized to secrete gibberellins, ethylene, and auxins among other PGPR species. Some plant-associated bacteria may also stimulate the production of phytohormones. Lodgepole pine, for example, showed higher amounts of IAA in the roots after being infected with *Paenibacillus polymyxa*. Rhizobium and Bacillus were discovered to synthesis IAA under a variety of culture conditions, including pH, temperature, and the presence of agro-waste as a substrate. Unlike other phytohormones, ethylene is responsible for dicot plant growth suppression. PGPR increases plant growth by decreasing ethylene expression. Intriguingly, a model has been proposed in which ethylene synthesis from 1-aminocyclopropane-1-carboxylate (ACC), an immediate precursor of ethylene, is hydrolyzed by bacterial ACC-deaminase enzyme in need of nitrogen and carbon source, is also one of the mechanisms of induction of growth conditions. Bacteria with ACC-deaminase activity include *Alcaligenes sp., Bacillus pumilus, Pseudomonas sp.,* and *Variovorax paradoxus*. The role of ACC deaminase in the indirect impact on plant development was shown in canola, where mutations in the ACC deaminase gene resulted in the loss of the effect of growth-promoting Pseudomonas putida. Interestingly, the potential of PGPRs was boosted further by inserting genes involved in the direct oxidation (DO) pathway and mineral phosphate solubilisation (MPS) into several beneficial PGPR strains. *Acinetobacter calcoaceticus*, *E. coli*, and

Enterobacter asburiae genes producing glucose dehydrogenase (gcd) implicated in the DO pathway were cloned and described. Furthermore, a gene producing a soluble form of GCD from *Acinetobacter calcoaceticus* and *G. oxydans* has been cloned.

Furthermore, site-directed mutagenesis of glucose dehydrogenase (GDH) and gluconate dehydrogenase (GADH) has been shown to increase enzyme activity. S771M substitution enhanced *E. coli* heat stability, while glutamate 742 to lysine mutation improved E. coli PQQGDH EDTA tolerance. The MPS phenotype was obtained by transferring genes implicated in the DO system, including GDH, GADH, and pyrroloquinoline quinine (PQQ), to rhizobacteria and phosphoenolpyruvate carboxylase (PPC) to *P. fluorescens.* Environmental stressors are becoming a big issue, and productivity is dropping at an unprecedented pace. Our reliance on chemical fertilizers and pesticides has promoted the growth of companies that produce life-threatening substances that are not only dangerous for human consumption but may also disrupt the ecological equilibrium. Biofertilizers may assist tackle the challenge of feeding the world's growing population at a time when agriculture is suffering a variety of environmental stressors. It is critical to recognize the benefits of biofertilizers and to apply them to contemporary agricultural methods.

The new technique created using the strong instrument of molecular biotechnology has the potential to improve the biological pathways of phytohormone synthesis. These technologies may assist give alleviation from environmental challenges if they are recognized and transferred to relevant PGPRs. However, one of the few reasons why many valuable PGPRs are still outside the understanding of ecologists and agriculturists is a lack of information about enhanced procedures of biofertilizer applications to the field. Nonetheless, recent advances in technology linked to microbial microbiology, plant-pathogen interactions, and genomics will aid in optimizing the essential procedures. The success of biofertilizer research is dependent on the development of novel techniques for PGPR functions and their correct use in agriculture. The key issue in this field of study is that, in addition to identifying different strains of PGPRs and their features, it is necessary to dissect the real mechanism of functioning of PGPRs for their usefulness in sustainable agriculture [5], [6].

The growing need for safe and healthful food, along with environmental concerns, has resulted in the establishment and growth of organic farming. It is a worldwide priority area in crop and animal production that supports and improves agroecosystem health, such as biodiversity, biological cycles, and soil biological activity. Organic farming is based on the creation and use of biofertilizers and plant strengtheners. The widespread use of chemical fertilizers has increased agricultural commodity output significantly, but they also have a negative impact on the soil. Excessive use of chemical fertilizers and other agrochemicals to improve output may pollute ground water and deplete soil nutrients, finally resulting in agricultural yield decrease. This issue might be solved by using a different method to create multiple biofertilizers.

Biofertilizers derived from microorganisms may be used in lieu of chemical fertilizers; they are less costly and less harmful to the environment. The present worldwide market for organically farmed agricultural goods is worth over $30 billion, with an annual growth rate of roughly 8%. Organic farming currently covers about 22 million hectares of land. Organic agriculture accounts for less than 1% of global conventional agricultural output and around 9% of total agricultural land. In the strictest sense, biofertilizers, or "microbial inoculants," are not fertilizers that provide direct nourishment to crop plants. They are natural and organic formulations containing living or dormant cells of beneficial soil microorganisms that, when added to seeds, plant surfaces, or soil, colonize the rhizosphere or interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. Inoculation with beneficial soil microbes is a potential strategy for increasing soil fertility since it promotes plant accessibility to a variety of critical nutrients such as nitrogen, phosphorus, and potassium. As a consequence, the consumption of synthetic fertilizers may be decreased greatly. Inoculation with microbes has been shown to increase vegetable yields in the literature. The living components of soil are microorganisms (bacteria, mycorrhizal fungus, and algae). Their soil fertility and plant feeding actions are varied. They influence soil structure and nutrient dynamics, participate in plant nutrition, and boost plant resistance to soil-borne diseases.

The increased need for safe and nutritious food, along with environmental concerns, has led to the creation and expansion of organic farming. It is a global priority area in crop and animal production that promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. Organic farming relies on the development and use of biofertilizers and plant strengtheners. Chemical fertilizers have considerably enhanced agricultural product output, yet they have a detrimental influence on the soil. Excessive use of chemical fertilizers and other agrochemicals to boost production may contaminate ground water and deplete soil nutrients, ultimately leading to a decline in agricultural productivity. This problem might be remedied by developing a new way for producing several biofertilizers.

Microorganism-derived biofertilizers may be used instead of chemical fertilizers since they are less expensive and less hazardous to the environment. The current global market for organically produced agricultural items is valued at more than $30 billion, with an annual growth rate of around 8%. Organic farming presently occupies around 22 million hectares of land. Organic agriculture produces less than 1% of worldwide conventional agricultural production and occupies around 9% of total agricultural land. Biofertilizers, also known as "microbial inoculants," are not fertilizers that offer direct sustenance to crop plants in the strictest sense. They are natural and organic formulations containing living or dormant cells of beneficial soil microorganisms that colonize the rhizosphere or interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant when added to seeds, plant surfaces, or soil. Because it enhances plant accessibility to a number of key nutrients such as nitrogen, phosphorus, and potassium, inoculation with beneficial soil microorganisms is a possible technique for boosting soil fertility. As a result, the use of synthetic fertilizers may be drastically reduced. Microbe inoculation has been demonstrated in the literature to boost vegetable yields. Microorganisms (bacteria, mycorrhizal fungus, and algae) are the living components of soil. Their soil fertility and plant feeding activities differ.

They have an impact on soil structure and nutrient dynamics, as well as plant nutrition and resistance to soil-borne illnesses. Biofertilizers include microorganisms that may initiate a biological process that promotes plant development and healthy growth. These bacteria are more than just fertilizers. They convert inaccessible soil components into those that plants can use. Despite their name, fertilizers do not include all of the nutrients that may be put directly to the soil to boost soil fertility. Microorganisms, on the other hand, gradually and consistently increase soil stability and phytosanitation. The number of microorganisms in biofertilizers and composts is what distinguishes them. Biofertilizers can only include a single strain of microbe that is designed for a particular activity in the soil. These microorganisms are divided into three categories: nitrogen-fixing, phosphate-transforming, and cellulose-degrading. They aid in the fixation of atmospheric nitrogen and the conversion of phosphorus into a form useable by plants [7].

Microorganisms also aid plants in the production of hormones, vitamins, and amino acids, all of which are critical in the development of disease resistance. Depending on their demands, almost all crops need various kinds of biofertilizers. The numerous forms of biofertilizers that aid plant growth at various stages of development may be divided into four categories: N-fixing biofertilizers: These include bacteria such as *Rhizobium*, *Azotobacter*, *Azospirillum*, *Clostridium*, and *Acetobacter*, as well as *blue-green algae (BGA)* and the fern *Azolla* (which works in symbiosis with BGA).

Phosphate-solubilizing/mobilizing biofertilizers include phosphate-solubilizing bacteria (PSBs) and phosphate-solubilizing microorganisms (PSMs) such as Bacillus, Pseudomonas, and Aspergillus. Mycorrhizae, also known as vesicular-arbuscular mycorrhizae or VAM, are nutrient-mobilizing fungus. Rhizobacteria that promote plant development (PGPR): Pseudomonas species are the most common. These bacteria do not supply nutrients to plants, but they do improve plant growth and performance. Cellulolytic (Trichoderma) and lignolytic (Humicola) fungal species, as well as other Gram-positive and Gram-negative bacteria, are composting accelerators.

The increased need for safe and nutritious food, along with environmental concerns, has resulted in the creation and expansion of organic farming. It is a global priority area in crop and animal production that supports and promotes agroecosystem health, such as biodiversity, biological cycles, and soil biological activity. Organic farming is based on the development and use of biofertilizers and plant strengtheners. Chemical fertilizers have considerably enhanced agricultural commodity production, but they also have a deleterious influence on the soil. Excessive use of chemical fertilizers and other agrochemicals to boost production may contaminate ground water and deplete soil nutrients, ultimately leading in a decline in agricultural productivity. This problem might be remedied by using an alternative technique for producing several biofertilizers.

Biofertilizers grown from microorganisms may be used instead of chemical fertilizers since they are less expensive and less hazardous to the environment. The current global market for organically produced agricultural items is valued more than $30 billion, with an annual growth rate of around 8%. Organic farming now occupies around 22 million hectares of land. Organic agriculture represents for less than 1% of worldwide conventional agricultural production and around 9% of overall agricultural land. Biofertilizers, also known as "microbial inoculants," are not fertilizers that feed crop plants directly. They are natural and organic formulations containing living or dormant cells of beneficial soil microorganisms that, when added to seeds, plant surfaces, or soil, colonize the rhizosphere or interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. Inoculation with beneficial soil microorganisms is a viable technique for boosting soil fertility since it increases plant accessibility to a number of important nutrients such as nitrogen, phosphorus, and potassium. As a result, the use of synthetic fertilizers may be significantly reduced. In the literature, microbial inoculation has been demonstrated to boost vegetable yields. Microorganisms (bacteria, mycorrhizal fungi, and algae) are the living components of soil. Their soil fertility and plant feeding behaviors differ.

They regulate soil structure and nutrient dynamics, participate in plant nutrition, and increase plant resistance to soil-borne illnesses. Biofertilizers include microorganisms that may trigger a biological process that encourages plant development and guarantees healthy growth. These microbes provide more than just as fertilizer. They convert inaccessible soil components into plant-accessible forms. Although they are termed fertilizers, they do not contain all of the nutrients that may be put directly to the soil to promote soil fertility. On the contrary, microorganisms gradually and consistently increase soil stability and phytosanitation. The number of microorganisms in biofertilizers and composts varies. Biofertilizers can only include a single strain of microorganism designed for a particular activity in the soil. These bacteria are divided into three groups: nitrogen-fixing, phosphate-transforming, and cellulose-degrading microorganisms. They aid in the fixation of atmospheric nitrogen and the conversion of phosphorus into a form that plants can use.

Microorganisms also aid plants in the production of hormones, vitamins, and amino acids, which are critical in the development of disease resistance. Depending on their requirements, almost all crops need various kinds of biofertilizers. There are four kinds of biofertilizers that assist plants grow at different stages of development. These include the bacteria Rhizobium, Azotobacter, Azospirillum, Clostridium, and Acetobacter, as well as blue-green algae (BGA), or cyanobacteria, and the fern Azolla (which works in symbiosis with BGA). P-solubilizing/mobilizing biofertilizers: These include phosphate-solubilizing bacteria (PSB) and phosphate-solubilizing microorganisms (PSMs) such as Bacillus, Pseudomonas, and Aspergillus. Mycorrhizae are nutrient-mobilizing fungus also known as vesicular-arbuscular mycorrhizae, VA-mycorrhizae, or VAM. These bacteria do not supply plant nutrients, but they do improve plant growth and performance. Composting accelerators include cellulolytic (Trichoderma) and lignolytic (Humicola) fungal species, as well as several Gram-positive and Gram-negative bacteria.

CONCLUSION

The use of nitrogen fertilizers raises crop production costs, pollutes the agro-ecosystem, and accelerates soil fertility loss. As a result, it became critical for researchers to devise and implement a strategy for supplementing or replacing inorganic nitrogen with organic sources, particularly those of microbial origin. Nitrogen-fixing biofertilizers were the most widely used in the business in 2012, accounting for more than 78% of worldwide demand. These biofertilizers are primarily used to boost crop yields and have various potential environmental advantages in addition to their agricultural use. Furthermore, rising consumption of leguminous and non-leguminous plant products is predicted to boost demand for nitrogen-fixing biofertilizers throughout the projection period. Nitrogen biofertilizers aid agriculturists in determining soil nitrogen levels. The amount of nitrogen is also determined by the kind of crops. Some crops need more nitrogen to flourish, while others require less. The kind of soil is a significant component in determining which biofertilizers are required for a crop.

REFERENCES:

[1] V. N. da Silva, L. E. de Souza Fernandes da Silva, A. J. N. da Silva, N. P. Stamford, en G. R. de Macedo, "Solubility curve of rock powder inoculated with microorganisms in the production of biofertilizers", *Agric. Nat. Resour.*, 2017, doi: 10.1016/j.anres.2017.01.001.

[2] S. Fendrihan, F. Constantinescu, O. Sicuia, en S. Dinu, "Azospirillum Strains As Biofertilizers And Biocontrol Agents -A Practical Review", *J. Adv. Agric.*, 2017, doi: 10.24297/jaa.v7i3.6324.

[3] L. F. Nava-López *et al.*, "Biofertilizer formulation from Azotobacter and Azospirillum regional isolates and its effect on sugar cane (Saccharum officinarum) in greenhouse", *Mex. J. Biotechnol.*, 2017, doi: 10.29267/mxjb.2017.2.2.183.

[4] A. Datta, H. Ullah, en Z. Ferdous, "Utilization of By-Products from Food Processing as Biofertilizers and Biopesticides", in *Food Processing By-Products and their Utilization*, 2017. doi: 10.1002/9781118432921.ch8.

[5] S. Islas-Valdez *et al.*, “Effectiveness of rabbit manure biofertilizer in barley crop yield”, *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-015-5665-2.

[6] Mahrous M. Kandil, “Characterization of Pantoea Sp. Strain MK1D, and Erwinia Sp. Strain MK2Y as Tricalcium Phosphate Dissolving Bacteria Isolated from Calcareous Soil”, *Alexandria Sci. Exch. J. An Int. Q. J. Sci. Agric. Environ.*, 2017, doi: 10.21608/asejaiqjsae.2017.3509.

[7] P. E. Díaz, C. Aranda, O. Martínez, R. Godoy, A. Gonzales, en E. Valenzuela, “Characterization of yeast in hapludands soil with biotechnological potential”, *J. Soil Sci. Plant Nutr.*, 2017, doi: 10.4067/S0718-95162017000400009.

CHAPTER 4

ANALYSIS OF COMMONLY USED BIOFERTILIZERS: A REVIEW STUDY

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ABSTRACT:

Commonly used biofertilizers are an important part of sustainable agriculture since they provide healthy alternatives for chemical fertilizers. The kinds, microbial consortia, mechanisms of action, and importance of commonly used biofertilizers in fostering soil health and crop yield are all covered in this research. This research intends to shed light on the critical function of widely used biofertilizers in contemporary and sustainable farming via a thorough evaluation of scientific studies and agricultural practices. Only utilized biofertilizers are crucial elements of sustainable agriculture because they enable efficient and eco-friendly nutrient management techniques. The many kinds of biofertilizers, such as rhizobia that fix nitrogen, bacteria that break down phosphate, and mycorrhizal fungus, harness the power of advantageous microbes to improve soil fertility and plant nutrient availability.

KEYWORDS:

Agriculture, Biofertilizers, Microbial Consortia, Sustainable Farming, Soil Health.

INTRODUCTION

Martinus Beijerinck, a Dutch scientist, developed biological nitrogen fixing. It is responsible for 60% of total nitrogen fixation. Diazotrophs are microorganisms that fix nitrogen. They raise the soil nitrogen level and, as a result, the soil fertility. Nitrogenase, a microbial multimeric enzyme co mplex, catalyzes biological nitrogen fixation. Nitrogenase complexes are found in all diazotrophs. It is made up of two conserved proteins: an iron-containing dinitrogenase reductase (Fe protein) encoded by the nifH gene and a molybdenum iron (Mo Fe) dinitrogenase (or Mo Fe protein) expressed by the nifDK genes While N_2 is attached to the nitrogenase enzyme complex, the processes take place. Ferredoxin electrons are used to decrease the Fe protein first. The reduced Fe protein then binds ATP, reducing the molybdenum-iron protein, which contributes electrons to N_2, resulting in HN=NH. HN=NH is reduced to H_2N-NH_2, which is then reduced to $2NH_3$ in two more cycles of this process each needing electrons given by ferredoxin. Reduced ferredoxin, which gives electrons for this activity, is produced by photosynthesis, respiration, or fermentation depending on the kind of microbe. The nitrogenase proteins of all nitrogen-fixing bacteria have a remarkable degree of functional conservation. Many of these bacteria have the Fe protein and the Mo-Fe protein isolated, and nitrogen fixation can be demonstrated in cell-free systems in the laboratory when the Fe protein of one species is mixed with the Mo-Fe protein of another bacterium, even if the species are very distantly related. Because oxygen interacts with the iron component of the proteins, molecular oxygen and reactive oxygen species block nitrogenase irreversibly. Although this isn't a problem for anaerobic bacteria, it might be a huge issue for aerobic bacteria like cyanobacteria which produce oxygen during photosynthesis and free-living aerobic bacteria like Azotobacter and Beijerinckia [1], [2].

To deal with the situation, these microbes have a variety of defensive mechanisms. Azotobacter species, for example, have the greatest known rate of respiratory metabolism of any creature, therefore they may safeguard the enzyme by keeping a very low quantity of oxygen in their cells. These species also create extracellular polysaccharide, which holds water and hence restricts the rate of oxygen transport into the cells. Plant growth-promoting bacteria (PGPB) have been utilized as biofertilizers across the globe because of their capacity to increase plant growth and hence crop yields and soil fertility, as well as their potential to contribute to more sustainable agriculture and forestry. In general, PGPB promote plant growth either directly by assisting in resource acquisition (nitrogen, phosphorus, and essential minerals) or indirectly by decreasing the inhibitory effects of various pathogens on plant growth and development in the form of biocontrol agents. They inhibit pathogen activity by creating a variety of metabolites such as siderophores, hydrolytic enzymes, and antibiotics. PGPB exist freely in soil, invade plant roots aggressively, and form symbiotic relationships with plants. The presence of PGPB in plant roots is broadly divided into two situations.

The hizosphere and endosphere are two types of environments. The rhizosphere is the volume of soil directly influenced by roots, while the endosphere is the interior root tissue. Rhizobacteria and endophytes are the strains that live in the rhizosphere and endosphere, respectively. Only N-fixing bacteria provide extra nitrogen (N) inputs to the soil/plant system. Other biofertilizers just solubilize or mobilize nutrients already present in soils. Microorganisms that can fix atmospheric N_2 may be utilized as effective biofertilizers. Their use in soil increases soil biota while decreasing the requirement for chemical fertilizers. Among all PGPB, diazotrophic (N_2-fixing) bacteria are classified as: Free-living heterotrophic or autotrophic bacteria. Bacteria in associative symbiotic relationships; and N Bacteria in symbiotic relationships with plants [3], [4].

Nitrogen fixers that are free-living Nitrogen-fixing bacteria that are free-living, or non-symbiotic, exist outside plant cells and are connected with the rhizosphere, the area of soil influenced by plant roots and exudates. They are classified into four types: Free-living non-photosynthetic aerobic nitrogen-fixing bacteria such as Azotobacter, Ijerinckia and Derxia; Free-living non-photosynthetic anaerobic nitrogen-fixing bacteria such as Clostridium; Free-living photosynthetic nitrogen-fixing bacteria such as Chromatium, Rhodopseudomonas, Rhodospirillum, cyanobacteria; Free-living chemosynthetic nitrogen-fixing bacteria such as Desulfovibrio.

Nitrogen-fixing bacteria that live in the absence of light. Although several genera and species of N2-fixing bacteria have been identified from the rhizosphere of different cereals, representatives of the Azotobacter and Azospirillum genera have been intensively tested in the field to boost grain and legume output. Azotobacter is an obligate aerobe that can thrive in low oxygen environments. *Azotobacter armeniacus, A. beijerinckii, A. chroococcum, A. nigricans, A. paspali,* and *A. vinelandi* are its six species. These species are utilized as a biofertilizer for wheat, barley, oat, rice, sunflower, maize, line, beetroot, tobacco, tea, coffee, and coconuts and play a significant role in nitrogen fixation in rice crops [5], [6].

Azotobacter species vary in their physical and physiological properties. Some are better in nitrogen fixation than others. Inoculation of soil with Azotobacter species increases crop yields by increasing the concentration of not just nitrogen, but also other chemicals that enhance plant development, such as vitamins, gibberellins, naphthalene, and acetic acid. Azotobacter also generates growth-promoting chemicals, such as nicotinic acid and pantothenic acid, biotin and heteroauxins, gibberellins, and C Nitrogen-fixing photosynthetic cyanobacteria blue-green algae are found abundantly in soil and belong to 15 genera. They fix free N_2 into nitrogenous and ammonium compounds. They are mostly heterocysts, such as Nostoc, Anabaena, Aulosira, Cylindrospernum, Calothrix, Totypothrix, and Stigonema. Because cyanobacteria are photosynthetic, they provide organic matter and nitrogen to the soil. Among them, Aulosira is the most active nitrogen fixer in Indian rice fields. Nitrogen fixation occurs in heterocysts, or heterocytes (H), which are found at regular intervals along the cyanobacterial filaments. Because cyanobacteria have oxygen-evolving photosynthesis, yet the nitrogen-fixing enzyme, nitrogenase, is unstable in the presence of oxygen, this separation of cellular activities is required. This issue is solved since heterocysts only have a portion of the photosynthetic equipment, photosystem I, which may create energy (as ATP). However, the heterocysts lack photosystem II, which is responsible for splitting water into hydrogen (which is then combined with CO_2 to form organic compounds) and oxygen. There is less nitrogen-fixing blue-green algae that are not heterocystous, such as Oscillatoria, Phormidium, and Gleocapsa. This category consists of bacteria from the Spirillaceae family, with two major genera, Azospirillum and Herbaspirillum. Bacteria of the genus Azospirillum are common in tropical, subtropical, and temperate soils, where they form a symbiotic mutualism around the roots of diverse wild and cultivated plants, a process known as risosphere association [7], [8].

They are an example of what are known as associative nitrogen fixers. Azospirillum are facultative endophytic diazotrophs that invade the surface and interior of nonlegume plants. They may fix a significant amount of nitrogen in the rhizosphere of non-leguminous plants such as grains, millets, oilseeds, cotton, rice, sugar cane, and so on. Nitrogen fixers, such as Azospirillum, help plants by promoting shoot and root growth and enhancing root water and mineral absorption. Increases in yield may be significant, up to 30%, but typically range from 5% to 30%. Azospirillum yield gains may be due to the synthesis of growth-promoting chemicals rather than N2 fixation. The fundamental issue limiting the usage of Azospirillum on a big scale is the high level of uncertainty and unpredictability of the outcomes.Despite these concerns, Azospirillum has a lot of potential as a growth-promoting N2-fixing biofertilizer. Commercially, the species *A. lipoferum, A. brasilense,* and *A. amazonense* have been employed as nitrogen-supplying biofertilizers.

DISCUSSION

Mutualistic (symbiotic) bacteria belonging to the group Alphaproteobacteria, family Rhizobiaceae, which includes the following genera, are the best known and most utilized symbiotic nitrogen fixers. Rhizobia includes Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium, and Allorhizobium. Rhizobia create mutually beneficial relationships with the roots of leguminous plants, where they produce noodles and carry out nitrogen fixation. The bacteria inside the nodules convert free nitrogen to ammonia, which the host plant uses for growth. To promote adequate nodule development and optimal growth of legumes e.g., alfalfa, beans, clovers, peas, soybeans, seeds are often inoculated with commercial cultures of suitable Rhizobium species, particularly in soils deficient in the necessary bacteria. Rhizobium can fix 15-20 kg N/ha and enhance pulse crop yields by up to 20%.

The microbial activities of Rhizobium are thought to fix 40-250 kg N/ha/year by diverse legume crops. The capacity of rhizobia to fix N_2 varies greatly across host plant species and bacterial strains. As a result, while producing biofertilizers, not only the bacterial strain but also the rhizobia-host compatibility must be considered. N_2-fixers in the genus Frankia also form symbiotic partnerships with some dicotyledonous species (actinorhizal plants). Frankia are gram-positive filamentous actinobacteria that may be found in root nodules or soil. Inoculation of actinorhizal plants with Frankia enhances plant growth, biomass, shoot and root N content, and survival rate following field transplantation. The success of establishing an actinorhizal plantation on degraded settings, however, is dependent on the selection of appropriate Frankia strains. This genus' species are capable of infecting and nodulating eight families of actinorhizal plants (primarily woody plants) used for wood production, land reclamation, timber and fuel wood production, mixed plantations, windbreaks, and shelterbelts along deserts and coastlines. Frankia inoculation may be beneficial in dry conditions, disturbed locations, and regions lacking natural actinorhizal plants. The symbiosis between actinorhizal plants and Frankia causes the creation of a perennial root organ termed a nodule, which hosts bacteria and fixes nitrogen. Actinorhizal nodules in the field may take on a variety of shapes and colors.

A comparison of actinorhizal and leguminous nodules reveals that the form, anatomy, genesis, and functioning of these two nitrogen-fixing plants' nodules vary. Actinorhizal symbiosis results in two forms of nodule formation: intercellular and extracellular infection. Cyanobacteria are essential ecologically because they contribute considerably to global N2-fixation. Their capacity to fix molecular nitrogen is critical in rice production and desert soil remediation. Nonetheless, cyanobacteria production and use are still in their early stages. Cyanobacteria, on the other hand, should be carefully regarded as a biofertilizer supporting sustainable agriculture methods in a variety of situations. Azolla, in addition to cyanobacteria (blue-green algae), which is an essential biological element in rice production, provides another affordable, economical, and environmentally acceptable biofertilizer.

The importance of employing Azolla as a biofertilizer for rice crops stems from its fast breakdown in the soil, effective nitrogen supply to rice plants, need for a shallow freshwater environment, rapid development, and growing alongside rice without competition for light and space. Rice grain yields have increased from 14% to 40% when Azolla was utilized as a dual crop. It increases rice plant height, tiller count, grain production, and straw yield. It receives 8-20 kg of phosphate per acre. These biofertilizers or biomanures provide considerable quantities of P, K, S, Zn, Fe, Mb, and other micronutrients in addition to N-fixation. Azolla is widely planted in Asian locations and is either put into the soil prior to rice transplanting or produced as a dual crop with rice.

Asians have realized the advantages of cultivating Azolla as a biofertilizer, human food, and medicinal. It also enhances water quality by removing excess nitrogen and phosphorus, and it is used as fodder and feed for fish, ducks, and rabbits. Azolla is a tiny floating pteridophyte having symbiotic relationships with cyanobacteria and eubacteria that last throughout its life cycle. It is special in that it serves as a host for N-fixing cyanobacteria, after which it is essentially utilized as green manure. It contributes not just the biologically fixed N, but also the other nutrients received from the soil and present in its biomass, throughout this process. The Azzolaceae family includes seven species: *Azolla caroliniana, Azolla filiculoides, Azolla maxicana, Azolla microphylla, Azolla pinnata, Azolla rubra,* and *Azolla nilotica. A. pinnata* is often seen in India. The algal symbiont belongs to the Nostocaceae family and is known as *Anabaena azollae*. In the partnerships between Azolla and the cyanobacteria *Anabaena azollae*, the eukaryotic partner Azolla shelters the prokaryotic endosymbiont Anabaena azollae in its leaf cavities and offers carbon sources in exchange for nitrogen. The algal symbiont captures atmospheric nitrogen. Heterocysts are nitrogen fixation sites. The number of heterocysts in the consecutive leaves increases down the stem from the apex to the base. This symbiosis promotes the fern's rapid growth and multiplication, as well as the production of a large quantity of biomass on the water's surface. It is then gathered, dried, and used as a biofertilizer to augment nitrogen demands in coffee plants.

Due to its crucial involvement in the physiological and biochemical operations of plants, be the most significant chemical component that inhibits plant development. Due to the strong reactivity of phosphate anions via precipitation with cations like Fe^{3+} and Al^{3+} in acidic soils or Ca^{2+} in calcareous soils, the use of chemical phosphorous fertilizers to address the phosphorus deficit in soil is not a particularly effective strategy. To enhance the amount of phosphorus in agricultural soil, the use of microbial inoculants with phosphate-solubilizing activity will be a beneficial strategy. This method is also a more sustainable option than applying chemical fertilizers [9], [10].

The process of mineralizing organic phosphorus, also known as the solubilization of organic phosphate, happens in soil at the cost of plant and animal remnants, which are rich in compounds that include organic phosphorus. Numerous saprophytes work to break down organic materials in the soil by releasing orthophosphate from the carbon backbone of molecules. Inorganic phosphate compounds including tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphates may be solubilized by a variety of bacterial species. For these microbes to function at their best in a variety of field circumstances, it is crucial to understand the precise process by which PSM solubilizes phosphorus. The breakdown of calcium phosphate $Ca(H_2PO_4)_2$ to dihydrogen phosphate anion (H_2PO_4) is thought to be crucial to the whole phosphorus cycle because microorganisms must ingest phosphorus through membrane transport.

Phosphate-solubilizing Microorganisms (PSM) from numerous genera, including Pseudomonas, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Microccocus, Aereobacter, Flavobacterium, and Erwinia, are responsible for the solubilization of phosphorus in nature. The symbiotic nitrogenous rhizobia exhibit phosphate-solubilizing activity in addition to their ability to fix atmospheric nitrogen into ammonia and export the fixed nitrogen to the host plants. For instance, by mobilizing both inorganic and organic phosphorus, *Rhizobium leguminosarum bv. trifolii* and *Rhizobium species* nodulating Crotalaria species increased plant phosphorus nutrition. There have also been a number of phosphate-solubilizing bacteria isolated from stressful settings. One such strain is the halophilic *Kushneria sinocarni* bacterium, which was found in the sediment of the Daqiao saltern on China's east coast and may be beneficial in agricultural soils afflicted by salinity. Based on the use of phosphate-mobilizing microorganisms and phosphate-solubilizing bacteria, two different kinds of phosphate biofertilizers have been created.

Species of bacteria and fungi that solubilize insoluble inorganic phosphate compounds such tricalcium phosphate, dicalcium phosphate, hydroxyapatite, and rock phosphate are included in this category. The most effective ones are from the bacterial species Bacillus and Pseudomonas as well as the fungal species Aspergillus and Penicillium. Instead of non-rhizosphere soil, they might be separated in greater quantities from rhizosphere soil. Their use into biofertilizers attempts to boost the yields of cereal, vegetable, fruit, and legume crops. Because they create more acids than bacteria do, phosphate-solubilizing fungus are more active at doing so. The most prominent genera of filamentous fungus that solubilize phosphate are Aspergillus and Penicillium, while several strains of Trichoderma and Rhizoctonia solani have also been identified as phosphate solubilizers. To explain the mechanics of phosphate solubilization, many ideas have been put forward. The proton and enzyme hypothesis and the theory of acid generation are the two most significant hypotheses.

Theory of acid generation

Production of organic acids, which either dissolve rock phosphate directly through anion exchange with acid anion or chelate Fe, Al, and Ca ions to bring the phosphate into solution, is the main mechanism by which phosphate-solubilizing microorganisms solubilize phosphate. Due to the ability of PSM to secrete and release organic acids (citric, oxalic, succinic, tartaric, malic, alpha keto butyric, 2-ketogluconic, gluconic and fumaric acids) in the soil environments, these bacteria lower the pH in their vicinity, which is a prerequisite for solubilization of bound phosphates in soil and consequently dissociate the bound form of phosphates like $Ca_3(PO_4)_2$ in calcareous soil. The oxidative respiration or fermentation of organic carbon sources yields the microbial organic acids. The two acids with the greatest capacity to dissolve phosphate from inorganic phosphate complexes are gluconic and fumaric. Depending on the kind and intensity of the acid, different amounts of soluble phosphate are released. When it comes to phosphate solubilization, aliphatic acids outperform phenolic and citric acids. Phosphorus-solubilizing bacteria including *Pseudomonas sp., Erwinia herbicola, Pseudomonas cepacia*, and *Burkholderia cepacia* create more gluconic acid than other bacteria. In addition to organic acids, the nitrifying process also generates inorganic acids including nitric and sulfuric acids. During the oxidation of nitrogenous or inorganic sulphur compounds that react with calcium phosphate and transform them into soluble forms, Thiobacillus and Nitrosomonas bacteria are present.

The availability of phosphorus is increased by adding effective phosphate solubilizers to the rhizosphere of plants, which raises crop output by 200–500 kg/ha. Microorganisms so significantly contribute to the solubilization and assimilation of both native and administered phosphorus. It is also known that phosphate-solubilizing bacteria create the phosphatase enzyme in addition to the acids that lead to the solubilization of phosphate in aquatic environments. Phosphorus is released from organic molecules via esterases. The release of protons that occurs in conjunction with respiration or ammonium absorption is what causes solubilization without the creation of acid. In addition to these processes, certain bacterial species produce syderophores, which are iron-chelating chemicals that bind the iron in the root region and prevent dangerous microbes from using it, protecting agricultural plants from them. Phosphate solubilization is also connected with the synthesis of various chelating compounds, mineral acids, and physiologically active chemicals including indole, acetic acids, gibberellins, and cytokinins.

Numerous significant crop species, such as maize, wheat, rice, and potatoes, are among the vascular plant species. Mycorrhizal fungi build a connection between the soil and the roots, bringing nutrients to the roots from the earth. Mycorrhizae may be divided into two main categories: ectomycorrhizal fungi (EM) and endomycorrhizal fungi (AM). The majority of plants, including grasses, shrubs, some trees, and many others, have endomycorrhizae. Ectomycorrhizal fungi are often exclusive to a particular host species, while the majority of endomycorrhizae species will develop connections with almost any host plant for AM-fungi and are therefore much simpler to identify. A common kind of endomycorrhiza seen in agricultural and horticultural plants, arbuscule-forming mycorrhiza (AMF) is when fungi from the Glomeromycota genus enter root cortical cells to produce branching structures known as arbuscules. With the aid of the fungus's fine absorbing hyphae, the host plant benefits by getting necessary nutrients, in particular phosphorus, calcium, copper, zinc, etc., that are otherwise unavailable to it. Because it is quickly absorbed by soil particles and forms a phosphate-free zone surrounding plant roots, phosphorus is a very immobile element.

Mycorrhizal fungi have external hyphae that may extend more than 10 cm from the surface of the roots, giving them access to a larger area of non-depleted soil than the root alone. Hyphae may enter soil pores that are inaccessible to roots due to their tiny (20–50 m) diameter. Additionally, they create extracellular alkaline phosphatases, which may release phosphate from organic sources. Mycorrhizae change the redox potential surrounding the root and mycelium by excreting protons, hydroxyls, and organic acids. This improves the conversion of insoluble phosphate from the soil into a soluble form in the soil solution. Therefore, a mycorrhizal root system will have a larger effective surface area for absorbing nutrients and exploring a larger amount of soil than a root system that is not mycorrhizal. Glomalin, a sticky sugar-based substance excreted by AM hyphae, aids in the binding of soil particles and the formation of solid soil aggregates. Given the widely acknowledged advantages of the symbioses to nutrition efficiency (for both macronutrients, especially P, and micronutrients), water balance, and the protection of plants from biotic and abiotic stress, there is growing interest in the use of mycorrhiza to promote sustainable agriculture. A biofertilizer called Vesicular Arbuscular Mycorrhiza Root Inoculant (VAMRI) uses chopped, dried maize roots that have been infected with *Glomus species* (*G. mosseae* or *G. fasciculatum*). This product works as a microbial inoculant as well as a biocontrol agent for a variety of crops' soil-borne illnesses. Pepper, tomato, papaya, onion, maize, peanuts, sugarcane, eggplant, banana, and other fruit crops are among the crops for which VAMRI may be used.

CONCLUSION

Microbial consortia that are specifically adapted to a crop's needs and the soil's characteristics increase the effectiveness of biofertilizers by optimizing nutrient absorption and increasing crop yields. In the end, their mechanism of action whether via nitrogen fixation, phosphate solubilization, or nutrient mobilization supports resilient and sustainable agriculture by improving the health of the soil and the nutrition of plants. Commonly used biofertilizers are essential for decreasing reliance on chemical fertilizers, preventing soil erosion, and fostering environmentally friendly and ethical farming in a world where the ecological impact of agricultural activities is being closely scrutinized. Commonly used biofertilizers serve as crucial instruments for improving soil health, crop production, and the long-term sustainability of our planet as we advance in our pursuit of sustainable and ecologically aware agriculture.

REFERENCES:

[1] N. O. Igiehon en O. O. Babalola, “Biofertilizers and sustainable agriculture: exploring arbuscular mycorrhizal fungi”, *Applied Microbiology and Biotechnology*. 2017. doi: 10.1007/s00253-017-8344-z.

[2] H. Korir, N. W. Mungai, M. Thuita, Y. Hamba, en C. Masso, “Co-inoculation effect of rhizobia and plant growth promoting rhizobacteria on common bean growth in a low phosphorus soil”, *Front. Plant Sci.*, 2017, doi: 10.3389/fpls.2017.00141.

[3] J. Kowalska, A. Niewiadomska, K. Głuchowska, en D. Kaczmarek, “Impact of fertilizers on soil properties in the case of solanum tuberosum L. During conversion to organic farming”, *Appl. Ecol. Environ. Res.*, 2017, doi: 10.15666/aeer/1504_369383.

[4] I. KHAN, D. SINGH, en B. L. JAT, “Effects of biofertilizers on plant growth and yield characters of Pisum sativum L.”, *Adv. Res. J. Crop Improv.*, 2017, doi: 10.15740/has/arjci/8.1/99-108.

[5] A. Jabeen *et al.*, “Technology of Organic production of spinach beet (Beta vulgaris var. bengalensis) through the use of manures and biofertilizers”, *~ 10 ~ J. Pharmacogn. Phytochem.*, 2017.

[6] “Beneficial microbiomes: Biodiversity and potential biotechnological applications for sustainable agriculture and human health”, *J. Appl. Biol. Biotechnol.*, 2017, doi: 10.7324/jabb.2017.50607.

[7] J. F. Da Silva, A. Da Cunha Honorato, M. A. Á. Queiroz, M. M. Da Costa, en A. M. Yano-Melo, “Morphogenic, structural, and productive characteristics of Cenchrus ciliaris L. grown using different levels of caprine and ovine biofertilizer”, *Semin. Agrar.*, 2017, doi: 10.5433/1679-0359.2017v38n1p355.

[8] A. Aponte, O. Castillo, G. Cabrera, M. Pernia, en Y. Hernandez, "Rhizobacteria Pseudomonas fluorescens and Azospirillum sp. association enhances growth of Lactuca sativa L. under tropical conditions", *J. Cent. Eur. Agric.*, 2017, doi: 10.5513/JCEA01/18.2.1916.

[9] A. S. Sánchez, Y. L. Silva, R. A. Kalid, E. Cohim, en E. A. Torres, "Waste bio-refineries for the cassava starch industry: New trends and review of alternatives", *Renewable and Sustainable Energy Reviews*. 2017. doi: 10.1016/j.rser.2017.02.007.

[10] S. Aechra, B. D. Ghosalya, J. Singh Bamboriya, en B. L. Yadav, "Effect of soil salinity, phosphorus and biofertilizers on physical properties of soil, yield attributes and yield of cowpea [Vigna unguiculata (L.) Wilczek]", ~ *1691 ~ J. Pharmacogn. Phytochem.*, 2017.

CHAPTER 5

A COMPREHENSIVE REVIEW OF PLANT-GROWTH-PROMOTING RHIZOBACTERIA (PGPR)

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ABSTRACT:

A class of helpful soil microorganisms known as Plant-Growth-Promoting Rhizobacteria (PGPR) has attracted growing interest in contemporary agriculture. This essay looks at a number of PGPR-related topics, including their characteristics, modes of operation, agricultural uses, and importance to sustainable farming methods. This study intends to shed light on the critical function of PGPR in increasing plant development and agricultural production via a thorough examination of recent research and market trends. Their crucial function in contemporary agriculture and sustainable farming methods is made clear by the research of Plant-Growth-Promoting Rhizobacteria (PGPR) PGPR are a broad collection of soil microorganisms that improve plant development, nutrient absorption, and disease resistance. They are distinguished from other soil microbes by their advantageous interactions with plants. Improved plant health and crop output are a result of the modes of action used by PGPR, such as nitrogen fixation, phosphate solubilization, and the synthesis of growth-promoting compounds.

KEYWORDS:

Farming Methods, Market Trends, PGPR, Phosphate Solubilization, Rhizobacteria.

INTRODUCTION

Plant-growth-promoting rhizobacteria, or PGPR, are a class of rhizosphere bacteria (rhizobacteria) that have a positive impact on plant development. The abbreviation PGPR refers to microorganisms that, in some often-unidentified manner, may promote plant development. Agrobacterium, Achromobacter, Alcaligenes, Arthrobacter, Actinoplanes, Azotobacter, Bacillus, Pseudomonas sp., Rhizobium, Bradyrhizobium, Erwinia, Enterobacter, Amorphosporangium, Cellulomonas, Flavobacterium, Streptomyces, and Xanthomonas are a few genera they belong to. These bacteria have a variety of mechanisms for promoting plant development, but they often have an impact on growth via phosphate solubilization, improved nutrient absorption, the creation of plant growth hormones, or the manufacture of several antimicrobial compounds with various modes of action. In oilseed rape (Brassica napus), demonstrated that a rhizobacterium from the genus Achromobacter may increase the quantity and length of root hairs. The absorption of NO_3 and K was accelerated by Achromobacter, resulting in increases in the shoot and root dry weights of 22 to 33 percent and 6 to 21 percent, respectively. Rhizobacteria produce antimicrobial metabolites such siderophores, antibiotics, cyanides, fungal cell-wall-degrading enzymes, and gaseous products like ammonia, which serve as antagonists against phytopathogenic microorganisms and promote plant development. The creation of several antimicrobial substances with various modes of action is the mechanism behind antifungal actions. Cytolysis, potassium ion leakage, disturbance of membrane structural integrity, reduction of mycelial development, and protein biosynthesis all contribute to the antagonistic effects. The majority of the *Pseudomonas biocontrol* strains that have been found generate antifungal metabolites such phenazines, pyrrolnitrin, pyoluteorin, and cyclic lipopeptides like viscosinamide. Viscosinamide has been shown to protect sugar beet against *Pythium ultimum* infection. These bacterial strains affect the defense mechanism of plants in addition to having an antagonistic impact. One of the processes behind *Pseudomonas spp.'s* antagonistic action is the siderophore-mediated competition for iron. The ferric ions (Fe^{3+}) that are bound by the secreted iron-chelating chemicals are then taken up by microbial cells via particular membrane protein recognition, because iron-chelating chemicals are present, bacteria are stronger iron competitors, which inhibits the development of harmful microbes. The two forms of siderophores produced by *Pseudomonas species* are pseudobactin and pyoverdin Because the siderophores made by biocontrol bacteria have a greater affinity for iron than certain fungal infections' do, the former microorganisms may scavenge the majority of the iron that is available and stop the growth of fungal diseases [1], [2].

According to some scientists, *Pseudomonas fluorescens* of the PGPR class generates siderophores and inhibits the growth of *P. ultimum, R. batatticola*, and *Fusarium oxysporum*. Chitinase and laminase, produced by other *Pseudomonas species* like *Pythium stutzeri*, are extracellular enzymes that may lyse the mycelia of *Fusarium solani*. Under iron-limited circumstances, *Pseudomonas aeruginosa* generates three different forms of siderophores, including pyoverdine, pyochelin, and its precursor salicylic acid. It also promotes plant disease resistance in the form of *Colletotrichum lindemuthianum* on beans and *Botrytis cinerea* on tomatoes. Numerous commercially significant crops are susceptible to vascular wilt, foot, root, and bulbrot diseases brought on by *F. oxysporum*. Leaf spots, root rot, and stem rot are also caused by *Alternaria spp.* and *Sclerotium spp.*, which result in significant yield losses. Many environmental and genetic variables affect the antifungal activity of PGPRs. Environmental cues from the biotic and abiotic realms may play a significant role in the regulation of biocontrol genes in pseudomonads, such as the inhibition of siderophore production. Low oxygen levels and the nearby carbon and nitrogen sources that affect the molecular processes are both factors in the biocontrol action [3], [4].

Composting is a managed microbial bio-oxidative process that turns organic biodegradable wastes into a sanitary, humus-rich product (compost) that may be used as an organic fertilizer and soil conditioner. It is a solid waste treatment that is affordable, effective, and sustainable. Temperature, moisture content (usually 40–60% by weight), the amount of oxygen needed to create an aerobic atmosphere (generally 5% or more), particle size, the C/N ratio, and the amount of turning required are all elements that affect the process. The composting process will go much more quickly if these components are properly managed. A broad range of agricultural, animal, human, and industrial wastes may decompose aerobically, anaerobically, or partly aerobically to form compost, which is an organic manure or fertilizer. There is a long history of composting practically everywhere in the globe. Although it has also been used for millennia in India and Europe, it was a key idea in early Chinese agriculture. Typically containing less than 2% (w/w) of nitrogen, phosphorous, and potassium (N:P:K), compost is a black, crumbly, earthy substance. Additionally, it contains tiny earthworms, bacteria, fungus, and dung beetles. A symbiotic food web develops as a result of this mixing in the soil. The decaying matter keeps the soil wet while feeding the organisms and aiding in soil aeration. Depending on the kind of compostable feedstock used, the nutritional content of composts varies greatly [5], [6].

Vermicompost is a crucial kind of compost that includes organic materials, plant nutrients, earthworm cocoons, excrement, advantageous microorganisms, actinomycetes, enzymes, hormones, etc. It is an all-natural fertilizer made by earthworms that typically comprises 0.6% N, 1.5% P_2O_5, and 0.4% K_2O. It is a source of micronutrients in addition to NPK, with an average of 22 mg/kg Fe, 13 mg/kg Zn, 19 mg/kg Mn, and 6 mg/kg Cu. It aids in the energy-efficient and cost-effective recycling of industrial wastes, agricultural wastes, and animal wastes (including chicken, horse, pig, and cow dung).

DISCUSSION

Many different factors are often used to assess compost quality. These variables typically include the germination index (GI), total organic matter (TOM) content, pH, electrical conductivity (EC), water-soluble organic carbon (WSOC), and water-soluble organic nitrogen (WSON). The compost maturity must be evaluated by a combination of different physical, chemical, biological, and chemical-physical (odour, color, temperature, and particle size), biological (microbial activity indicators such as respiration, ATP content, enzyme activity, microbial biomass, and nitrogen mineralization), and chemical (C/N ratio, mineral N, pollutants content (heavy metals and organics)).

The mature compost typically has a pH around 7.5 and a C:N ratio between 10:1 and 20:1. The temperature within the pile is the same as the temperature outside. Compost has an earthy odor, does not heat up when stirred or watered, resembles black soil, and is devoid of recognizable food items, leaves, or grass. When immature compost is applied to soil, it inhibits seed germination, destroys roots, and lowers the O_2 concentration and redox potential, necessitating the evaluation of the compost's maturity. Composts (organic manure) and compost extracts are excellent soil amendments because they have a positive impact on plant development when added to the soil. Application of compost is a well-liked technique for enhancing the physical characteristics of soil and providing plant nourishment. Additionally, it increases the variety of soil microbes by supplying nutrients rich in organic carbon to the microbial biomass, which transforms inaccessible nutrients in plant wastes into ones that can be used by crops. Organic fertilizers (animal or plant-based) are a great way to increase the natural microbial population since they also stimulate the soil's and the plant's rhizosphere's natural microflora. Contrary to synthetic fertilizers, composts release nutrients slowly over months or years, including macro- and micronutrients that are often lacking in synthetic fertilizers. Composts act as a soil buffer, neutralizing both acidic and alkaline soils to bring pH levels to the ideal range for plant nutrient availability. Aggregates groups of soil particles that are bound together help give soil its desirable structure. Such soil is packed of holes and small air channels that may contain nutrients, moisture, and air. This facilitates soil manipulation and aids in erosion prevention. Low soil fertility often leads to erosion. Humus found in compost has the ability to bond to soil, creating a solid structure that promotes maximum fertility and erosion resistance. Bioremediation is a relatively recent use for compost. Soils, reservoirs, and surface waterways are all susceptible to contamination. Contaminants in soil or water are digested, metabolized, and converted into humus and benign byproducts like carbon dioxide, water, and salts by the microorganisms in compost. Chlorinated and non-chlorinated hydrocarbons, wood-preserving agents, solvents, heavy metals, pesticides, petroleum products, and explosives may all be altered or degraded via compost bioremediation.

Different decomposing microbes having cellulolytic/lignolytic activity, such as *Trichoderma viridae, Aspergillus niger, Aspergillus terreus, Bacillus sp.,* etc., break down diverse animal/plant wastes, such as dead plants, farm yard trash, and cow manure, during composting. Bacterial populations with a high percentage of Gram-negative cultures may flourish in compost. Some isolates exhibit proteolytic activity, which is thought to be a possible strategy for preventing or out-competing other germs. Pseudomonas, Serratia, Klebsiella, and Enterobacter are the main gram-negative species found in mature compost. *Bacillus species* are used to identify all Gram-positives. Carbon, nitrogen, and oxygen are important components needed for composting microbes, in addition to moisture. The bacteria won't thrive and won't produce enough heat if any of these components are missing or aren't delivered in the right amounts. When a composting process runs at peak efficiency, organic waste is transformed into stable compost that is free of pathogens and odors, as well as being a poor breeding ground for flies and other insects. Additionally, since a large portion of the biodegradable component is converted to gaseous carbon dioxide during the composting process, it will greatly decrease the volume and weight of organic waste [7], [8].

Temperature, moisture, oxygen, oxygen content, particle size, the carbon-to-nitrogen ratio, and the amount of turning that takes place all affect how long composting takes. The composting process will typically be sped up by proper control of these components. Mesophiles are bacteria that like a moderate temperature, whereas thermophiles prefer a high temperature. Composting often starts off at mesophilic temperatures and moves up into the thermophilic range. This is a result of the exothermic, oxidative metabolism of microbes, which raises the temperature of organic matter to 65–75 °C over the course of up to 10 days. Pathogens, thermolabile microbial agents, and plant toxins seem to be eliminated during the thermophilic stage of composting. Temperature and biological activity inside the composting system are inversely correlated. The temperature in the system rises as the microorganisms' metabolic rate quickens. On the other hand, the system temperature drops as the bacteria' metabolic rate rises. Not every organic material is entirely broken down. The final stable compost includes modified lignin, lignocellulosic material, and other plant components. Sap and soluble plant exudates biodegrade more quickly. The compost's biological activity slows down when the most easily decomposable organic material is eaten, which also lowers temperatures and oxygen consumption. The compost subsequently moves into the curing phase, when decomposition slows down and organic matter is transformed into humic compounds that are stable—the completed or mature compost. Crop wastes are biodegradable material, however although being rich in carbon, they lack nitrogen. Animal waste, on the other hand, tends to be low in carbon content and high in nitrogen.

Following the inoculation of biological control agents that are especially effective against a plant disease, compost may be changed into suppressive compost. Because the latter are killed by high temperatures during active composting, composts are not regularly or organically colonized by a wide range of biocontrol agents. Biocontrol agents must recolonize composts throughout the curing process in order to be effective, however this does not always happen. For instance, composts generated adjacent to a forest are considerably more likely than those produced in an enclosed system to be colonized by efficient biocontrol agents and to consistently inhibit rhizoctonia infections. Biocontrol agents are microbes that have a propensity for colonizing and lysing plant pathogens.

The four control mechanisms used by the microorganisms that are encouraged by compost amendments antibiosis, competition, parasitism, and induced systemic resistance help the modified soil to inhibit the activity of the microorganisms. Antibiosis is the process by which a metabolic byproduct, such as an antibiotic generated by another organism, prevents the development of one organism. Agrocin, a bacteriocin produced by *Agrobacterium radiobacter*, is a widely used commercial medicine for treating crown gall, a devastating disease that affects many other woody plants as well as nursery-grown stone fruit trees. Numerous lytic enzymes are known to be produced by Lysobacter and Myxobacteria, and several isolates have been shown to be efficient at inhibiting fungal plant diseases. Different microorganisms' expression and release of these enzymes may sometimes directly decrease the activities of plant pathogens. For instance, *Serratia marcescens'* influence on *Sclerotium rolfsii* seems to be mediated via the expression of chitinase. Some byproducts of lytic enzyme activity may help indirectly decrease illness. For instance, it is well known that oligosaccharides produced from fungal cell walls are powerful inducers of plant host defenses. *Lysobacter enzymogenes* strain C3's biocontrol capabilities considerably benefit from the enzyme 1,3-glucanase [9], [10].

Competition occurs when microbes contend with one another for resources including oxygen, high-energy carbohydrates, nitrogen, and iron as well as for infection sites. Parasitic fungi that enter plant diseases and cause lysis and death are an example of parasitism. Applying isolates of *Trichoderma species* together with any of numerous bacterial biocontrol agents can effectively control *Rhizoctonia solani*. The primary microorganism recovered from compost made from lignocellulosic wastes and capable of parasitizing *Rhizoctonia solani* are members of the Trichoderma genus. The stimulation of the synthesis of plant metabolites like salicylic acid, defense-related proteins, or other substances that result in systemic plant resistance to pathogens forms the basis of the process of induced systemic resistance. *Some Pseudomonas sp.* and *Trichoderma sp.* biocontrol strains are known to significantly stimulate plant host defenses. Plant-growth-promoting rhizobacteria (PGPR) inoculations have been successful in a number of cases in controlling multiple diseases, including bacterial wilt (*Erwinia tracheiphila*), angular leaf spot (*Pseudomonas syringae pv. lachrymans*), and anthracnose (*Colletotrichum lagenarium*).

The composition and carbon-to-nitrogen ratio of the soil organic matter, which acts as a food supply for microbial communities in the soil and rhizosphere, is expected to have an impact on the quantitative contribution of biologically active chemicals to disease suppression. Such actions may be controlled, however, to more effectively inhibit illness. It is necessary to increase the activity of relevant antagonists when they are already present in the soil or substrate but do not adequately control the illness. For instance, the inclusion of chitosan may encourage the microbial breakdown of pathogens in a manner similar to that of an applied hyperparasite in the management of post-harvest illness. Chitin is converted into the non-toxic and biodegradable beta-1,4-glucosamine polymer known as chitosan by an alkaline deacylation process. Chitosan amendment to the plant development medium prevented tomato root rot brought on by *Fusarium oxysporum f. sp. radicis-lycopersici*.

Chitosan therapy has been shown to promote pathogen resistance, even if the precise mechanism of action is not entirely known. The degree to which composts control this disease varies with compost maturity and is dependent on the chemical-physical makeup of the composted components. In order to add biofertilizers to the soil, either "seed inoculation," in which the inoculant (a bacteria-carrier combination) is combined with water to create a slurry-form and then mixed with seeds, or "soil inoculation," or spreading over the field during cultivation, is used. When inoculating seeds, the carrier must take the form of a fine powder. Use of an adhesive, such as gum a sucrose solution, and vegetable oils, is advised to establish a tight covering of inoculant on the seed surface. Due to poor nodule occupancy or low establishment of the injected rhizobacterial strain as a consequence of the inoculation, seed inoculations may not always be effective. This might be as a result of the injected bacterial strain's low population and/or poor survival on the seed surface and in the soil. In this case, "soil inoculation" will be used, which allows for the introduction of a significant number of a particular bacterial strain into the soil. Granular inoculant is inserted into the furrow underneath or next to the seed for soil inoculation in general. The likelihood of the inoculated strain coming into touch with plant roots is increased as a result. As carriers for seed or soil inoculation, several sorts of materials are used. As carrier materials, peat soil, lignite, vermiculite, charcoal, press mud, farmyard manure, and soil mixture may all be employed. For the creation of biofertilizers, neutralized peat soil and lignite are discovered to be preferable carrier materials. The carrier material is ground into a fine powder with a particle size of between 10 and 40 microns in order to prepare the seed inoculant. Granular carrier material (0.5-1.5 mm) is often utilized for soil inoculation. For soil inoculation, granular types of peat, perlite, charcoal, or soil aggregates are acceptable.

Two fundamental factors the quantity of cells and the ability of the microorganisms to fix nitrogen or solubilize phosphates determine the potency of biofertilizers. Liquid biofertilizers are formulations that include the required microorganisms in their latent state, together with their nutrients and compounds that promote the creation of dormant spores or cysts for a longer shelf life and greater resistance to stress. When the dormant forms are introduced to the soil, they begin to germinate and create a new batch of active cells. By consuming the carbon supply in the soil or via root exudates, these cells develop and proliferate. The Department of Agricultural Microbiology, TNAU, Coimbatore, has developed liquid formulation technology as an alternative to traditional carrier-based biofertilizers. This method offers more benefits than carrier-based inoculants. The following is a list of the benefits of liquid biofertilizers over traditional carrier-based biofertilizers: Higher potential to compete with native populations; High populations can be maintained at more than 109 cells/ml up to 12 to 24 months; Easy identification by typical fermented smell; Cost savings on carrier material, pulverization, neutralization, sterilization, packing, and transport; and longer shelf life, 12 to 24 months.

The idea of effective microorganisms (EM), which are accessible in liquid form, as one of the methods to generate biofertilizer in 1991. The main types of microorganisms found in the EM include yeast, lactic acid bacteria, filamentous fungus, and various soil bacteria. The purpose of applying EM is to act as a microbial inoculum to the soil, aiding in the establishment or restoration of soil ecosystems. Commercially, EM is offered in a concentrated form that must be processed before use. The concentrated form of EM (EM Bokashi), when combined with molasses and water, may be utilized right away, as advised by the EM producer. To make either liquid or solid biofertilizer, the typical procedure is to ferment the raw ingredients using EM Bokashi as a starter. On farms, leftover plant or animal products are a frequent source of raw materials. The product should be utilized within three months, and the fermentation phase should last at least seven days. Due to the ease for small-scale agricultural or household applications where the users do not have room and raw materials available for fermentation, the manufacturing of ready-to-use liquid biofertilizer from EM is now becoming accessible on the market.

CONCLUSION

The creation of chemicals that encourage growth results in better agricultural yield and plant health. Their use in agriculture, whether as biopesticides or fertilizers, lessens the need for chemical inputs, slows down soil erosion, and encourages environmentally friendly agricultural methods. In the age of sustainable agriculture, PGPR is essential for boosting plant development and agricultural yields while reducing the negative effects of farming on the environment. PGPR continues to be a viable instrument for boosting agricultural output and maintaining food security in a changing world as we investigate new and sustainable farming techniques. Their significance arises from their contribution to environmentally friendly farming and the worldwide initiative to develop robust and sustainable agricultural systems.

REFERENCES:

[1] N. Xiang, K. S. Lawrence, J. W. Kloepper, P. A. Donald, en J. A. McInroy, “Biological control of Heterodera glycines by spore-forming plant growth-promoting rhizobacteria (PGPR) on soybean”, *PLoS One*, 2017, doi: 10.1371/journal.pone.0181201.

[2] T. M, "Antagonistic features displayed by Plant Growth Promoting Rhizobacteria (PGPR): A Review", *J. Plant Sci. Phytopathol.*, 2017, doi: 10.29328/journal.jpsp.1001004.

[3] C. Kenneth, "International Journal of Advanced Research in Biological Sciences Plant Growth Promoting Rhizobacteria (PGPR): A Bioprotectant bioinoculant for Sustainable Agrobiology. A Review", *Int. J. Adv. Res. Biol. Sci*, 2017.

[4] S. Kalam, S. N. Das, A. Basu, en A. R. Podile, "Population densities of indigenous Acidobacteria change in the presence of plant growth promoting rhizobacteria (PGPR) in rhizosphere", *J. Basic Microbiol.*, 2017, doi: 10.1002/jobm.201600588.

[5] Y. Kang, M. Shen, D. Xia, K. Ye, Q. Zhao, en J. Hu, "Caution of intensified spread of antibiotic resistance genes by inadvertent introduction of beneficial bacteria into soil", *Acta Agric. Scand. Sect. B Soil Plant Sci.*, 2017, doi: 10.1080/09064710.2017.1314548.

[6] A. H. Ahkami, R. Allen White, P. P. Handakumbura, en C. Jansson, "Rhizosphere engineering: Enhancing sustainable plant ecosystem productivity", *Rhizosphere*. 2017. doi: 10.1016/j.rhisph.2017.04.012.

[7] G. Ilangumaran en D. L. Smith, "Plant growth promoting rhizobacteria in amelioration of salinity stress: A systems biology perspective", *Frontiers in Plant Science*. 2017. doi: 10.3389/fpls.2017.01768.

[8] S. Dorjey, D. Dolkar, en R. Sharma, "Plant Growth Promoting Rhizobacteria Pseudomonas: A Review", *Int. J. Curr. Microbiol. Appl. Sci.*, 2017, doi: 10.20546/ijcmas.2017.607.160.

[9] G. R. Kudoyarova *et al.*, "Effect of auxin producing and phosphate solubilizing bacteria on mobility of soil phosphorus, growth rate, and P acquisition by wheat plants", *Acta Physiol. Plant.*, 2017, doi: 10.1007/s11738-017-2556-9.

[10] K. E. Gerhardt, G. J. MacNeill, P. D. Gerwing, en B. M. Greenberg, "Phytoremediation of salt-impacted soils and use of plant growth-promoting rhizobacteria (PGPR) to enhance phytoremediation", in *Phytoremediation: Management of Environmental Contaminants, Volume 5*, 2017. doi: 10.1007/978-3-319-52381-1_2.

CHAPTER 6

STRATEGIC ROLE OF NANOTECHNOLOGY IN DEVELOPMENT OF FERTILIZERS

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ABSTRACT:

Particularly in the area of fertilizers, nanotechnology has emerged as a paradigm-shifting strategy in agriculture. This essay investigates the use of nanotechnology in fertilizers, including its concepts, nanomaterials, delivery systems, and promise to transform sustainable agriculture and nutrient management. This study intends to provide insights into the importance and potential applications of nanotechnology for fertilizers in contemporary agriculture via a thorough evaluation of scientific papers and research results. The study of nanotechnology for fertilizers highlights its revolutionary potential in contemporary agriculture and environmentally friendly agricultural methods. Nanotechnology provides creative approaches for effective nutrition delivery and management via the use of nanoparticles. The improved solubility, controlled release, and targeted delivery of nanoscale nutrients and transporters to plants.

KEYWORDS:

Agriculture, Biofertilizer, Nanomaterials, Nutrient Management, Sustainable Farming.

INTRODUCTION

Building the foundations of the multidisciplinary science of nanotechnology, human capacity to create and control materials at the nanoscale has expanded dramatically during the last ten years. Due to their tiny size, great mobility, and low toxicity, nanomaterials act differently than the same material when it is not being used in nanotechnology. They have a high surface area to volume ratio, are highly soluble, and are targeted specifically. They may be designed for surface reactivity or other desirable qualities, exhibiting unusual behavior that can be lucrative as well as beneficial. As of March 2011, nanoparticles were included in more than 1300 commercially accessible items. In 2015, the market for nanotechnology was worth $1 trillion.

According to the National Nanotechnology Initiative (NNI), "Nanotechnology research and development is directed towards understanding and creating improved materials, devices, and systems that exploit nanoscale properties. According to the Royal Society's definition, "Nanotechnologies are the design, characterization, production, and application of structures, devices, and systems by controlling shape and size at the nanometer scale." After the biotechnology and green revolutions of the 1990s and the 1960s, nanotechnology has recently emerged as the sixth revolutionary technology. Utilizing tools and materials that may change a substance's physical and chemical characteristics at the molecular level is known as nanotechnology. It is a unique scientific method. As a result of the fusion of science and technology, the fields of electronics, energy, remediation, transportation, space technology, and life sciences have all seen revolutionary advances. Nanotechnology has a vast range of possible applications and advantages. Nanotechnology is now gradually moving from the experimental into the practical fields. It promises to make a significant contribution to agricultural research, among other things, by helping to solve significant agricultural issues like the detection of pollutants, plant diseases, pests, and pathogens; the controlled delivery of pesticides, fertilizers, nutrients, and genetic material; and the formation and binding of soil structure. Nanotechnology has shown intriguing applications for precision farming at a time when agricultural scientists are experiencing significant issues including decreased crop productivity, nutritional deficit, and climate change. Wide-ranging uses of this ground-breaking technology include the management of plant diseases, increased nutrient absorption, greater plant development, and prolonged release of agrochemicals. It's interesting to note that a nanoparticle (NP)-based approach has gathered steam and become more widely accepted in the agriculture industry due to its distinct advantages over biopesticides. The use of nanotechnology in agriculture [1], [2].

The use of nanotechnology in managing sustainable agriculture is now widely acknowledged. It has a significant role in changing agriculture and food production. The creation of nanomaterials and nanodevices may lead to innovative uses in agriculture and plant biotechnology. Thus, it is currently essential for advancing the development of environmentally friendly and sustainable agriculture to produce slow/controlled release fertilizers based on nanotechnology. The creation of "smart fertilizer" innovative technologies that improve nutrient usage effectiveness and lower environmental protection costs results from using nanoscale or nanostructured materials as fertilizer transporters. The recent surge in global population has made it necessary to increase agricultural production in order to meet the requirements of billions of people for food. On the one hand, farmers suffer enormous financial losses due to the growing nutrient deficiencies in soils, and on the other, the nutritional value of grain for food and feed is significantly reduced. Although fertilizers also play a part in increasing food production, particularly with the advent of high yielding and fertilizer-responsive crop types, they may increase agricultural output [3], [4].

The most common methods for applying conventional fertilizers to crops are broadcasting or spraying. The actual final concentration of the fertilizers in the plants is a crucial variable that affects the manner of delivery. Chemical types of nutrients included in conventional fertilizers prevent plants from completely using them. Additionally, the relatively poor use of the majority of the macronutrients is caused by the inversion of these compounds to insoluble form in soil. Due to chemical leaching, drift, runoff, evaporation, hydrolysis by soil moisture, and photolytic and microbiological degradation, a concentration substantially lower than the lowest intended one reaches the targeted location. According to estimates, the nitrogen, phosphorous, and potassium contents of applied fertilizers are lost in the environment and never make it to the plant at all. The constant use of fertilizers is added to these issues. The International Fertilizer Industry Association reports that with growth rates of 5-6% in 2009–2010 and 2010–2011, the global fertilizer consumption substantially increased. By 2016–2017, the global demand is anticipated to reach 192.8 Mt. Repeated usage, in turn, degrades the soil's natural nutrient balance and causes environmental pollution that harms common flora and wildlife. According to reports, excessive fertilizer usage decreases soil microflora, hinders nitrogen fixation, promotes disease and insect resistance, leads to the bioaccumulation of chemicals, and damages bird habitats. This cycle of death results in long-term and substantial losses [5], [6].

It is generally known that uneven fertilization and a decline in soil organic matter have caused yields of several crops to start to decline. Additionally, excessive nitrogen and phosphorus fertilizer applications harm the groundwater and cause eutrophication in aquatic environments. The residual minerals might either seep and get fixed in the soil or leach down and contribute to air pollution. In light of these facts, it is clear that using chemical fertilizers on a broad scale to boost agricultural output is not a sustainable solution. Even while traditional fertilizers boost crop output, they disrupt the soil's mineral balance and reduce soil fertility, especially over the long term. In addition to causing permanent harm to the soil structure and mineral cycles, excessive use of chemical fertilizers also degrades the soil microflora, plants, and subsequently the food chains throughout ecosystems, resulting in heritable mutations in subsequent generations of consumers. In order to meet the nutritional needs of crops and reduce the chance of environmental damage, it is urgently necessary to maximize the use of chemical fertilization. Therefore, it is crucial to create intelligent materials that can deliver chemicals in a controlled manner to particular target places in plants. This might help to reduce food insecurity in agriculture, preserve the integrity of the soil, and contribute to a cleaner environment. In this situation, the nano-fertilizers offer a potential option.

DISCUSSION

A product that supplies nutrients to crops on a nanoscale scale is referred to as a "nano-fertilizer." The use of nano-fertilizers is a new development. Nano-fertilizers may be used as a replacement for conventional fertilizer application techniques in order to deliver nutrients into the soil gradually and under regulated conditions. As a result of site-specific delivery, reduced toxicity, and improved nutrient uptake, nano-fertilizers demonstrate regulated release of agrochemicals. They have special qualities that improve plants' productivity in terms of very high absorption, growth in production, increase in photosynthesis, and noticeably increased leaf surface area. Additionally, the regulated release of nutrients helps to stop eutrophication and water resource contamination.

Nutrients may be given as emulsions or nanoparticles in nano-fertilizers, covered with a thin layer of protection, or enclosed in nanomaterials. There are several applications for nano-fertilizers in high throughput. Therefore, treatment of maize with TiO_2 nanoparticles had a significant impact on growth, but the effect of treatment with TiO_2 bulk was minimal. The transmission of photons and the absorption of light were both enhanced by titanium nanoparticles. In a different experiment, a mixture of SiO_2 and TiO_2 nanoparticles boosted soybean nitrate reductase activity and boosted plant absorption capacity, improving the efficiency of the plant's use of water and fertilizer.

It has been shown that nano-organic iron-chelated fertilizer is ecologically responsible. The favorable impact of ZnO_2 nanoparticle uptake and penetration on tomato plants' leaves supports its possible usage as a nano-fertilizer in the future. The efficiency of nutrient intake may be increased using nano-fertilizers that enable delayed, focused, effective release. Engineered nanoparticles may improve crop yield by improving the availability of nutrients in the rhizosphere and reducing the persistent issue of moisture retention in dry soils. Nanoparticle coating and binding aid in controlling how quickly nutrients are released from the fertilizer capsule. Application of a nitrogen, phosphorus, potassium, micronutrient, mannose, and amino acid-rich nano-composite improved the absorption and utilization of nutrients by grain crops. Chemicals that influence plant development have been released under controlled conditions using Zn-Al layered double hydroxide nanocomposites. To increase the effectiveness of nitrogen utilization in agricultural production systems, an alternative technique that uses nano-porous zeolite-based nitrogen fertilizer may be applied. Carbon nanotubes were discovered to enter tomato seedlings as super fertilizer, affecting their germination. The formulation of the nano-fertilizers should keep crucial characteristics like high solubility, stability, efficacy, time-controlled release, increased targeted activity with effective concentration, and decreased eco-toxicity owing to the safe, simple means of delivery and disposal.

The nanoparticles have enormous promise for the precise delivery of nutrients to biological systems. Most often, they may be nutrient-loaded in one of the following ways: The utilization of chitosan nanoparticle suspensions containing N, P, and K fertilizers in agricultural applications has thus been shown. Similar to this, urea-modified hydroxyapatite (HA) nanoparticles are used to release nitrogen slowly and continuously over time as crops develop. Urea can adhere to the huge surface area of HA with ease, and the strong interaction between HA nanoparticles and urea helps to slow down and regulate the release of urea. Mesoporous nanoparticles made of polymers may act as effective carriers for agrochemical chemicals. Urea has been shown to be trapped by mesoporous silica nanoparticles (150 nm) and released in a controlled way in soil and water [7], [8].

The development of technology has enhanced methods for the mass manufacture of physiologically significant metal nanoparticles, which are currently employed as "smart delivery systems" to enhance fertilizer formulation by reducing nutrient loss and improving absorption in plant cells. To bypass biological obstacles and enable effective targeting, "smart delivery system" refers to a mix of highly controlled, remote regulation, multifunctionality, and especially targeted characteristics. Because of their large surface area, sorption capacity, and controlled-release kinetics to specified areas, nano-fertilizers are considered smart delivery systems. Through the use of nanotechnology in the reformulated formulation of traditional goods, smart fertilizers are becoming a reality. A fertilizer may intelligently manage the rate at which nutrients are released to conform to the absorption pattern of a particular crop thanks to the nanostructured composition. It enhances the bioavailability, which increases nutrient uptake efficiency, as well as the solubility and dispersion of insoluble nutrients in soil. It also decreases soil absorption and fixation.

The utilization of well-known microbial technologies and methods for scaling up the acquisition of biomass are only two of the numerous benefits of using biotechnological methods for the synthesis of nanoparticles. The capacity to quickly cover huge surface areas by the appropriate development of the microorganisms is leading to economic viability, which is a key benefit in the sector of agriculture for the simpler manufacturing of bio-fertilizers. The adoption of such technologies at a wide scale is particularly challenging due to the drawbacks of conventional methods for generating metal nanoparticles, such as high energy and cost manufacturing needs as well as the development of harmful byproducts. A clever alternative method of synthesizing metallic nanoparticles is to exploit the cell factories produced by microorganisms like bacteria, fungus, algae, viruses, and actinomycetes. These bacteria produce metallic nanoparticles using an expensive and environmentally beneficial process called biosynthesis. Numerous prokaryotic and eukaryotic microorganisms are used in the synthesis of a wide variety of metal nanoparticles, including gold (Au), silver (Ag), lead (Pb), platinum (Pt), copper (Cu), iron (Fe), cadmium (Cd), and metal oxides like titanium oxide (TiO) and zinc oxide (ZnO), among others.

These bacteria constitute a diverse environment for the creation of nanoparticles. The generated nanoparticles have several uses and are very beneficial, secure, and environmentally benign. The most popular nanoparticles used in agriculture as bio effectors are copper (Cu), iron (Fe), silver (Ag), and gold (Au). Future obstacles in this regard include optimum biosynthesis of nanoparticles with specified size and shape as well as optimum fermentation process length to increase the durability of the particles. In the biogenesis of nanoparticles, components such as enzymes, proteins, polysaccharides, and others function as reducing and stabilizing agents. They may be used in the procedure as entire microorganism cells, unpurified or crude cell preparations, or unpurified enzymes derived from the microbes. The primary source of the acquired nanoparticles is bioreduction, which is carried out by co-enzymes such NADH, NADPH, FAD, etc. According to research, isolated enzymes from the same fungus strain are substantially more expensive to use in the creation of nanoparticles than complete fungus cells.

Reactions that promote the production of nanoparticles: To prevent incorrect byproduct reactions, the biosynthesis of nanoparticles is started by collecting microbial biomass, which is connected to leftover nutrients and metabolites. The production rate and product yield are particularly important for scaling-up operations, and optimization is required (e.g., production time, pH, temperature, etc.). The process of optimizing these variables may have an impact on the shape and characteristics of the particles. As a result, current research focuses on setting up the ideal reaction conditions as well as the machinery used in the bioreduction process (Syed, PhD Thesis).

The growing circumstances of the microorganisms that make the nanoparticles, such as nutrients, pH, temperature, etc., affect the biosynthesis of the nanoparticles. It's important to maximize these variables. They are crucial when employing entire cells and unprocessed enzymes. The harvesting period is a crucial factor in inoculum optimization, thus it's critical to keep an eye on the enzyme activities as development progresses. Examining the possibility for nano-farming using microbial nanoformulations Microbe-produced nanoparticles are very stable and might replace chemical ones as a non-toxic, economical, and environmentally acceptable method of synthesis. This environmentally friendly synthesis offers several advantages over chemical processes, which have a negative impact on the environment. Therefore, the employment of agriculturally significant microorganisms for the production of nanoparticles and their subsequent involvement in agriculture are of significant importance. Bio-fertilizers and bio-stimulators may be more resistant to desiccation, heat, and UV inactivation if nanoformulations are used.

Uptake, translocation, and fate of nano-fertilizers in plants

An expanding area of study interest is the assimilation and destiny of nano-fertilizers in plants. Nanoparticle absorption, translocation, and accumulation are all influenced by the plant, particularly by its species, age, and environment for growth. Additionally, these processes relate to the nanoparticles' physicochemical characteristics, functionalization, stability, and route of distribution. Several routes of cellular absorption in the plant system along with a graphic illustration of the uptake, translocation, and biotransformation pathway of different nanoparticles. This presentation claims that regardless of a plant's species appurtenance, ZnO_2^+, Cu^{2+}, Al^{3+}, Ag^{2+}, and Fe_3O_4 Nano-Particle (NP), the root system absorbs and translocates to the foliar section of a plant. Additionally, there are indications of species dependency for the translocation of Cu, ZnO, Al, and Ag NPs (all in the leaves), $Ni(OH)_2$ NPs in the stem, and CeO_2 NPs in both the stem and the leaves. It is also hypothesized that the Fe_3O_4 NP has moved somewhere in the stem. The cell wall pore diameter, which ranges from 5 to 20 nm, determines how easily nanoparticles may enter the cell wall. As a result, nanoparticles or aggregates of nanoparticles with a diameter smaller than the pore size of a plant cell wall may readily pass through the cell wall and reach the plasma membrane. In order to increase the absorption of functionalized nanoparticles, the pore size may be increased or new cell wall pores can be induced. The absorption of nanoparticles into plant cells by binding to carrier proteins via aquaporin, ion channels, or endocytosis is a topic of active research [9], [10].

Additionally, by forming interactions with membrane transporter proteins or root exudates, nanoparticles may potentially be absorbed by plants. According to other research, nanoparticles may penetrate a leaf's stomata or trichome base. The mucilage secreted by the roots forms a pectin hydrogel complex surrounding the root, which is most likely what allows the nanoparticle-dye complex to enter the Arabidopsis thaliana seedling during studies on the absorption and translocation of TiO_2-alizarin red S complex. Fluorescently labeled monodispersed mesoporous silica nanoparticles were used in recent studies on the mechanism of nanoparticle uptake and translocation. These particles were shown to penetrate the roots through symplastic and apoplastic pathways and then move through xylem tissue to the aerial parts of the plants, including the stem and leaves. But the precise method by which plants absorb nanoparticles is still not entirely understood. Nanoparticles in the cytoplasm are directed towards various cytoplasmic organelles and obstruct various cell metabolic functions. It has been shown that the parenchyma and vascular tissues of the root are locations where TiO_2 nanoparticles are absorbed by wheat. ZnO nanoparticles in Lolium perenne (ryegrasses) internalize into cells and travel upward via the root cells before reaching the vascular tissues.

When administered at larger concentrations, ZnO nanoparticles become agglomerated, which prevents them from passing through the pores in the cell wall, which restricts their absorption and accumulation. Furthermore, X-ray absorption spectroscopy of seedlings treated with ZnO showed the presence of Zn^{2+} ions rather than ZnO, indicating that the roots play a role in ionizing ZnO on their surface. The behavior of a different class of nanoparticles, magnetite NP, is such that the type of the growing media has an impact on how much of the nanoparticles are absorbed in the root, stem, and leaves. While no absorption was shown in plants cultivated in soil, a larger uptake was attained in hydroponic medium as compared to plants grown in sand, which may be because magnetite nanoparticles attach to soil and sand grains. Finally, it should be noted that the majority of absorption, translocation, and accumulation studies in plants are only reported up to the germination stage, with the exception of a few decisive research on TiO_2 and ZnO nanoparticles. As a result, nothing is known about nanoparticles' destiny in the plant system.

Most recent findings are in favor of the theory that nanoparticles have some negative impacts on plants. There are, however, a few studies that have demonstrated that nanoparticles may help to promote plant growth and yield when given in a safe, regulated amount. In this regard, it has been shown that multi-walled carbon nanoparticles (MWCNP) stimulate tomato seed germination and growth as well as tobacco cell proliferation. MWCNTs from the mustard plant underwent the same phenomena. It was shown that oxidized MWCNPs exert superior effects at lower concentrations than the non-oxidized ones using the so-called germination index and relative time of root elongation as etalon parameters.

Studies comparing the performance of silver nanosilver and silver nitrate for evaluating seed output and preventing leaf abscission in borage plants revealed that the former was performing better. Leaf abscission is known to be significantly influenced by the plant hormone ethylene, which silver ions suppress by taking the place of copper ions in the receptors. It was shown that nanosilver was more effective than silver nitrate at lower concentrations when both compounds were administered to the plants using the foliar spray technique. Many commercially significant plant species have reported that biosynthesized silver nanoparticles have a similar encouraging impact on seedling emergence and different plant growth indices.

The impact of ZnO nanoparticles on the development of various plants has been the subject of several research. Thus, it was demonstrated that ZnO nanoparticle adsorption on the root surface had a stimulating effect on the growth of *Vigna radiata* and *Cicer arietinum*; this was observed through correlative light and scanning electron microscopy, and such by the seedlings through inductively coupled plasma/atomic emission spectroscopy. The cellular antioxidant system was used as a model to explore the impact of ZnO nanoparticles on plant cell physiology. It was demonstrated using the foliar spray technique on chickpea seedlings that low concentrations of ZnO nanoparticles have a positive impact on the growth of the plants. The seedlings' ability to accumulate biomass has also improved, which may be related to lower reactive oxygen species (ROS) levels (as indicated by the lower malondialdehyde content). Field tests showed that using 15 times less ZnO nanoparticles than the authorized amount of $ZnSO_4$ resulted in a pod yield that was 29.5% greater. On the fruit quality of Cucumis sativus, ZnO and CeO_2 nanoparticles both had comparable favorable impacts. The use of both nanoparticles raised the starch content and may have changed the carbohydrate pattern.

In addition to the improved productivity and increased ability of the model plant to absorb water and fertilizer, it was discovered that a blend of SiO_2 and TiO_2 nanoparticles stimulated the antioxidant activity and nitrate reductase in *G. max*. TiO_2 nanoparticle application has been shown to support spinach growth and photosynthesis under both visible and ultraviolet light. After seed treatment, it was found that spinach had a 73% increase in dry weight, a threefold rise in photosynthetic rate, and a 45% increase in chlorophyll. The authors hypothesize that an increase in the uptake of inorganic nutrients may have increased the consumption of organic compounds and quenched oxygen-free radicals, which may have contributed to the rise in photosynthetic rate.

TiO_2 nanoparticles treated at concentrations as high as 2,000 ppm boosted seed germination and seedling vigor in Brassica napus, in contrast to most nanoparticles for which application at high concentration is not advised owing to the documented detrimental effect In light of this, it is evident that different metal nanoparticles had favorable effects at a variety of concentrations, including Pd and Au at low concentration, Si and Cu at high concentration, and Au and Cu in a mixed combination. Field investigations with G. max and Brassica juncea verified this pattern of behavior. Nanocrystalline powders of iron, cobalt, and copper at very low concentrations increased seed germination, and a noticeable rise in the chlorophyll index, number of nodules, and crop production was seen. Similarly, spraying gold onto plants' leaves in field studies had a favorable impact, increasing the plants' height, stem diameter, number of branches, pods, and seed production as well as, curiously, improving their redox condition.

CONCLUSION

Particularly in the area of fertilizers, nanotechnology has emerged as a paradigm-shifting strategy in agriculture. This essay investigates the use of nanotechnology in fertilizers, including its concepts, nanomaterials, delivery systems, and promise to transform sustainable agriculture and nutrient management. This study intends to provide insights into the importance and potential applications of nanotechnology for fertilizers in contemporary agriculture via a thorough evaluation of scientific papers and research results. The study of nanotechnology for fertilizers highlights its revolutionary potential in contemporary agriculture and environmentally friendly agricultural methods. Nanotechnology provides creative approaches for effective nutrition delivery and management via the use of nanoparticles. The improved solubility, controlled release, and targeted delivery of nanoscale nutrients and transporters to plants. More efficient nutrient utilization is made possible by the concepts of nanotechnology, such as increased surface area and reactivity at the nanoscale, which also reduce waste and have a positive influence on the environment. The regulated release of nutrients is made possible by delivery techniques including nanoencapsulation and nanocoating, which optimize plant absorption and growth. Nanotechnology for fertilizers is a viable path for lowering reliance on chemical fertilizers, preventing soil erosion, and advancing precision agriculture in the age of sustainable agriculture. Nanotechnology for fertilizers has the potential to revolutionize nutrient management, boost crop yields, and assure food security in a world with limited resources as we continue to research cutting-edge and ecologically friendly agricultural techniques. The contribution it makes to environmentally friendly farming methods and the worldwide initiative to develop resilient and sustainable agricultural systems is what gives it its significance.

REFERENCES:

[1] S. Suppan, “Applying Nanotechnology to Fertilizer: Rationales, Research, Risk and Regulatory Challenges”, *Inst. Agric. Trade Policy*, 2017.

[2] J. S. Duhan, R. Kumar, N. Kumar, P. Kaur, K. Nehra, en S. Duhan, “Nanotechnology: The new perspective in precision agriculture”, *Biotechnology Reports*. 2017. doi: 10.1016/j.btre.2017.03.002.

[3] E. F. Mohamed, “Nanotechnology: Future of Environmental Air Pollution Control”, *Environ. Manag. Sustain. Dev.*, 2017, doi: 10.5296/emsd.v6i2.12047.

[4] I. Iavicoli, V. Leso, D. H. Beezhold, en A. A. Shvedova, “Nanotechnology in agriculture: Opportunities, toxicological implications, and occupational risks”, *Toxicol. Appl. Pharmacol.*, 2017, doi: 10.1016/j.taap.2017.05.025.

[5] M. Kaushal en S. P. Wani, “Nanosensors: Frontiers in precision agriculture”, in *Nanotechnology: An Agricultural Paradigm*, 2017. doi: 10.1007/978-981-10-4573-8_13.

[6] H. DAĞHAN, “Nano Fertilizers”, *Türkiye Tarımsal Araştırmalar Dergisi/Turkish Journal of Agricultural Research*. 2017.

[7] T. Hussain, “Nanocides: Smart Delivery System in Agriculture and Horticultural Crops”, *Adv. Plants Agric. Res.*, 2017, doi: 10.15406/apar.2017.06.00233.

[8] N. S. Ali en H. W. A. Al-Juthery, “The application of nanotechnology for micronutrient in agricultureal production (review article)”, *Iraqi Journal of Agricultural Sciences*. 2017. doi: 10.36103/ijas.v48i4.355.

[9] G. Jungmeier, “The Biorefinery Fact Sheet”, *Int. J. Life Cycle Assess.*, 2017.

[10] Y. F. C. Putra, “Efek Pemberian Ekstrak Ketepeng Cina (Cassia Alata L.) Terhadap Kadar Glukosa Darah Pada Tikus Wistar (Rattus norvegicus) Dengan Induksi Aloksan”, *Carbohydr. Polym.*, 2017.

CHAPTER 7

AN ANALYSIS OF GENETICALLY ENGINEERED MICROBES

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ABSTRACT:

Genetically Modified Microbes (GEMs) are a cutting-edge area that combines microbiology and biotechnology and provides ground-breaking solutions for a variety of sectors. The concepts, applications, regulatory issues, and effects of GEMs' widespread usage are all covered in this paper's exploration of several GEM facets. This study attempts to provide insights into the relevance and possibilities of genetically engineered microbes in contemporary biotechnology and beyond via a thorough analysis of scientific papers and research results. The study of Genetically Engineered Microbes (GEMs) highlights their transformative potential in various fields and underscores the importance of responsible and ethical use. GEMs, through genetic modification, offer innovative solutions across diverse applications, from bioremediation and pharmaceutical production to agriculture and biofuel generation. The principles of genetic engineering enable the customization of microorganisms for specific tasks, enhancing their efficiency and effectiveness. Regulatory considerations are paramount in ensuring the safe and ethical use of GEMs. Robust oversight is essential to address potential risks and to harness the benefits responsibly.

KEYWORDS:

Biotechnology, Genetically Engineered Microbes (GEMs), Microbiology, Regulatory Considerations, Applications.

INTRODUCTION

There are many bacterial genera, and some of these genera include members that may affect plant development and productivity. Plant pathogens that may reduce plant diseases and are utilized as biocontrol strains are among these examples. Increased nutrient availability may be caused by a different bacterial species or group, which can then lead to greater plant development. These bacteria, sometimes referred to as growth-promoting rhizobacteria (PGPR), make up the biofertilizers. The capacity of PGPR to thrive in the rhizosphere the region where soil meets plant roots gives them their moniker. PGPR may be administered directly to soil or as a seed coating. However, for the transplanted PGPR to exercise their growth-promoting impact, sufficient quantities must survive in the soil and rhizosphere, which does not always occur. As a result, PGPR's effectiveness is sometimes insufficient for commercial applications, and its performance has to be enhanced. Applying genetic alterations to increase their chances of surviving is one of the options. The relationship between environmental factors and bacterial physiological state determines whether microbes will survive. Bacterial cells may change their metabolism to various physiological states as a consequence of these interactions. For example, cells may create exopolysaccharides for protection, become more stress resistant, form dwarf cells, enter a viable but non-cultivable state, and some can develop spores or connections with plants [1].

One may assume that the GM bacteria's survival pattern will resemble that of one of its wild-type parents. This extrapolation should really be used with considerable care. First off, the increased energy needed to express the implanted genes may compromise the organisms' ability to survive in the environment. Additionally, the insertion could have interfered with other functions, reducing the strains' ability to compete. Second, the GMMs could develop and adapt to the current environmental circumstances via natural selection. Evidence supporting evolutionary adaptation of bacteria to digest the herbicide 2,4-dichlorophenoxyacetic acid, which led to higher competitive fitness to utilise succinate as a substrate, supports the final point. Similarly, it has been suggested that environmental pressures might lessen the detrimental consequences of mutations; under particular environmental conditions, organisms could grow more tolerant of genetic perturbations [2], [3].

In tests using artificial growth circumstances, GMMs have been shown to survive even better than the wild-type strain. However, under field circumstances, improved GMM survival has only sometimes been shown. In soil, the number of newly introduced bacterial cells often falls quickly, while the GM species persist in a manner similar to that of naturally occurring bacteria. There are several experimental experiments (for *Pseudomonas chlororaphis, P. fiuorescens*, and *Sinorhizobium meliloti*) in which no difference in survival between GMM and parent strain could be found. Furthermore, it was claimed that the parent strains outcompeted several GMMs. It is hypothesized that a GMM's ability to compete successfully with the wild-type strain was negatively impacted by the presence of many constitutively expressed marker genes. Given that this impact does not exist under nutrient-rich environments, the metabolic burden is likely to blame for the reduced fitness.

Since cells that reach a non-culturable condition cannot be recognized using conventional cultivation-based approaches, a reliable method for detection must be used in order to appropriately interpret crucially important bacterial survival data. Additionally, several studies have shown that GMMs injected into soil stop being cultivable. The complexity and ecological relevance of GMMs, as well as their fitness when viewed in the context of the impact of the genetic mutation delivered, are influenced by the presence of living but uncultivable cells, dead cells, or bare DNA, which may be discovered using molecular methods. By co-inoculating GMM and its parental strain and putting them in direct competition, it will be possible to measure the influence of even minor fitness variations. However, as commercial deployment of GMMs does not involve direct rivalry between GMM and wild-type strain, data from such direct competition trials must also be evaluated carefully. All of these results, which are somewhat conflicting, demonstrate that conclusions about the survival of GMMs relative to their parental strains cannot be made with certainty. These criteria will need to be established for each situation where colonization potential and GMM survival are crucial [4], [5].

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DISCUSSION

The discharge of GMMs may have a wide range of consequences on natural microbial communities. The spectrum includes occurrences including the introduction of organic substrate, the eviction of species, modifications to population dynamics, and potential functional losses, as well as the generation of hazardous compounds that may affect important ecological processes. The link between microbial diversity and ecosystem functioning is not entirely evident, and it should be noted that modest changes in community composition are difficult or even impossible to detect. Without a doubt, the variety and functional redundancy of soil microbes are immense.

Since numerous processes might be carried out by a broad variety of distinct microorganisms, it will be challenging to notice the disappearance of a small number of species with specific roles. In this way, only severe disruptions may have an adverse impact on the microbial communities in soil to the point where certain of their functions are compromised. One of the main issues in microbial ecology is the native soil microflora's poor cultivability. Currently, methods based on DNA and RNA that do not need the production of microorganisms are employed to assess how GMMs affect the local microbial population. Denaturing gradient gel electrophoresis (DGGE), amplified ribosomal DNA restriction analysis (ARDRA), terminal restriction fragment length polymorphisms (T-RFLP), and single-strand conformation polymorphism (SSCP) are techniques that may be used to examine changes in community structures.

GM versions of bacteria that boost the availability of nutrients for plants and thereby promote plant development. The most significant bio-fertilizers are nitrogen-fixing bacteria like

Azospirillum and *Rhizobium*. Plant symbionts called Rhizobium, Bradyrhizobium, and Sinorhizobium create root nodules in leguminous plants and fix atmospheric nitrogen. In order to boost the output of leguminous crops, these bacteria have been routinely utilized as plant inoculants. Non-modified rhizobia have a long history of being used safely as inoculants to boost crop yields. The effectiveness of inoculants seems to rely on competition with native strains, which are often less successful, since yield growth is vary. It has been shown that Rhizobium, Bradyrhizobium, and Sinorhizobium may live for many years in soil, sometimes even in the absence of their particular host. The ability of Rhizobium to produce nodules was shown when its host plant was replanted after a period of time. This demonstrates that the presence of the host plant is not necessarily required for their survival and that the strain's ability to persist in bulk soil for years is also influenced by factors unrelated to symbiosis. It was discovered that Bradyrhizobium, which grows more slowly, is more sensitive to desiccation than fast-growing Rhizobium species.

Plants only acquire carbon dioxide (CO_2) from the atmosphere, and all of their other nutrients come from the soil. The finest illustration of this concept is biological nitrogen fixation in leguminous plants, which is one of the many ways natures has created to feed plant nutrients using renewable resources. It is possible to think of nitrogen-fixing bacteria as a self-replicating source of nitrogen for plants. Unfortunately, not all plants have the capacity to connect in this way with bacteria that fix N_2. This is why chemical fertilizer input continues to have a significant impact on plant output yields today. The majority of these fertilizers are administered in higher amounts than necessary for optimum plant development since they are extremely mobile in the soil. Losing valuable chemicals has consequences for the environment that go beyond only the economy, since they seep into surface and groundwater and build up in the atmosphere [8], [9].

A variety of tactics have been developed to improve fertilizer absorption by plant roots. These include of different fertilizer formulations (such as slow-release fertilizer) and the application of Plant Growth Promoting Rhizobacteria (PGPR). PGPR may have an impact both directly and indirectly. The indirect pattern includes the use of harmful microbes and diseases as targets for biocontrol. Phytostimulation is the best-documented instance of PGPR functioning directly to promote plant growth. Auxins, cytokinins, and other substances produced by different bacterial species may stimulate plant development, and when they colonize plant roots, they encourage root growth. This ensures that the plants will better absorb water and nutrients, which may lead to larger agricultural harvests.

A common strategy to boost the output of leguminous crops is to inoculate the plants with highly effective nitrogen-fixing bacteria. This inoculation is not always effective because native soil bacteria that are not very effective at fixing nitrogen might outcompete the imported strains in terms of starting nodulation. Rhizobial inoculants must be competitive, or have the capacity to control nodulation, in order to be effective. As a result, inoculant strains are altered such that they occupy a sufficient number of root nodules to provide the plant host high rates of nitrogen fixation. Studies on the competitiveness of *Sinorhizobium meliloti* strains from various geographical origins for alfalfa roots have shown that this trait has always been improved by genetic engineering. The aforementioned genetic alteration entails changing the way the nifA gene, which regulates the expression of all the other nitrogen-fixation (nif) genes, is expressed. Thus, when wild-type and GM *S. meliloti* strains were combined, the former occupied the majority of the nodules on the alfalfa roots. Although the specific mechanism behind this enhancement is yet unknown, it is hypothesized that nifA affects the expression of genes other than those in the nif cluster, providing a benefit during nodule formation and development.

Another quality that increases the competitiveness of Rhizobium strains for nodulation is their capacity to detect the plant root effectively. This is crucial since an effective inoculation requires less of the bacterial strain overall. Another element affecting competitiveness is the migration of the inoculation strain toward the plant roots. Studies using GM *Rhizobium leguminosarum* strains modified to produce the -glucuronidase reporter gene (gusA) revealed that the GM gusA-labeled strain induces a larger proportion of nodules compared to a non-motile, flagella-deficient strain. It was shown in this manner that functioning flagella are necessary for efficient competition for nodulation. All of these data provide insightful information about the root attraction process, enabling the creation of Rhizobium strains with improved nodulation competitiveness and better host specificity.

Field tests revealed that all examined strains colonized the rhizosphere to an equivalent degree; equal values were found for each strain's respiration rate, soil metabolic activity, and ability to convert nitrogen. These findings suggest that although the plant's presence had a significant impact on soil carbon mineralization, the effects of GM Rhizobium strains are identical to those of wild-type Rhizobium strains. They also suggest that the plant's influence on microbial activity is much greater than the effects of GM inoculants when compared to wild-type strains. Despite the fact that there have only been a few field tests using GM bio-fertilizers, the preliminary findings concerning their usage are encouraging in terms of the enhanced performance in agricultural applications. The introduction of GM bio-fertilizers has been successful in terms of the inoculants' ability to survive and function, which depends on the environment. The documented nontarget impacts of GM bio-fertilizer strains are so far negligible and modest in comparison to natural changes like fluctuations in populations of various plant species. Our understanding of the advantages, future, and impacts of GM strains in the environment, however, is currently relatively restricted and fragmentary. How and when (in what physiological state) bacteria live best in soil; what is their impact on the native microflora; and how can a mix microbial community be organized and maximized for use in agriculture are among the issues that need to be resolved. Last but not least, how do GM strains affect ecosystems, particularly non-target organisms.

Farmers are being pressured by environmental challenges including freshwater contamination, energy conservation, and soil erosion to provide development options with a smaller effect on pollution. The adoption of environmentally friendly methods is promoted by both legally obligatory rules (such as the EU Directive 2009/128 aimed at the application of sustainable pest management practices) and voluntary certification programs such as Global GAP or organic farming schemes). In this perspective, using more organic fertilizers while using fewer chemical fertilizers is seen as the only practical way to reduce the environmental impact of agricultural operations. Chemical pesticides and fertilizers have played a significant role in promoting rural development in recent years, although their use in contemporary agriculture is relatively new. Due to their quick response and minimal cost, they were able to quickly become the center of attention. However, their harmful impacts on the environment, plants, animals, and people shifted attention away from environmentally responsible plant conservation. Additionally, the problem of insects developing resistance to typical insecticides has not yet been resolved. As a result, techniques like Integrated Pest Management (IPM) have become increasingly significant. Biofertilizers are an essential component of IPM. They may have enormous financial impact since they can partially replace various agrochemicals, which are becoming more and more expensive, and because of growing demand for agricultural methods that are more environmentally friendly. The phrase "biofertilizer" is often used to describe a substance used to aid in the development of plants that contains soil microorganisms. It has, however, also often been incorrectly used as a synonym for a variety of goods, including green or animal manure, intercropping, or chemical fertilizer with an organic addition. A biofertilizer is a substance that contains living microorganisms that, when applied to soil, seed, or plant surfaces, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant, according to Vessey's definition from 2003. After inoculation, the microorganisms they carry, known as plant growth-promoting rhizobacteria (PGPR), help the plant hosts.

The excitement for using these goods is growing as a result of enhanced nutrient absorption efficiency, societal expectations for more green technology, and rising agrochemical prices. Additionally, the optional beneficial effects of biofertilizers and phytostimulants would improve the value of these substances as bioinoculants. In fact, it has been shown that bacteria like Rhizobium and Glomus spp. also contribute to the decrease in plant diseases. When a product containing Rhizobium sp. was patented in the 20th century, the practice of inoculating plants with PGPM began. Even though mycorrhizal fungi have been used as biofertilizers for a few decades, it has been known since the late 1950s that they may stimulate plant growth by increasing P absorption. Since then, efforts to further study in these areas have continually increased, leading to the selection of diverse strains that exhibit a number of advantageous traits.

The inclusion of multiple strains for both biocontrol and biofertilization has been made possible by policies that support sustainable rural development and extensive research that has improved the sufficiency and consistency of microbial inoculum, with mycorrhizal and PGPR preparations being marketed in numerous nations. However, the variety and inconsistency of findings across laboratory, greenhouse, and field investigations has repeatedly prevented a broader use of microbial inoculants, particularly those functioning as phytostimulators and biofertilizers. These inconsistencies may be explained by the incomplete understanding of the intricate connections that have been made between the system's constituent parts the plant, the microbes, and the environment, especially the soil. One of the things preventing the use of PGPM on a larger scale is the lack of suitable formulations as well as the expensive and time-consuming registration processes.

The inoculation of legumes with rhizobia in 1995 in the USA and UK marked the beginning of the true commercialization of PGPR. However, interest in additional PGPR has grown over time, and a number of new products have lately been created. The majority of the non-rhizobial PGPR inoculants now on the market include biocontrol agents and bacteria from the genera Azospirillum and Bacillus free living N_2-fixing bacteria and phosphate-solubilizing bacteria, respectively). Arbuscular mycorrhizal fungus (AMF)-containing products are likewise being used more widely all over the globe. The variety of PGPR and AMF populations that may be present in soil, however, as well as the range of their possible mechanisms of action, are very diverse, for the most part poorly known, and as a result, underutilized. It is also acknowledged that the different processes used to promote plants may be strain and host-specific, and that the beneficial effects may vary greatly depending on the environment. Additionally, once introduced to the soil, microbes must contend with harsh, competing circumstances that may significantly diminish their positive benefits.

Liquid, peat, granules, and freeze-dried powders are the four primary formulation forms now in use Target crop, price, market accessibility, environmental restrictions, and usability are all important factors in their success. The inoculant business has significant challenges in creating a better formulation that includes all of the aforementioned traits and is acceptable for usage in field settings. Furthermore, even while a microbe may seem promising in a lab setting, commercializing it in order to get comparable outcomes in a variety of field circumstances is a challenging step. In order to increase the advantages for the host plants, some producers combined at least two different kinds of microorganisms such as rhizobia and AMF, rhizobia and PSB, or different strains of AMF or PSB in a single package. Only a small number of reviews, meanwhile, highlighted these co-inoculants' beneficial effects. Their effectiveness has not been established, and both their marketing and manufacture present a number of technological challenges. The most crucial factor in inoculant creation is quality assurance, which ensures the dependability of the products and maximizes their possibilities of success. The lack of consistency in field outcomes due to inconsistent quality has had a significant impact on the marketing of biofertilizers.

CONCLUSION

Regulatory factors are essential for guaranteeing the ethical and safe deployment of GEMs. To address possible dangers and direct appropriate and sustainable uses, strong control is necessary. GEMs are being used widely, which has significant potential for solving some of the most important global problems. However, it is essential to traverse this revolutionary sector with moral foresight, environmental care, and a dedication to maximizing its positive effects for the sake of society. Genetically Modified Microbes serve as both a potent instrument for tackling complicated issues and a symbol of human creativity as we continue to explore the biotechnological frontiers. Their capacity to spur innovation and advancement while encouraging moral and responsible scientific activities makes them important.

REFERENCES:

[1] P. Kanwar, T. Mishra, en G. Mukherjee, “Microbial bioremediation of hazardous heavy metals”, *Environ. Sci. Eng. (Subseries Environ. Sci.*, 2017, doi: 10.1007/978-3-319-48439-6_21.

[2] J. Czajka, Q. Wang, Y. Wang, en Y. J. Tang, “Synthetic biology for manufacturing chemicals: constraints drive the use of non-conventional microbial platforms”, *Applied Microbiology and Biotechnology*. 2017. doi: 10.1007/s00253-017-8489-9.

[3] Y. Higashikuni, W. C. Chen, en T. K. Lu, “Advancing therapeutic applications of synthetic gene circuits”, *Current Opinion in Biotechnology*. 2017. doi: 10.1016/j.copbio.2017.06.011.

[4] D. F. R. Doud, E. C. Holmes, H. Richter, B. Molitor, G. Jander, en L. T. Angenent, “Metabolic engineering of Rhodopseudomonas palustris for the obligate reduction of n-butyrate to n-butanol”, *Biotechnol. Biofuels*, 2017, doi: 10.1186/s13068-017-0864-3.

[5] P. A. Garcia, Z. Ge, L. E. Kelley, S. J. Holcomb, en C. R. Buie, “High efficiency hydrodynamic bacterial electrotransformation”, *Lab Chip*, 2017, doi: 10.1039/c6lc01309k.

[6] S. K. Singh, S. Verma, en P. K. Verma, “Genetically Engineered Crops Against Bacterial and Fungal Diseases: A War of Attrition”, in *Current Developments in Biotechnology and Bioengineering: Crop Modification, Nutrition, and Food Production*, 2017. doi: 10.1016/B978-0-444-63661-4.00006-2.

[7] B. Awate, R. J. Steidl, T. Hamlischer, en G. Reguera, “Stimulation of electro-fermentation in single-chamber microbial electrolysis cells driven by genetically engineered anode biofilms”, *J. Power Sources*, 2017, doi: 10.1016/j.jpowsour.2017.02.053.

[8] A. N. M. Alamgir, *Progress in Drug Research: Therapeutic Use of Medicinal Plants and Their Extracts*. 2017.

[9] G. Gosset, “Biotechnological Production Of Melanins With Microorganisms”, in *Bio-Pigmentation and Biotechnological Implementations*, 2017. doi: 10.1002/9781119166191.ch7.

CHAPTER 8

INVESTIGATING THE PRODUCTION OF INOCULANTS: AN OVERVIEW

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ABSTRACT:

Production of inoculants, such as microbial biofertilizers and biopesticides, is a crucial component of environmental management and sustainable agriculture. The manufacture of inoculants is examined in this study in terms of processes, quality assurance, application methods, and the contribution of inoculants to the promotion of environmentally friendly agricultural practices. This research intends to provide insights into the relevance and possibilities of inoculant production in contemporary agriculture and environmental stewardship via an exhaustive analysis of scientific papers and industrial experiences. Inoculant production is essential for environmental management and sustainable agriculture, providing green answers to today's problems. To maximize the potential of helpful microorganisms, inoculants which include microbial biofertilizers and biopesticides are made utilizing a variety of techniques, from solid-state fermentation to liquid culture.

KEYWORDS:

Agriculture, Biofertilizers, Biopesticides, Inoculant Production, Sustainable Farming, Quality Control

INTRODUCTION

The process of creating an efficient inoculant involves many steps, including attaching one or more strains of microorganisms to a specific carrier along with sticking agents or other additives that guarantee the safety of the cells throughout storage and transit. The inoculants must have a long shelf life since they are often kept in less-than-ideal circumstances (such as high temperatures and light exposure), therefore the microorganisms must either be resistant or have a stronger ability to live in large numbers in adverse environments. In order to get the most advantages after inoculating the host plants, a suitable formulation will also effectively introduce microorganisms into the soil and will boost their activity. To ensure that the microorganisms are transported to the target plant in the most efficient manner and form, an inoculant must be affordable and easy to handle and apply in order to be readily accepted by farmers. A little amount of research has been done on formulation, a key concern [1], [2].

According to the data that was available, less than 1% of rhizobial research since the 1980s has focused on the formulation of rhizobia inoculants and more than 99% on the genetics and physiology of bacteria. In any event, there is a clear need for enhanced inoculant formulations in order to create and market novel biofertilizers that will be more effective, longer-lasting, higher-quality, and able to meet agricultural demands. There is no such thing as the optimum formulation, and each variety undoubtedly has its own unique benefits and limitations. However, there are a few crucial stages that must be carefully taken into account while producing biofertilizers. The decisions taken at these stages may determine whether the vaccination is successful or not. It is of utmost significance to choose which microorganisms to inoculate. The ability to benefit target crops, be competitive with native populations, migrate from the inoculation site to the hosts, and survive in hostile soil without the presence of a host are some of the most crucial desirable traits of the inoculant strain (bacterial or fungal). The ability of the strain to grow in laboratory conditions with the exception of AMF, which cannot grow without a host plant, grow or survive in carriers during curing or storage, grow or survive on seeds and in soil, and be compatible with agrochemical products that might be applied on seeds are other crucial features sought during production [3], [4].

The live inoculant must also have the ability to resist different technological manufacturing procedures and keep its useful qualities. To achieve large biomass yields, bacterial inoculants are often cultured in liquid media. The physiology-biochemical characteristics of the specific strain and the kind of inoculant that is to be generated are directly connected to the medium composition and growth circumstances temperature, pH, agitation, aeration, etc. The different carriers are then inoculated with the obtained bacterial cultures (by encapsulating or impregnating peat and granules), or liquid formulations may be created with the inclusion of various ingredients. The use of bioreactors for the large-scale generation of bacteria in isolated cultures is a widely used technique.

Once the precise strain(s) for the inoculum have been selected, a consistent industrial manufacturing process may be established. Contrary to biopesticides, the cost of manufacturing is a significant restriction for biofertilizers. This is because the cost of biofertilizers must not be higher than that of conventional ones. As a result, numerous low-cost raw materials, such as whey, water sludge, compost, etc., have been used as PGPM growing medium. Utilizing agro-industrial waste that has been enhanced with rock phosphate is another strategy for reducing production costs. Free or immobilized microorganisms that create organic acids are introduced to the matrix during composting or fermentation, improving the solubilization of phosphate and hence increasing its availability to plants.

Biofilms have recently been used as a potential method of creating efficient plant inoculum. The microbial population is protected and given shape by a biofilm, which is made up of microbial cells attached to an inert or alive surface and embedded in an extracellular polymeric substance (EPS). In the soil, bacterial (including Actinomycetes), fungal, and fungal bacterial biofilms are the three main forms of biofilms that are seen. While fungi serve as the biotic surface in the development of fungal-bacterial biofilms, bacterial and fungal biofilms also originate on abiotic surfaces. Most of the bacteria that are connected with plants and are found on roots and in soil create biofilms. In order to formulate and produce biofertilizers, it may be effective to use PGPM strains that form biofilms. While ectomycorrhizal fungi may be generated under fermentation conditions, the creation of AMF inoculum is significantly more challenging since the mycorrhizal fungus require a plant host to multiply. The initial efforts at producing AMF used either aeroponics or pot cultures with soil combinations. However, the advent of monoxenic cultures in the late 1980s made it possible to produce AMF in tightly regulated environments. Split-plate cultures and carrot roots with Ri T-DNA transformations were used to establish a technique for producing spores [5], [6].

Although the technique enables the generation of 15.000 spores per Petri dish on average in 4-5 months after starting the production cycle, it has mostly been employed for physiological and laboratory investigations. This approach was improved by switching out the medium in the distal compartment every two months while also adding glucose to the proximal compartment's carbon supply. In 7 months, the creation of around 65.000 spores is the consequence of the results. However, these techniques are mostly employed to maintain gene banks or to produce spores in batches for research purposes. The reason is that, depending on the technique used, the projected yearly cost to produce one spore is up to 30-50 USD. Mycorrhizal fungus production at a big scale in vitro that is practical for deployment on a commercial scale has recently been presented. It is founded on numerous crucial ideas, including the selection of suitable Ri T-DNA altered host roots for various AMF species, the choice and upkeep of the best growing media, and the use of quality control measures.

Commercial inoculants with AMF species are still, however, primarily made by cultivating host plants under controlled conditions and adding various fungal structures (spores, mycelium hyphae, and residues from mycorrhizal roots from plants used as propagating material, such as sorghum, maize, onion, or Plantago lanceolata) to the inoculant. This technique might be regarded as a traditional one since it involves mass-producing AM fungal inoculum in pots, bags, or beds for industrial purposes using substrates made of sand, dirt, and/or other materials (such zeolite, perlite). The following factors are crucial to this production strategy: (i) using known AMF species; (ii) choosing hosts with short life cycles, adequate root development, good colonization levels by a wide range of AM fungi, and tolerance to relatively low levels of phosphorus; (iii) managing the level of mineral nutrients in the soil; and (iv) selecting an appropriate mix of AMF species and host plants.M This method allows for inoculum densities of between 80 and 100 thousand propagules per liter. This suggests that in order to prepare a commercial product, the inoculum must be diluted with a carrier.

DISCUSSION

Given that mycorrhizal symbiosis may be promoted by microbial interactions between bacteria and mycorrhizal fungi found naturally in the soil, it stands to reason that formulations containing two or more species of distinct PGPM would benefit plants more. Through a variety of processes that enhance nutrient absorption and control fungal plant diseases, microbial consortia may promote plant development. The many theories put out to explain this stimulation of development are based on the accelerated rate of nutrient cycling. The last is because soils with mycorrhizal plants have higher levels of biodiversity and microbial richness. Through better nutrient absorption, simultaneous inoculation with various PGPR and/or AMF often led to greater growth and yield in comparison to single inoculation. The intake of nutrients is positively impacted by the interactions between bacteria and AM fungus, especially when PGPR and N2-fixing bacteria are present [7], [8]. A. brasilense and AMF injections into maize and ryegrass produced N and P levels that were on par with those of fertilizer-grown plants. Due to the absence of AMF fungal colonization sensitivity for certain plant species/cultivars, co-inoculation with various AMF species is often more successful. It has also been shown that PGPR, such as *Azospirillum, Azotobacter, Bacillus*, and *Pseudomonas species*, may interact synergistically with AM fungi to promote plant development. The co-inoculation of such PGPR with mycorrhizal fungus led to improved AMF root colonization. In comparison to a single *Rhizobium trifoli*, plants inoculated with a mixture of *Rhizobium trifoli and Glomus deserticola* produced four times as many nodules. Co-encapsulated *Rhizobium trifoli* and *Yarrowia lipolytica* also promoted mycorrhization and nodulation.

Additionally, carriers comprised of a combination of the aforementioned materials are available, including soil and compost, soil and peat, bark, and husks, among others. Dry inoculant (powders), slurries (powder-type inoculants suspended in liquid), granules, and liquids are the four dispersion types that are most often utilized. The most popular transporter, particularly for bacterial inoculants, is peat. It is not widely available, however, and its usage has an unfavorable effect on the ecology and environment from which it is collected. This emphasizes the need for the creation of novel formulations employing alternative substances to compete with the current inoculants.

Soil, an organic substance, or an inert carrier are used to administer dry inoculants. In various regions of the globe, peat (a kind of soil transporter) is used to create inoculants. Peat is a layer of collected, partly degraded plant material. A broad range of microorganisms that can grow and establish microcolonies both on the surface of the particles and in cracks may do so because it offers a nutritional and protective growing environment. Peat must be nontoxic (to microbes, plants, animals, and humans), extremely adsorptive, simple to sterilize, rich in organic matter and water-holding capacity, and readily accessible locally at a fair price in order to be suitable for inoculant application. Due of its widespread availability, peat has mostly been used. However, since it must go through a number of stages before being utilized as an inoculant carrier, its processing is costly. To eliminate coarse particles, harvested peat must be drained and sieved before being carefully dried to 5% moisture. This process of drying is very important since it might result in the creation of hazardous chemicals. Lowest temperatures should be used when drying, and definitely never go beyond 100°C. The process of air drying is preferred over oven drying. The degree of drying depends on the kind of peat and the desired particle size. To ensure that the following addition of liquid culture raises the inoculant's ultimate moisture content to the desired level, the moisture content must be sufficiently reduced. Peat is powdered after it has dried, usually such that it can pass through at least a 250-m sieve.

An appropriate final moisture level for bacterial inoculant is typically between 40 and 55 percent. For a certain amount of time, inoculated peat is incubated to facilitate bacterial growth in the carrier. This process, which is also known as maturing or curing, is crucial because it increases the likelihood that bacteria will survive both during storage and on seeds. AMF and ectomycorrhizal inoculants may also be made from peat; however, the latter is very sometimes employed outside of forest regeneration. Ectomycorrhiza are often cultivated in media that contains glucose, and the spores that are generated are utilized for inoculation. Pure mycelia cultures are recommended because they inhibit the development of impurities and pathogens. Ectomycorrhizal inoculants may be created using a vermiculite and 5–10% peat–based carrier that has been moistened with salts and glucose nutritional medium. This formulation increases the generation of fulvic acid, which promotes development, and has a great buffering ability.

Before planting, inoculated peat is often applied locally to the seeds. The quantity of the product needed is not very large. However, since they come into touch with other chemicals that may have been applied to the seeds, the number of microbes utilized per seed is not adequately regulated. Machines (including big dough mixers, cement mixers, and mechanical tumblers) may cover the seeds. This process makes it possible to inoculate lots of seeds. Peat has a severe drawback due to its variable quality and content, which are source-dependent. Since peat is an ill-defined and complex substance, various sources will have varying capacities for promoting cell growth and survival. Additionally, toxic substances may be generated during sterilization, which would have a detrimental effect on the development and survivability of desirable bacteria.

This might make it more difficult to determine the best conditions for storage or consumption, as well as to ensure consistent quality and outcomes in the field. Despite these limitations, peat continues to be the benchmark by which all other materials are measured. Different regions have access to coal, clays, and inorganic soils such lapillus, volcanic pumice, or diatomite earths, which might be used as carriers. Their microbial load (approximately 102–103 CFU g1) varies depending on the source, although it is often lower than in organic carriers. Vermiculite, perlite, and bentonite are also accessible in many nations, although their use is often restricted because to the challenges involved in creating an efficient formulation. Actually, the pH, ion concentration, and electrolyte in the solution all affect how these carriers affect the viability and proliferation of bacteria. Mycorrhized roots combined with dirt are also employed for AMF inocula, and expanded clay has also been explored as a possible AMF carrier. Glass beads have been suggested as an alternative to other inorganic substances for AMF inocula. The activity and shelf life of *Burkholderia sp.* have been successfully increased by a combination of organic and inorganic ingredients. The bulk of the carriers previously discussed rely on the microbes being absorbed by the carrier's material or matrix. The survival of the microbes and their protection during handling, storage, and transport are two drawbacks of this inclusion technique. However, several processes involving various carriers and such a methodology have been patentable:

(i) the British patent no. 1.777.077 for the use of bentonite for Rhizobium, (ii) the Belgian patent no. 521.850 for the use of diatomaceous earth and colloidal silica for Rhizobium, (iii) the French Patent no. 1.180.000 for the use of must juice with the addition of substances with an adsorbing action, such as cellulose, bone meal, kaolin, or silica gel, in the (iv) U.S. Patent No. 4956295 for stabilizing dried bacteria extended in particulate carriers, in which dried viable bacteria are mixed in a particulate carrier made primarily of an inorganic salt with a low moisture absorbing capacity and a small amount of a silica gel absorbent. The inorganic salts might be bicarbonates, sulfates, phosphates, or sodium or calcium carbonates.

In order to address the drawbacks associated with peat application, interest in alternate formulations, particularly granular inoculants, is rising. Granules are created by combining a powder-type inoculum with peat pills, tiny marble, calcite, or silica grains that have been moistened with an adhesive substance. As a result, the target microorganism(s) are coated or impregnated into the granules. Although the granule sizes vary, there is a clear correlation between the density of the original microbial population and the quality of the final product: the better the initial microbial population, the better the result. Compared to peat, granules offer several benefits. They are also simpler to handle, store, and use and contain less dust. The inoculant is placed in a furrow close to the seed to facilitate lateral-root interactions but is not in direct contact with the chemicals or pesticides that could be toxic for the microorganisms. This allows for easy placement and application control and overcomes the limitations of seed applications. Granule uses are constrained by their larger nature, which results in increased transport and storage costs.

Numerous studies have examined the preference of rhizobial granular inoculants versus peat and liquid inoculants, with varying degrees of success. Other studies on the inoculation of legumes showed that granular formulations are superior to peat-based products and liquid inoculants in terms of number of nodule formation and weight, N accumulation, N2 fixation (% Ndfa), and total biomass generation. Some reviews showed that granular application of rhizobia did not display predominant nodulation or biological N2 fixation compared with the other formulations (peat and seed coating). Granular inoculants provide advantages in a variety of soil stress situations, including those with high acidity, moisture stress, or cold, wet soils. Aqueous (broth cultures), mineral or organic oils, oil-in-water suspensions, or polymer-based suspensions are the bases for liquid inoculants. Liquid treatments have gained popularity since they are easier to use and apply to soil or seedlings. So, in the most recent ten years, their prevalence has increased. Due to their high cell densities, they are now in demand and have been used for legume inoculation (in the USA and Canada, for example). This feature enables the use of a less amount of inoculant with a comparable efficiency. A few restrictions prevented their use, nevertheless. For example, inoculants made from liquid cultures lack carrier protection and soon lose viability on the seed. They often have a short shelf life and need more specialized storage conditions (low temperatures). It was also discovered that liquid inoculants were less resilient in the carrier and more susceptible to environmental challenges. The addition of several additional ingredients, such as sugar, glycerol, gum arabic, and PVP, may increase the viability of microorganisms in liquid inoculants.

New varieties of microbe entrapment and immobilization methods have emerged as a result of the advancements achieved in formulation modification, and they look especially promising.

The term "immobilization" refers to a variety of cell attachment or matrix trapping mechanisms. These consist of cell cross-linking, flocculation, adsorption on surfaces, covalent binding to carriers, and encapsulation in a polymer gel. The method of encapsulation has emerged as the most promising for the creation of microbial carriers. The live cells are shielded from mechanical and environmental challenges (such pH, temperature, organic solvents, or toxicity) as well as predators after they have been enclosed in a nutritive shell (or capsule). The target cells are progressively released in vast amounts when soil microorganisms gradually break down the capsules after being buried in the soil. This often takes place when a seed germinates or a seedling emerges. It is possible to encapsulate a variety of cells, such as bacterial spores, fungal spores, or tiny hyphal segments. In this sense, the encapsulation technique is a potential technology for the creation of products based on single or multiple strains, such as PSB-AMF or rhizobia-AMF.

Polymers of many sorts, including homo-, hetero-, and co-polymers, may be utilized for encapsulation, whether they are synthetic (polyacrylamide, polyurethane), natural (polysaccharides, protein material), or both. There are more than 1,350 different polymer combinations that might be used for encapsulation. Selection is often based on a component's chemical make-up, molecular weight (too low or too high molecular weights are disadvantages), and capacity for interaction with other elements. The two polymers that are most often used for cell encapsulation are polyacrylamide and alginate. Alginate is recommended, however, since polyacrylamide must be handled with extra care because to its toxicity. Alginate is a naturally occurring, biodegradable, and non-toxic substrate that when combined with multivalent cations (Ca^{2+}), creates a 3D porous gel. Microorganism cells are combined with the polymer matrix to create beads, which are then simply put into the cationic solution. It is possible to add nutrients and other supplements to increase the shelf life and vaccination effectiveness. The beads are then dried to make handling and packing easier. The size, shape, and texture of the beads are controlled using a variety of methods, including spray drying, extrusion, emulsion technique, coacervation, solvent extraction/evaporation, thermal gelation, and pre-gel dissolving technique. Microencapsulation, which uses smaller beads between 10 and 100 m, is preferable because it allows for direct contact with seeds, as opposed to microencapsulation, which uses bigger beads between a few millimeters and centimeters, which forces the released cells to travel through the soil in order to reach the plants.

CONCLUSION

Farmers are given confidence by quality control techniques that guarantee the dependability and effectiveness of inoculant products, such as regulated manufacturing procedures and stringent testing. The efficient integration of inoculants into agricultural methods is made possible by application techniques including seed coating, soil application, and foliar spraying, which optimize nutrient absorption and pest control. Inoculants provide a substantial contribution to environmentally friendly agricultural methods by lowering the need for chemical inputs, preventing soil erosion, and encouraging sustainable agriculture. The creation of inoculants serves as a crucial tool for boosting agricultural output, reducing environmental impact, and protecting the earth for future generations as we continue to adopt ecologically aware farming approaches and sustainable environmental management. Their significance arises from their contribution to environmentally friendly farming methods and the international drive to build robust and sustainable agricultural systems.

REFERENCES:

[1] A. J. Leal *et al.*, "Changes in the microbial community during bioremediation of gasoline-contaminated soil", *Brazilian J. Microbiol.*, 2017, doi: 10.1016/j.bjm.2016.10.018.

[2] F. Muñiz-Paredes, F. Miranda-Hernández, en O. Loera, "Production of conidia by entomopathogenic fungi: from inoculants to final quality tests", *World Journal of Microbiology and Biotechnology*. 2017. doi: 10.1007/s11274-017-2229-2.

[3] A. Nurbaity, E. T. Sofyan, en J. S. Hamdani, "Responses of Potato (Solanum tuberosum) to Glomus sp. Combined with Pseudomonas diminuta at Different Rates of NPK Fertilizers", *KnE Life Sci.*, 2017, doi: 10.18502/kls.v2i6.1025.

[4] S. S. Mariana, H. Mariangela, en A. N. Marco, "Production of polyhydroxybutyrate (PHB) and biofilm by Azospirillum brasilense aiming at the development of liquid inoculants with high performance", *African J. Biotechnol.*, 2017, doi: 10.5897/ajb2017.16162.

[5] J. Zhou, B. Deng, Y. Zhang, A. B. Cobb, en Z. Zhang, "Molybdate in rhizobial seed-coat formulations improves the production and nodulation of alfalfa", *PLoS One*, 2017, doi: 10.1371/journal.pone.0170179.

[6] B. N. Ndusha, N. K. Karanja, P. L. Woomer, J. Walangululu, N. Mushagalusa, en J. Sanginga, "Effectiveness of rhizobia strains isolated from South Kivu soils (Eastern D . R . Congo) on nodulation and growth of soybeans (Glycine max)", *Africa J. Soil Sci.*, 2017.

[7] R. T. Sarimong, P. B. Sanchez, R. B. Badayos, E. S. Paterno, en P. C. Pompe, "Effect of organic amendments and microbial inoculant on nitrogen, phosphorus and potassium use efficiency of sugarcane under acid typic hapludand", *J. Int. Soc. Southeast Asian Agric. Sci.*, 2017.

[8] R. de C. N. Marinho, L. de V. M. Ferreira, A. F. da Silva, L. M. V. Martins, R. S. A. Nóbrega, en P. I. Fernandes-Júnior, "Symbiotic and agronomic efficiency of new cowpea rhizobia from Brazilian semi-arid", *Bragantia*, 2017, doi: 10.1590/1678-4499.003.

CHAPTER 9

A COMPREHENSIVE REVIEW OF CROP RESPONSE TO BIOFERTILIZERS

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ABSTRACT:

An essential component of sustainable agriculture is understanding how crops react to biofertilizers. This has consequences for soil quality, agricultural yield, and environmental sustainability. The different aspects of crop response to biofertilizers are examined in this research, including the processes at play, crop-specific responses, agronomic practices, and the contribution of biofertilizers to environmentally friendly farming. This research attempts to provide insights into the importance and potential of crop response to biofertilizers in contemporary agriculture via an exhaustive analysis of scientific studies and agricultural practices. Nutrient mobilization, increased nutrient absorption, and better soil microbial activity are just a few of the complex processes that play a role in the crop's response to biofertilizers, all of which boost crop health and yield. Crop-specific reactions to biofertilizers differ and rely on elements including crop type, soil conditions, and biofertilizer composition, emphasizing the necessity for specialized agronomic methods.

KEYWORDS:

Agriculture, Biofertilizers, Eco-Friendly, Sustainable Farming, Microorganisms.

INTRODUCTION

The inoculant is administered to the soil below or next to the seeds when using the indirect application technique. When seeds are treated with fungicide or pesticide and a large volume of inoculant is required to outcompete the local rhizobial population, the technique is utilized. The easiest technique of vaccination is to produce the inoculant's liquid formulation and spray it over the soil or straight onto the seeds after planting. In this situation, a large dose of inoculant is required. Loss of rhizobia viability, a short storage duration, and challenges with inoculant dispersion are some drawbacks of this approach. In general, biofertilizers from associative nitrogen-fixing bacteria might be utilized for a variety of crops, including income crops like vegetables, fruits, flowers, tobacco, cotton, oilseed, tea, and medicinal or herbal plants, as well as cereal crops like rice and wheat.

In the Philippines, rice, maize, and other agricultural products including tomatoes, peppers, aubergines, okra, lettuce, peaches, and ampalaya may benefit from the use of BIO-N, a microbial-based fertilizer. The country's farmers stand to benefit greatly from this ground-breaking technology, which also promises to save the nation's dollar reserve by reducing the importation of inorganic nitrogenous fertilizers while enhancing agricultural production and profitability. It is mostly made up of microorganisms that can transform nitrogen gas into a form that host plants may use to maintain their nitrogen needs. The roots of Talahib, a plant related to sugar cane, were used to extract the active organisms (bacteria). These bacteria can improve the root formation, growth, and yield of plants including rice, maize, sugar cane, and several vegetable varieties. Associative nitrogen-fixing bacteria biofertilizers have enhanced yields by 10–30% and decreased the usage of commercial N fertilizer by 15–25% in China and other FNCA nations. According to reports, applying biofertilizer with associated nitrogen-fixing bacteria might hasten crop maturity, cut the vegetative time by 5 to 10 days, and boost soil fertility and quality [1], [2]. The following techniques are used to apply inoculant to seeds.

Dusting

The inoculant is combined directly with the dry seeds using this technique. Rhizobia may not cling well to the seeds as a result; this is the least efficient approach.

Slurry

The inoculant may be diluted with water and some stickers, such as 1% milk powder, or combined with wet seeds. Gum Arabic and sucrose of methyl ethyl cellulose may sometimes be used as stickers.

Seed coating

You may combine the seeds with the inoculant to create a slurry. The seeds are then covered with talc, clay, rock phosphate, charcoal, dolomite, calcium carbonate, or lime that has been finely pulverized. The technique offers a number of benefits, including the ability to protect rhizobia against low pH soil, desiccation, acidic fertilizers, fungicides, and pesticides. Biofertilizers are often administered to the soil as organic materials in powder form. Users find this form of biofertilizer management to be quite convenient. The usage of certain biofertilizers would be limited by the unique agronomic circumstances since they are expensive items for farmers. Biofertilizer manufacturers often provide the microorganisms; consumers or farmers merely need to apply the application technique advised by the makers. The common application approach, nevertheless, is thought of as the following step. The use of mixed cultures or co-inoculation with other microorganisms is an alternate method to the use of phosphate-solubilizing bacteria as microbial inoculants. Evidence supports the benefit of PGPR strains that include phosphate-solubilizing bacteria in mixed inoculations. Under glasshouse and field settings, the impact of combining the inoculation of Rhizobium, a phosphate-solubilizing *Bacillus megaterium ssp. phospaticum strain*-PB, and a biocontrol fungus *Trichoderma spp.* on the growth, nutrient absorption, and yield of chickpea was examined [3], [4].

In comparison to either individual inoculations or an inoculated control, the combined inoculation of these three organisms boosted germination, nutrient absorption, plant height, number of branches, nodulation, pea production, and total biomass of chickpea. However, it has also been suggested that certain phosphate-solubilizing bacteria operate as mycorrhiza assistance bacteria. The phosphate that the bacteria solubilized may be more easily absorbed by the plants thanks to a mycorrhizal pipeline that connects their roots to the soil around them and facilitates the transfer of nutrients from the soil to plants. There is a lot of evidence that phosphate solubilization has a special function in the promotion of plant development by phosphate-solubilizing bacteria. However, not every laboratory or field study has produced fruitful outcomes. As a result, the effectiveness of the inoculation depends on the kind of soil, particular cultivars, and other factors.

The possibility to boost rice yields, productivity, and resource use efficiency may be provided by biofertilizers. Additionally, the expanding availability of biofertilizers in many nations and locations as well as the sometimes-aggressive marketing bring this technology to the attention of more and more farmers. However, since so little is known about biofertilizers' potential in rice, rice farmers seldom get advice on how to utilize them from research or extension. In the Philippines, an irrigated lowland rice system was used to evaluate several biofertilizers over the course of four seasons. The grain yield rose when the quantity of applied biofertilizer was increased in all four seasons and across all biofertilizer treatments. The yield increase fluctuated greatly across seasons, and this increase was not always statistically significant [5], [6].

Generally speaking, the season's poor yields were brought on by a storm that seriously damaged the experimental field by flooding it and lodging the crop. As a result, the crop was harvested roughly a week early, substantially lowering the yields that could be obtained. Similar grain yields were obtained throughout the remaining three testing seasons. The biofertilizer BN produced the greatest average grain yields across all four inorganic fertilizer treatments and all four seasons. It is possible that the impact of the biofertilizer was unrelated to the rate of inorganic fertilizer since statistically significant interactions between biofertilizer treatment and inorganic fertilizer treatment could not be found in any season (at p 0.05). However, the application of biofertilizer at low to medium inorganic fertilizer rates showed a tendency for larger production gains. The performance of the BS (*Trichoderma parceramosum, T. pseudokoningii*, and a UV-irradiated strain of *T. harzianum*) and BG (rhizobacteria) biofertilizers was less consistent, but the BN biofertilizer most clearly demBonstrated this pattern.

DISCUSSION

When using the finest biofertilizers, grain production gains resulting from their usage ranged from 200 to 300 kg/ha, while the BN treatment had a nearly 800 kg/ha superior grain yield than the control. Relatively, the seasonal yield increase for each fertilizer treatment ranged from 5% to 18% for the BN biofertilizer, up to 24% for individual treatment combinations, for the BS biofertilizer (*Trichoderma parceramosum, T. pseudokoningii,* and a UV-irradiated strain of *T. harzianum*), and between 1% and 9% for the BG (rhizobacteria) biofertilizer. Only average data could be compared in order to calculate the relative yield increase; statistical analysis was not possible. The investigated biofertilizers did considerably boost grain production, and particularly the BN biofertilizer consistently did so. The yield of grain with biofertilizer was often higher than that without it, even in seasons when no discernible impact could be seen owing to the yield variability across plots. The seasonal yield increase for the BN biofertilizer was between 5% to 18% across fertilizer treatments, which is within the 5-30% range reported for non-rice crops and *Azospirillum inoculums* [7], [8].

Similar to this, the observed yield increase for the Trichoderma-based BS (3–13%) was close to the 15-20% rice yield increase described by the trend of yield increases between the various inorganic fertilizer treatments. However, the trend was less obvious across seasons and the yield increases were frequently lower at higher inorganic fertilizer rates. The gains in grain production attributable to biofertilizer were often less than 0.5 t/ha. The goal of the research was to determine the impact of various biofertilizers on the grain production of lowland rice and to look into potential interactions with various inorganic fertilizer dosages.

The findings revealed considerable yield improvements for all products tested in various growing seasons, but the biofertilizer based on azospirillum produced the most reliable results. The reported grain production improvements were often small (0.2 to 0.5 t/ha), but given the generally cheap prices of all biofertilizers evaluated, they might result in significant revenue benefits. The investigated biofertilizers' advantageous effects were not restricted to low rates of inorganic fertilizers; some effects were still shown at grain yields as high as 5 t/ha.M However, the patterns in our data appear to suggest that low- to medium-input systems may benefit from biofertilizer usage the most. The obtained data may already be utilized to better advise farmers on the usage of biofertilizer in lowland rice, although a number of significant problems remain. In particular, biofertilizers must be tested in a variety of genotypes and under abiotic stressors that are common for most low- to medium-input systems (such as drought or poor soil fertility), since their effects may vary depending on the variety. To make the most of biofertilizers in rice-based systems, more upstream-focused research would be required to better understand the real processes at play.

Two cotton types were tested consistently for two years) in field circumstances with different strains of *Azotobacter, Acetobacter, Azospirillum*, and *Pseudomonas*. The genetic makeup of these two cotton cultivars varies. HD123 is a diploid Desi cotton type with poorer nutrient absorption and insect susceptibility. Tetraploid American cotton variety H1098 has a great capacity for nitrogen absorption but is also quite vulnerable to pests. The chosen cultures were primarily tolerant to high temperatures since cotton is a summer crop and summer temperatures may reach 48 °C. Azotobacter is capable of producing cysts. Because of this, it can endure high temperatures. According to many studies, PGPRs (plant-growth-promoting rhizobacteria) promote plant development by assisting the absorption of essential micronutrients including N, P, and K and other minerals. The overall increase in root system volume is thought to be the cause of this absorption.

Wheat seed emergence is impacted by higher IAA levels predominantly as a result of bacterial synthesis of growth regulators. The increased temperature tolerance of certain cultures throughout the cotton crop season is blamed for better performance. It is also because the inoculant strains' superior procreation, survival, capacity to fix more nitrogen, antifungal capabilities, and growth-promoting chemicals are believed to have contributed to the favorable impacts on crops. The Azotobacter strains employed in this study have also been examined for the aforementioned characteristics, and it has been shown that they can fix nitrogen, create IAA and siderophores, excrete ammonia, and excrete IAA. Numerous variables may contribute to increased seed production, plant development, and bio-inoculant survival, but root exudates, which include acids, organic acids, carbohydrates, and growth hormones such indole acetic acid, have the greatest positive effects. IAA produced by bacteria is absorbed by plants and may promote cell division. The solubilization of insoluble phosphate and nitrogen fixation both make substantial contributions to plant development.

The absorption of nutrients may be significantly influenced by phosphate solubilizers. Therefore, by lowering soil fraction fixation, the application of *Azotobacter chroococcum*, a phosphate-solubilizing, IAA-producing organism, may improve the effectiveness of applied and native P_2O_5.The potential for using free-living nitrogen fixers in cereals and other non-legume crops has thus been increased by the selection of isolates with high temperature tolerance, phosphate solubilization, phytohormone synthesis, and high nitrogen fixation. According to our research, microbial inoculants may be utilized as a cost-effective input to boost crop output, reduce fertilizer consumption, and extract more nutrients from the soil. However, there is still more study to be done on the subject of improved nutrient absorption and the generation of phytohormones, which is a crucial factor in plant-microbe interactions.

Capability of crop plants to absorb nutrients. Bacteria that fix nitrogen and phosphorus have an additive influence on the growth and development of cereal crops. Rhizobacteria that control plant development is often utilized in non-leguminous crops including rice, maize, and wheat. Positive yield response to Bacillus species inoculation has been seen in rice, sorghum, barely, and maize. Due to the roots' strong potential to absorb nutrients, treatment of wheat seeds with PGPR has resulted in an optimistic rise in wheat output. Azotobacter, Bacillus, and Azospirillum are the bacterial genera implicated in PGPR [9], [10]. Crop yield has increased as a result of seed treatment with Bacillus species for wheat and barley. In a similar manner, Bacillus sp. treatment of wheat seeds increased soil structure, plant development, and root growth. Collective seed treatment with bacteria that fix nitrogen and mobilize phosphorus is more efficient than a single application. Biofertilizers increase the availability of crucial nutrients for agricultural plants while also inhibiting dangerous soil diseases. In contrast to treatments using solely nitrogen-fixing or phosphorus-solubilizing bacteria, combined application of these organisms increases the yield in sorghum and barley.

The germination, growth, and yield of wheat are all improved by treating wheat seeds with *Pseudomonas putida* and *Baccilus lentus*. When phosphorus-solubilizing bacteria are combined with Azotobacter, wheat seed inoculation with Azotobacter boosts each yield metric individually as well as the crop's overall output. The biological yield of wheat is increased by using nitrogen-fixing bacteria (*Azotobacter chroococcum*) as a source of biofertilizer. When used as a source of biofertilizer in wheat, *Azotobacter chroococcum* and *Bacillus magatherium* work together to provide outcomes that are more favorable for plant development than a single *Bacillus magatherium* treatment.

In comparison to the control treatment, inoculating wheat cultivars with PSB and nitrogen-fixing bacteria produces good results. *Azotobacter chroococcum* inoculation has been shown to increase cereal crop yields by 15 to 20% and non-leguminous crop yields by 10%. Azotobacter is often utilized as an inoculant in agricultural crops because of its exceptional capacity to fix atmospheric nitrogen and make it accessible to crop plants. The combined treatment of flax seeds with nitrogen-fixing bacteria and phosphorus-solubilizing bacteria, such as Bacillus sp., increases the generation of growth-promoting chemicals that aid in the multiplication and cell enlargement of plant cells and ultimately increases all growth parameters.

Even while biofertilizer usage isn't widespread for all crops, farmers are becoming more aware that some cash crops, such as vegetables and sugarcane, as well as cereals, pulses, and oil seeds, may all benefit from using biofertilizers to boost productivity. The use of biofertilizers in horticulture agricultural operations is a relatively new idea. Fruit crops today often get more attention than decorative and vegetable crops. For several horticultural crops, *Glomus fasciculatum, Glomus mosseae*, *Azospirillum, Azotobacter, and PSB have* been proven to be helpful. Use of biofertilizers, especially Azotobacter inoculation, might replace 50% of the nitrogen needed for banana growth and result in greater yields than complete nitrogen treatment. In correlation with VAM fungus, there is a rise in the absorption of nutrients that are mobile, such as nitrogen.

It has also been shown that Azotobacter and Azospirillum have positive effects on banana production. The uptake of less mobile nutritional elements including P, Ca, S, Zn, Mg, and Cu from the rhizosphere has increased more than twofold as a result of VAM fungus. These are well suited for mosambi (sweet lime) because to the great efficiency of AzospiriIlum for fixing nitrogen and improved mobilization of fixed phosphorus by VAM even at high temperatures. Guava trees treated with VAM have been shown to have a lower percentage of wilting than untreated trees. Due to the VAM inoculation, the content of N, P, K, as well as Fe, Mn, Zn, and Cu, rises. Studies on biofertilizers and chemical fertilizers have been conducted to evaluate their impact on mosambi's growth, production, and quality.

Biofertilizers speed up certain microbial activities in the soil that provide nutrients in a way that plants can readily absorb. Biofertilizers are compounds that help plants develop by supplying nutrients via natural processes including nitrogen fixation, phosphorus solubilization, and growth-stimulating substance production. Biofertilizers are now a significant part of the integrated nutrient delivery chain. Blue-green algae (BGA) and other biofertilizers including Rhizobium, Azotobacter, Azospirillum, and others have been used for decades. To speed up the microbial activities in soil, it is necessary to apply massively multiplied cultures of chosen efficient microorganisms since thesemicroorganisms are often not as effective in natural environments as required. Therefore, to ensure healthy plant development and increased output yields, the usage of biofertilizers is highly advised by qualified specialists.

CONCLUSION

Biofertilizers may be applied in a variety of ways, including seed coating, soil application, and foliar spraying, giving farmers flexibility in incorporating these environmentally friendly substitutes into their routines. Biofertilizers are essential for encouraging eco-friendly agricultural methods, lowering reliance on chemical fertilizers, and minimizing soil erosion in a time when the ecological impact of farming activities is being closely examined. Biofertilizers are crucial instruments for boosting soil health, crop production, and the long-term health of our planet as we continue to practice ecologically friendly agricultural techniques and work to maintain food security in a changing world. Their significance arises from their contribution to environmentally friendly farming methods and the worldwide initiative to build robust and sustainable agricultural systems.

REFERENCES:

[1] T. Mahanty *et al.*, “Biofertilizers: a potential approach for sustainable agriculture development”, *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-016-8104-0.

[2] R. Chatterjee en S. Bandyopadhyay, “Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (Vigna unguiculata L. Walp.) in acid soil of eastern Himalayan region”, *J. Saudi Soc. Agric. Sci.*, 2017, doi: 10.1016/j.jssas.2015.11.001.

[3] S. Mukhtar, I. Shahid, S. Mehnaz, en K. A. Malik, “Assessment of two carrier materials for phosphate solubilizing biofertilizers and their effect on growth of wheat (Triticum aestivum L.)”, *Microbiol. Res.*, 2017, doi: 10.1016/j.micres.2017.08.011.

[4] R. W. Mukhongo, J. B. Tumuhairwe, P. Ebanyat, A. A. H. AbdelGadir, M. Thuita, en C. Masso, “Combined application of biofertilizers and inorganic nutrients improves sweet potato yields”, *Front. Plant Sci.*, 2017, doi: 10.3389/fpls.2017.00219.

[5] L. N. P. Patola, S. Supriyono, en P. Pardjanto, “EFFECT USE BIOFERTILIZER AND DIFFERENCES TYPE SOIL ON GROWTH AND YIELD ARROWROOT”, *Sains Tanah - J. Soil Sci. Agroclimatol.*, 2017, doi: 10.15608/stjssa.v14i1.600.

[6] N. K. & Y. K. S. Rakesh Kumar, “Role of Biofertilizers in Agriculture”, *Popular KhetiVolume -5, Issue-4 (October-December), popularkheti.infoISSN: 2321-0001*, 2017.

[7] S. Islas-Valdez *et al.*, “Effectiveness of rabbit manure biofertilizer in barley crop yield”, *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-015-5665-2.

[8] R. T. KATOLE, U. R. CHINCHMALATPURE, en G. B. MORE, “Constraints faced by the farmers in adoption of biofertilizers”, *Agric. Updat.*, 2017, doi: 10.15740/has/au/12.4/628-633.

[9] J. Larsen, H. Pineda-Sánchez, I. Delgado-Arellano, V. Castellano-Morales, L. Carreto-Montoya, en J. Villegas-Moreno, “Interactions between microbial plant growth promoters and their effects on maize growth performance in different mineral and organic fertilization scenarios”, *Rhizosphere*, 2017, doi: 10.1016/j.rhisph.2017.01.003.

[10] S. H. Hong en E. Y. Lee, “Phytostabilization of salt accumulated soil using plant and biofertilizers: Field application”, *Int. Biodeterior. Biodegrad.*, 2017, doi: 10.1016/j.ibiod.2017.05.001.

CHAPTER 10

ANALYSIS OF BIOFERTILIZERS AND STAINABLE ECONOMIC DEVELOPMENT

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ABSTRACT:

The key idea of sustainable economic development blends sustainability with economic growth to provide long-term prosperity without endangering the environment or social equality. This essay examines the many facets of sustainable economic growth, including its essential elements, difficulties, and possible remedies. To build a circular and green economy, it entails maximizing resource utilization, cutting waste, and stimulating innovation. Short-term profit-seeking, resource depletion, and uneven distribution of rewards are obstacles to establishing sustainable economic growth. Governments, corporations, and civil society must work together to create sustainable policies and practices in order to overcome these obstacles.

KEYWORDS:

Economic Growth, Environment, Social Equity, Sustainability.

INTRODUCTION

The so-called liquid biofertilizers are an option. In addition to the desired microorganisms and their nutrients, liquid biofertilizers also include unique cell protectants or compounds that encourage the creation of dormant spores or cysts for a longer shelf life and greater resistance to harsh environmental conditions. The bacteria in liquid biofertilizers have a two-year shelf life and can maintain a consistent count of up to 109 cfu/ml. They can withstand UV rays and high temperatures (55 °C). Since these compositions are liquids, field application is likewise quite straightforward and uncomplicated. They are administered with the use of fertigation tanks, power sprayers, hand sprayers, etc. Standardizing the medium, the manner of inoculation, etc. for the new formulations is necessary in order to develop acceptable alternative formulations, such as liquid inoculants or granular formulations for all bioinoculants. Lack of knowledge of fundamental microbiological processes during inoculant production jeopardizes the effectiveness and quality of the vaccines. Poor germination may be caused by the loss of the seed coat from the seed caused by rubbing the seed with the biofertilizers solution. The commercialization of biofertilizers may be seriously hampered by inadequate product formulation. However, the increased need for high-quality inputs spurs innovation [1], [2].

The following factors must be taken into account while creating high-quality inoculants: using biotechnological techniques for strain improvement; exchanging cultures between nations with similar climatic conditions and evaluating their performance to find better strains for a specific crop; and identification/selection of effective location/crop/soil/soil-specific strains for and absorbing (mycorrhizal); to prevent spontaneous mutations, cultures should be monitored for activity while being stored. Effective storage is necessary since the shelf life is so short (typically 6 months). Because they can't hold the goods for a long period, this deters business owners from manufacturing more than they can sell right away and farmers from purchasing more than they need right away. When it comes to shelf-life and storage conditions, the majority of the biofertilizers sold in nations where imports are the norm are usually not adapted to local requirements. For instance, biofertilizers that need to be stored in a cold environment to have a longer shelf life are not appropriate for locations where temperatures are often rather high. It follows that it is not unexpected that such items will not fulfill the quality criteria, most likely as a consequence of viability loss due to improper storage conditions. Because of this, it's crucial that while creating a product, you take into account how long it will last under various storage and handling circumstances [3], [4].

Low demand brought on by a lack of knowledge and comprehension of biofertilizers is often the cause of the sector's growth challenges. In many circumstances, manufacturing is still difficult due to the high cost, as well as the low demand and inadequate delivery methods that may be related to the unique needs for handling and storage conditions. The field performance and, as a result, the adoption rate is influenced by the product shelf life, carrier material quality, storage circumstances such as temperature, handling such as transportation, as well as the presence of contaminants. To maintain product viability over a long length of time, it is crucial to increase the shelf-life of locally produced biofertilizers under varied storage circumstances. The lack of adequate manufacturing facilities is a significant infrastructure restriction. Another issue is that inputs are either not available at all or are not available at the right moment. It is a good idea to establish cold storage facilities in production centers and employ microbiologists in production units to monitor the output as a way to enhance production infrastructure. Farmers are left in the dark and at danger due to the biofertilization's poor marketing infrastructure and lack of consistent information about its use.

Equipment: Because the manufacturing process is sluggish and time-consuming in this scenario due to a lack of needed equipment and electricity, there is an increase in labor.

It is crucial to have enough space available for a lab, manufacturing, storage, etc. Additional area is required for cultivating, for example, green manure crops, in order to increase biofertilizer output. Other significant difficulties are the absence of subsidies and the trade of biofertilizers at fair prices. However, the rising demand for biofertilizers and farmers' growing knowledge of their usage have made it easier to produce biofertilizers and inspired entrepreneurs to start their own biofertilizer businesses. Since inoculant packets need to be kept in a cold location away from direct sunlight or strong winds, a concern that affects the quality of biofertilizers is the lack of facilities for cold storage of inoculant packets. Biofertilizers may be exposed to high temperatures, which are unfavorable circumstances, due to the insufficient storage facilities.

Issues obtaining bank loans and a lack of adequate finances: Both the overall consumption and cost of inorganic fertilizers are rising. Their effectiveness in usage is still limited, and regulations and environmental concerns are pushing back against their use. As an alternative, sustainable biofertilizers provide excellent usage efficiency, a cheap cost, and little environmental effect. Their financial situation is improving right now. The 6biofertilizer sector is susceptible to lower profits due to the selling of goods in more compact manufacturing units. This is a significant issue since managing the structure and management of big production facilities involves dealing with a variety of scientific, economic, social, and environmental issues [5], [6].

Due to the seasonal nature of both biofertilizer supply needs and demands, biofertilizer manufacturing and distribution take place only during a select few months of the year. In order to meet the geographical and temporal variety of crop responses, biofertilizer companies must develop superior formulations that are suited to local circumstances. In order to create formulations that might fulfill these needs, substantial study on the technology is required. Producers won't be able to take use of biofertilizers' full potential without this study.

The use of biofertilizers often depends on the other agricultural procedures requiring concurrent activity. Additionally, the brief window of sowing or planting in a certain location must be taken into account. As a result, biofertilizers must be administered in the proper quantities using a suggested technique. Any application of biofertilizer will be less effective if low-quality adhesives are used, especially when combined with high concentrations of plant protection agents. Salinity, acidity, dryness, water logging, and other soil properties are crucial. Since these factors influence microbial development and crop response, they should all be taken into account. These factors include high soil temperature or low soil moisture, excessive acidity or alkalinity in the soil, inadequate availability of phosphorus and molybdenum, and existence of a high native population or presence of bacteriophages. For instance, the characteristics of the plant (crop genotype), the inoculant (the microbial strain), and the environmental factors (such as soil and weather) as well as agronomic management all have an impact on the field performance of biofertilizers, such as Rhizobium inoculants [7], [8].

DISCUSSION

Controlling the inoculum's quality is crucial. Unfortunately, the inoculum quality is sometimes problematic, and it's possible that up to 90% of all inoculum are useless for increasing the yield of legumes. There are several potential causes for agricultural yields that failed to respond to vaccination. Poor inoculum production management (low density of infectious propagules or poor inoculum storage conditions) and incompatible inoculum-crop species are a few of them. combinations or edaphic factors that might make vaccination unsuccessful. To streamline and explain the laws governing commerce and quality, both federally managed and globally standardized regulations are required. Inoculations made in industry. Institutions of higher learning and agriculture experimental stations would contribute to a network that is currently in place and might easily assist services to assess available immunization and deliver necessary quality control.

The fundamental issue preventing the widespread usage of *Azospirillum* is the findings' extreme unpredictability and ambiguity. Despite these concerns, Azospirillum has a lot of potential as a biofertilizer that stimulates growth by fixing N_2. Its growth-promoting qualities are widely known, and both commercial manufacturing and field use are straightforward. Inoculum may be created and used similarly to peat formulation, and its creation is affordable. The peat mixture may also be directly used to agricultural uses and field research. To choose a trustworthy and efficient method for inoculum manufacture and field application, various carriers deserve and demand more investigation. As well as enhancing plant nutrition by fixing atmospheric N or saturating pools of P inaccessible to plants, bacteria may also have an impact on plant development by producing plant hormones. Alder (*Alnus glutinosa*) rhizosphere-isolated *Bacillus pumilus* and *B. licheniformis* have the capacity to generate large quantities of physiologically active gibberellins.

Possibly over 80% of all terrestrial plants engage in mycorrhizal symbioses. The prevalence of mycorrhizal symbioses draws attention to the long evolutionary history and possible significance of fungal symbioses for plant physiology and productivity. The relationship between plants and the mycorrhizal fungi that colonize their roots is a functional symbiosis in which the mycorrhizal fungus is either obligatorily or facultatively reliant on the photosynthetic products and energy of the host plant. The carbon that the plant has absorbed is exchanged for the host plant's many mycorrhizal advantages. Nutrients from the soil solution are taken up by the fungal mycelium that spreads from the root surfaces into the soil matrix. The tiny width of the fungal hyphae increases the surface area that the plants may use to absorb nutrients. Plant development is often enhanced when mycorrhizal fungi invade the root systems due to the more effective nutrient intake. The creation of extensive inoculation programs has been hindered by the uncultivability and obligatory biotrophy of arbuscular mycorrhizal (AM) fungus (Wood and Cummings, 1992). Growing the inoculum in symbiosis with live host plants or in root organ cultures, or, to put it another way, never in the absence of living host tissue, is the only practical method for producing infectious propagules. Such production techniques have the benefit of enabling continuous monitoring of the inoculum's infectious potential, but their main disadvantages include high production costs, sluggish turnaround times, and difficulties eliminating secondary root colonizers such root diseases [9], [10].

Spores, pieces of roots that have been colonized by AM fungus, a mix of the two, or soil mycelium may all be used as the inoculum for AM. It is possible to separate AM spores and hyphae from the soil substrate and combine them with carrier substrate. Pumice or clay, sand, perlite, vermiculite, soilrite, and soil or glass pellets are examples of often used transporters. While pieces of colonized roots are efficient for certain AM species but not others, pores may be the most dependable source of inoculum for all AM taxa The whole substrate, including the soil mycelium, plant roots, and fungus spores, may also be employed and homogenized to create a crude soil carrier. Experimentally, a variety of alternatives have been tried, such as soil-free aeroponic nutrient film and root organ culture (systems. However, the high costs of these alternatives seem to rule them out. Furthermore, these alternative techniques have not been well established for producing inoculum on a wide scale.

The necessity for AM inoculation should be carefully assessed in light of the high costs and challenges involved in inoculum production. It may be necessary to take into account the deciding elements such as the anticipated crop response to AM inoculation, the accessibility of soilborne inoculum, and alternative methods such cropping system management for AM inoculum maintenance. Recent research also implies that AM fungi may not be as host specific as previously thought. The likelihood that AM fungi have patterns of host specialization emphasizes how crucial strain and taxon selection are for each inoculation application. Large-scale inoculation has not yet shown to be feasible or practicable in routine agricultural methods, despite AM inoculum being commercially accessible.

As a result, the AM inoculation has only been used to produce high-quality nursery stock. The inoculation is often exceedingly beneficial in these nursery applications, leading to enhanced crop growth, quicker development, and homogenous final products. The significance of management for the preservation of soilborne fungus must be stressed in the absence of practical applications for the development of AM inoculum for agricultural activities. Other reviews and discussions of the potential and comparative advantages of various immunization and land management approaches have been published. We just highlight a few broad suggestions. Maintaining sufficient inoculum levels in the soil may be possible by intercropping or sequential cropping systems that provide continuous plant cover. The indigenous inoculum is also likely to be supported by reducing disruption. As P, in particular, often prevents AM colonization, extensive fertilization may also need to be avoided. The last argument emphasizes the significance of management techniques for higher soil AM inoculum in agricultural systems, which may not enable the use of commercial fertilizers in an economically feasible manner. In intensive agriculture systems that mainly depend on fertilizing with N and P.

Programs for EM fungus vaccination have shown some success. There doesn't seem to be a single fungal species or strain that can be universally used across diverse places and host species, however, similar to how AM or bacterial inoculum applications work. The P. tinctorius strain that had proved to be very useful for seedling development and establishment elsewhere was less advantageous when compared to native strains and species in the northern United States The performance of the planted seedlings is often only slightly improved by strains that readily colonize seedlings in nurseries and are simple to manage). The poor performance of the fungi used in the inoculation programs may simply be a result of the indigenous mycorrhizal fungus's widespread distribution in reforested areas and their competitive exclusion of the fungi from the nursery in the field. In light of this, plantations that will be developed on previously unforested lands or sites with a poor history of reforestation may benefit the most from EM fungus inoculation.

The effect that imported and potentially invasive EM fungi have on the indigenous fungus and the makeup of their communities has received very little consideration in the study concentrating on the creation of the forest nursery inoculation programs. Long-lasting inoculation fungus may outcompete less invasive indigenous strains and species in the root systems may homogenize local fungal populations and communities even if there is presently no clear evidence for such competitive exclusion. For instance, imported and planted Eucalyptus trees in the United States often encourage substantial colonization by the fake truffle *Hydnangium carneum*. Similar to how cork oaks were introduced from Europe, Amanita phalloides is expanding in California's natural oak stands. The unanswered issue is whether the local EM communities have been negatively impacted by these successful invaders.

The creation of inoculum programs for these diverse fungi that may be helpful has received very little attention. Although many of these fungi can be readily cultivated, which also makes them simple to manage in inoculation applications, the issues with inoculation are similar to those that have been discussed with regard to mycorrhizal fungi and root-associated bacteria. The favorable effects, whether they promote growth or not, may vary greatly depending on the genotype of the host and the chosen fungal strain or species, and they can alter as a plant develops or the environment changes. However, many of these mushrooms seem to have a high level of environmental tolerance based on their widespread existence and potential worldwide dispersal. This, along with the mentioned lack of host specificity.

More knowledge on the interactions between plants and rhizosphere microorganisms is urgently needed in order to improve our understanding of the role of various root-associated organisms in plant growth and health as well as make use of their potential beneficial features as biofertilizers in plant production. We have briefly discussed a few instances of bacteria and fungi that have the potential to be very effective biofertilizers. We admit that the examples we used were oversimplified. Studies using streamlined laboratory trials, however, are crucial for disentangling many aspects and selecting the best potential candidates for biofertilizers. However, it might be challenging to apply the findings of such trials to actual field situations. The rhizosphere also poses new difficulties since it is a manipulable environment. A clear result from inoculation trials in the field may be hindered by the difficulties of removing indigenous bacteria and fungus since the rhizosphere is a very dynamic system with many fungi and bacteria interacting at once. We are aware of the challenges involved in carrying out such studies on a scale that would be useful in routine agricultural operations. The financial feasibility of immunization programs won't be clear, however, until the beneficial impacts can be repeatedly shown in real-world settings. Multiple inoculations may be used to encourage N_2 fixation, P absorption, and overall mineral nutrition, but they can also aid in the management of plant diseases. Such uses would be appreciated since they permit the decrease of costly and ecologically hazardous chemical pesticides and fertilizers. The durability of the biofertilizer after inoculation is an intriguing problem in addition to the risk of infection. Agricultural soils may be able to develop inoculum potential, which might lengthen the time between biofertilizer treatments and save expenses.

Extracellular enzymes are produced by a variety of bacteria and fungi, and they may be used to increase agricultural yields and lower the price of inorganic fertilizers. We stress the need of doing field tests with various organism inoculations. If diverse organisms with different confirmed or speculated advantages to the crop plants can be incorporated, these inoculum combinations could be of maximum value. It is desired to include various microbial capabilities into combination biofertilizers with a variety of possible yield-promoting effects. The best way to do this is probably to use biofertilizer research and application at a scale that is relevant to agricultural operations. It is appropriate to start by looking for financing and partnership opportunities between research centers and the biotechnology sector. To accomplish the aforementioned research and practical application objectives, large-scale inocula production is necessary. Inoculum manufacturing for field trials as well as testing of industrial scale inoculum production for direct marketing are both made possible because to the connection between research and industry.

CONCLUSION

The need to strike a balance between economic growth and social equity and environmental preservation drives sustainable economic development. To build a circular and green economy, it entails maximizing resource utilization, cutting waste, and stimulating innovation. Short-term profit-seeking, resource depletion, and uneven distribution of rewards are obstacles to establishing sustainable economic growth. Governments, corporations, and civil society must work together to create sustainable policies and practices in order to overcome these obstacles. In summary, sustainable economic growth is an all-encompassing strategy that places a high priority on the welfare of future generations. It highlights the need of responsible resource management and social equality and acknowledges that economic development alone is inadequate. Societies may advance towards a more sustainable and prosperous future by addressing the issues and implementing creative solutions, ensuring that economic growth does not come at the price of the environment or disadvantaged populations.

REFERENCES:

[1] E. W. F. Peterson, “The role of population in economic growth”, *SAGE Open*, 2017, doi: 10.1177/2158244017736094.

[2] M. A. Al-Jarhi, “An economic theory of Islamic finance”, *ISRA Int. J. Islam. Financ.*, 2017, doi: 10.1108/IJIF-07-2017-0007.

[3] M. Tremmel, U. G. Gerdtham, P. M. Nilsson, en S. Saha, “Economic burden of obesity: A systematic literature review”, *International Journal of Environmental Research and Public Health*. 2017. doi: 10.3390/ijerph14040435.

[4] C. Padoa-Schioppa en K. E. Conen, “Orbitofrontal Cortex: A Neural Circuit for Economic Decisions”, *Neuron*. 2017. doi: 10.1016/j.neuron.2017.09.031.

[5] R. Islam, A. B. A. Ghani, I. Z. Abidin, en J. M. Rayaiappan, “Impact on poverty and income inequality in Malaysia’s economic growth”, *Probl. Perspect. Manag.*, 2017, doi: 10.21511/ppm.15(1).2017.05.

[6] D. Collins, F. Hafidz, en D. Mustikawati, “The economic burden of tuberculosis in Indonesia”, *Int. J. Tuberc. Lung Dis.*, 2017, doi: 10.5588/ijtld.16.0898.

[7] D. L. Bennett, H. J. Faria, J. D. Gwartney, en D. R. Morales, “Economic Institutions and Comparative Economic Development: A Post-Colonial Perspective”, *World Dev.*, 2017, doi: 10.1016/j.worlddev.2017.03.032.

[8] B. F. M. Wijnen *et al.*, “A systematic review of economic evaluations of treatments for patients with epilepsy”, *Epilepsia*. 2017. doi: 10.1111/epi.13655.

[9] N. D. Johnson en M. Koyama, “States and economic growth: Capacity and constraints”, *Explorations in Economic History*. 2017. doi: 10.1016/j.eeh.2016.11.002.

[10] S. Zhu en R. Li, “Economic complexity, human capital and economic growth: empirical research based on cross-country panel data”, *Appl. Econ.*, 2017, doi: 10.1080/00036846.2016.1270413.

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CHAPTER 11

INTERPRETATION OF BIOFERTILIZERS MARKET SIZE AND GROWTH PROSPECTS

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ABSTRACT:

Due to its importance for environmental preservation and sustainable agriculture, the biofertilizers industry has seen rapid expansion in recent years. The biofertilizers market is thoroughly examined in this research, with particular attention paid to its size, future development potential, and consequences for the agriculture sector. The research investigates the elements influencing the growth of the biofertilizers industry via an analysis of market trends, drivers, and obstacles. The study emphasizes the significance of biofertilizers in maintaining soil health, decreasing reliance on chemical fertilizers, and increasing agricultural output. It does this by drawing on empirical evidence and industry perspectives. In the article, important geographic areas and market categories for biofertilizers are also covered. This article offers a thorough overview of the market for biofertilizers and its potential benefits to sustainable agriculture, making it an invaluable resource for academics, investors, regulators, and agricultural experts.

KEYWORDS:

Agriculture, Biofertilizers, Crop Productivity, Environmental Conservation, Market Growth, Market Size, Soil Health, Sustainable Agriculture.

INTRODUCTION

The market is influenced by a number of variables, an increase in fertilizer demand owing to an increase in world food production; and the development of novel biofertilizer manufacturing methods. Players in the biofertilizers market have new development prospects due to the high growth potential in developing markets and undeveloped areas. On the other side, inadequate infrastructure, a lack of understanding about biofertilizers, and low adoption rates are some problems limiting the market for these products. Due to their ability to act as a physical barrier against pests, the global market for biofertilizers is predicted to expand significantly between 2015 and 2017. These items also shield plants from infections and improve zinc and phosphorus uptake. The use of biofertilizers in agriculture also promotes plant growth and development overall while assisting in the breakdown of organic wastes. The usage of biofertilizers has been prompted by the growing need for high agricultural production in order to satisfy rising population needs because of their little effect on the environment. Over the next five to seven years, consumers' growing demand for organic foods is anticipated to positively affect the market for biofertilizers. In addition, the market for biofertilizers is anticipated to be significantly impacted by the increasing costs of chemical fertilizers as well as the commercial reaction to rising food prices between 2015 and 2017 [1], [2].

The industrial value chain is a major barrier to the development and adoption of the biofertilizers market. It comprises of end users (farmers, household growers), makers and suppliers of biofertilizers, distribution networks, and raw material suppliers. Biofertilizers are made from a variety of materials, including ley crops, frying oils, potato peels, manures, slaughterhouse wastes, home organic wastes, and leftovers from the food sector. The feedstock providers that supply the manufacturers of biofertilizers are also quite present. As an example, Swedish Biogas is an integrated business that produces biofertilizers as a consequence of the manufacturing of biogas. Additionally, the business provides raw materials to independent biofertilizer manufacturers. The majority of raw material providers pay for logistics, or the purchasing and delivery of raw materials to manufacturers. Given that bio-waste makes up the majority of the raw materials, suppliers are very profitable, adding an estimated 10% to the final product's worth [3], [4].

Since the demand for the product is heavily reliant on the expansion of the end-use industries, the majority of biofertilizer producers are integrated throughout multiple stages of the value chain. In sum, corn, rice, and maize cultivation employ 90% of the biofertilizers produced. Natural items devoid of synthetic chemicals or food additives make up organic food and drinks. Organic fruits, vegetables, animal products, and organically produced alcoholic drinks like wine and beer are some of the main product types of organic foods. Growing consumer awareness of the harmful effects of inorganic food on human health has caused an industry trend change in favor of boosting the organic food market and is anticipated to continue to be a major driver of the biofertilizers market over the coming years.

Biofertilizers that fix nitrogen dominated the market in 2012, accounting for around 79% of worldwide sales. Leguminous and nonleguminous crops alike employ nitrogen-fixing biofertilizers, particularly when producing rice and sugarcane. Due to the fact that nitrogen-fixing biofertilizers are the most widely used biofertilizers worldwide, the nitrogen-fixing sector is expected to develop. The main factors fueling the development of this market are significant R&D efforts that have been made in recent decades, together with rising farmer awareness. Over the course of the forecast period, the market is anticipated to benefit from the growing relevance of nitrogen fixation, which helps plants consume more components including nucleic acids and chlorophyll. Over the next seven years, the need for nitrogen-fixing biofertilizers is anticipated to be seriously threatened by the market presence of synthetic fertilizers.

Phosphate solubilizing bacteria are anticipated to account for nearly 18% of the market for biofertilizers, up from 14% in 2012. Low molecular weight organic acids are mostly transformed into soluble nutritional product forms using these products. Biofertilizers that solubilize sulfur, zinc, and potash are additional product kinds. In 2012, the aforementioned product types together accounted for 7% of the market for biofertilizers worldwide. The introduction of liquid biofertilizers is one of the next developments anticipated to fuel the growth possibilities of this industry. The last kind of formulation is a liquid one that includes the appropriate bacteria, micronutrients, and substances that encourage the production of resting spores. With a shelf life of over two years and a tolerance for high temperatures and ultraviolet rays, the biofertilizer benefits from this and can withstand harsh circumstances. Additionally, compared to solid biofertilizers, the microorganism density in such fertilizers is greater. Power sprayers, fertigation tanks, hand sprayers, and basal manure mixed with farmyard manure are used to apply them. The strong enzymatic activity of these liquid biofertilizers contributes to their widespread use among farmers.

The usage of fertilizers, which enable farmers to double crop yields by three to four, has been driven by the deterioration of soil quality. Many farmers are turning to liquid fertilizers as a result of the increase in cropland and the rising need to increase crop output since plants can quickly absorb these nutrients and provide results more quickly. Additionally, small-scale farmers are buying liquid fertilizers to lessen their reliance on the weather and enhance their production even in gloomy, windy, or rainy circumstances. As soil quality deteriorates and crops all over the globe experience micronutrient deficiencies, there is also an increase in demand for fertilizer application techniques that are effective. Due to the expansion of hydroponic system fields, the availability of fertilizers at reduced prices, and an increase in mechanization, which has led to a rise in the adoption of technologies like liquid fertilizer sprayers, APAC (Asia Pacific) will experience the fastest market growth between 2012 and 2017. Australia, Indonesia, Malaysia, the Philippines, Thailand, Vietnam, Japan, South Korea, China, India, Pakistan, and Bangladesh are a few of the region's largest consumers of fertilizer. Due to the expansion of initiatives that encourage the balanced use of fertilizers, the demand for fertilizers in the area is expected to increase significantly [5], [6].

Additionally, the global sales of new fertilizer spreaders are increasing due to the rising need for fertilizers to increase output yield. In order to increase spreading accuracy and maintain soil quality, manufacturers have developed new spreader models with enhanced features like expanded spreading widths, intelligent speed monitoring systems, and slow-releasing fertilizer spreaders. Other innovations in the spreaders include section shut-off mechanisms, larger hopper capacity, and LED back lighting systems. During the projection period, such technical breakthroughs and enhanced features would hasten the volume sales of fertilizer spreaders. The worldwide fertilizer spreader market is expected to expand at a CAGR of more than 6% by2018 according to a market research analyst at Technavio. Through calibrating systems to control fertilizer quantity and mass flow controls to track the amount of fertilizer needed per subplot, precision fertilizer spreaders will aid in increasing agricultural yields and productivity. These spreaders will also aid in soil mapping, the use of satellite technology to direct fertilizer application, and software programs that analyze soil nutrients to decide fertilizer delivery. Some of the well-known manufacturers of precision fertilizer spreaders on the market include KUHN, AMAZONE, BBI, and Sulky.

In 2015, the broadcast spreader market category had a commanding 64% of the overall market share. The majority of the time, granular fertilizers are dispersed using these spreaders, sometimes referred to as rotating spreaders or centrifugal spreaders. The future development of this market will be favorably impacted by the consolidation of agriculture, since these spreaders are mostly used on big farms. Additionally, the manufacturers are releasing new broadcast spreaders with enhanced features including balanced fertilizer distribution, GPS speed sensors to maintain the proper speed, and pressure-based nozzle control systems to guarantee a constant pattern in the fertilizer spreading. The market for fertilizer spreaders is divided geographically into the Americas, Asia Pacific, and Europe regions. Throughout the projection period, APAC will maintain its market dominance, and by 2018, it is anticipated to hold more than 60% of the total market share. The growing reliance on fertilizers for increased agricultural production is a significant element in the high market share of the area. Farmers are using more phosphorous and potassium fertilizers as a result of the increased attention being paid to the quality of crop output, which has increased demand for fertilizer spreaders in the area.

DISCUSSION

Bio-fertilizers, which are a crucial part of organic farming, are solutions containing active or dormant cells of effective strains of nitrogen-fixing, phosphate-solubilizing, or cellulolytic microorganisms that are applied to seed, soil, or composting areas in order to boost the population of these organisms and speed up the microbial processes that increase the availability of nutrients that are simple for plants to absorb. By fixing atmospheric nitrogen, both in conjunction with plant roots and separately, biofertilizers significantly contribute to enhancing soil fertility. They also solubilize insoluble soil phosphates and generate plant development factors in the soil. One of the key elements of integrated nutrient management is the use of biofertilizers, which may be used as an alternative to chemical fertilizers for sustainable agriculture and are both affordable and renewable sources of plant nutrients. Biofertilizers are made by using a variety of microorganisms and their interactions with agricultural plants. In India, organic agricultural practices have been used since the dawn of time. It is a farming system that focuses on cultivating the soil and growing crops in a way that preserves the soil's life and health by using organic wastes (crop, animal, and farm waste, aquatic waste), other biological material, and helpful microbes (biofertilizers) to release nutrients to crops for increased sustainable production in a clean, pollution-free environment.

Organic farming is based on the principles and logic of a living organism, in which all components (soil, plants, farm animals, insects, farmers, and environmental factors) are interdependent. This is achieved by using, wherever practical, agronomic, biological, and mechanical approaches, adhering to the interactions' guiding principles, and utilizing natural ecosystems as models. Many methods utilized by other sustainable agricultural methods may be used to organic agriculture. Understanding the governing principles of organic agriculture is essential to comprehending the goals, methods, and motivations of organic farmers. These guidelines include the essential aims and restrictions that are thought to be significant for producing high-quality food, fiber, and other items in a manner that is ecologically sustainable. The fundamentals of organic farming have evolved along with the movement. The integration of modern organic agriculture with the broader environmental movement has led to concepts that are more strongly focused on the environment than those from the first half of the 20th century. In addition, the ideas haven't been formalized or properly articulated until the last 30 years. Since they were ingrained in the farmers' practices and mentality for a large portion of the history of organic agriculture, the following concepts were not codified:

1. The idea that a farm is a living thing that is sensitive to its surroundings and tends to be a closed system in terms of nutrient fluxes.
2. The idea that soil fertility may be improved through time by creating a "living soil" that has the power to impact and transmit health to plants, animals, and [people] via the food chain.

As of today, the 'fundamental criteria' of the IFOAM organic guarantee system have been published as the principles. The objectives of organic agriculture were made clearer by using them as an introduction to the standards. Over the ensuing time, there have been several modifications and additions to the initial seven principles. Members of the General Assembly submitted proposals for revisions, which were discussed and decided upon during the annual General Assembly. As part of the standards reform, they have also been modified. The present "principle aims of organic agriculture for production and processing" are the result of this process. Compared to the seven principles of the 1980s is far lengthier and includes more "principle aims" than actual principles.

There has been a rising perception in recent years that the main objectives have deteriorated, lack coherence, and have become bloated. A taskforce to revise the principles was established by the global board as a consequence of a resolution adopted at the IFOAM General Assembly in 2002. The group will present its findings to the 2005 General Assembly for approval after extensive engagement. As a result, they are now a work in progress, with a first draft already available. The proposed principles are significantly different from the present principal objectives and are more like the original 1980 principles in terms of philosophy and organization. Others have been discussing and improving organic concepts in addition to this effort. In order to give stakeholders and decision makers with a uniform framework on which to base suggestions, Benbrook and Kirschenmann (1997) produced a concise set of principles during the 1990s when the governments in the USA were drafting legislation to manage the manufacture, marketing, and sale of organic items. The Danish Research Centre for Organic

Farming (DARCOF), in response to perceived ambiguities in current principles and the necessity for unambiguous principles to guide research planning, started a national discussion on the fundamentals of organic agriculture at around the same time [7], [8].

Equity between and among generations is another aspect of sustainability. By lowering the loss of arable land, water pollution, biodiversity erosion, GHG emissions, food losses, and pesticide toxicity, organic agriculture improves societal well-being. Traditional knowledge and culture are the foundation of organic agriculture. Its agricultural practices adapt to the specific biophysical and socioeconomic limits and possibilities of the local area. The economic climate and growth of rural areas may be enhanced by using regional resources, regional expertise, and establishing connections between farmers, consumers, and their markets. In order to maximize farm production, reduce farm susceptibility to weather whims, and ultimately improve food security, whether via the food the farmers produce or the cash from the items they sell, organic agriculture places a strong emphasis on variety and adaptive management. Organic farming seems to increase employment in rural regions by 30%, and labor productivity is greater for each hour worked. Organic farming helps smallholders access markets and generate revenue by better using local resources. It also relocalizes food production in market-marginalized regions. In wealthy nations, organic yields are typically 20% lower than high-input systems, but in dry and semi-arid regions, they may be up to 180% greater. In humid environments, rice paddy yields are comparable but perennial crop output is lower, while agroforestry adds extra benefits.

New export potential is brought about by the demand for organic goods. Exports of organic goods often command premiums of 20% or more over comparable goods grown on non-organic farms. By raising household incomes under the correct conditions, market returns from organic agriculture may be able to support local food security. It's difficult to break into this profitable sector. To ensure that their farms and companies uphold the organic criteria imposed by different trade partners, farmers must yearly hire an agency that certifies organic products. Farmers cannot market their food as "organic" during the 2 to 3 years it takes to switch to organic management, preventing them from benefiting from price benefits. While the majority of manufacturers in developing nations have focused on the EU and North American export markets, local market potential for organic food is now expanding globally.

Alternative alternatives to certification have developed globally, acknowledging the part local organic markets play in fostering a thriving organic industry. Consumers and organic farmers have established direct routes in industrialized nations for the home delivery of non-certified organic products (such as community supported agriculture). Farmers in the USA are technically excluded from certification if they sell modest amounts of organic goods. Participatory Guarantee Systems (PGS) are increasingly being accepted as a viable alternative to third-party certification in developing nations (such as India, Brazil, and the Pacific islands). More recently, organic farming has emerged as a viable alternative for enhancing family food security or lowering input costs. This behavior is being seen in industrialized nations as a result of the economic crisis. Farmers either consume their own produce or sell it on the open market at no premium since it is not certified. The goals of organic farmers are frequently to maximize interactions between the land, animals, and plants, preserve natural nutrient and energy flows, and enhance biodiversity, while also protecting the health of the family farmers and contributing to the overall goal of sustainable agriculture.

Larger farms make up the bulk of intensively managed farms in Asia, Latin America, and Africa that heavily depend on outside inputs. These farms mostly cultivate a small number of annual or perennial commercial crops, largely reliant on the use of fertilizers for plant nutrition and pesticides and herbicides for the management of pests, diseases, and weeds. On these farms, farm animals are often not included in the nutrient cycle and crops are frequently planted without a scheduled rotation. On these farms, diversification is often minimal. To allow for considerable automation, trees and shrubs are often cut down, and crops are typically produced on their own. In order to ensure the humane treatment of animals, the fairness principle is concerned with the interactions between the many groups of people engaged in agriculture, such as landowners, employees, and consumers. Even though the social equity component of organic agriculture was less prominent in the 1980s and 1990s, there are growing requests for it to be given more attention.

This implies that customers should be able to purchase high-quality goods at fair prices, that employees shouldn't be treated unfairly and should be given a living wage, and that farmers should be paid a fair price for their produce. The organic and fair-trade movements are now collaborating closely to implement these concerns, which are also central to the "fair trade" movement. The idea that the actions of the current generation should not harm future generations also applies to generations that will follow the present. Producers of livestock are obligated under the concept to treat animals humanely and ethically. This is a complicated and divisive topic since opinions on how to treat animals have evolved significantly over the last several decades and vary significantly between cultures. As a result, the organic movement continues to address animal rights, compassionate treatment of animals, and even the need of livestock in organic systems. In this discussion, the emphasis is on making sure that animals are healthy, that their living circumstances are in line with their physiology and natural behavior, and that stress and discomfort are kept to a minimum. As a result, there are certification requirements for livestock house designs, stocking densities, avoiding foods that animals wouldn't normally consume, and not breeding animals with intrinsic flaws like weak legs in turkeys [9], [10].

According to the definition given at the Wingspread Conference Centre in Wisconsin in January 1998, "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically” the "Precautionary Principle" is a manifestation of the "Principle of Care." In actuality, the precautionary and care principles work in opposition to the logic of risk management and cost-benefit analysis, which requires proof of a proposed activity's negative effects in order to forbid its usage. Activities that have the potential to be dangerous must demonstrate their safety before being approved, according to the precautionary and care principles. The care principle makes sure that new technologies that are probably hazardous are not used in organic agriculture without a full study of them and safeguards against possible damage. This perspective, which holds that the technology has a high potential for producing unanticipated negative effects and that the cost of such effects will be borne by people other than those benefiting from the technology, is a key factor in the organic movement's decision to ban the use of genetically modified organisms. Despite the fact that genetically modified organisms (GMOs) are now prohibited under organic standards, IFOAM World Board member Liz Clay (2003) has written on "facing up to GMOs." This suggests that applying the organic movement's standards for assessing new technology will be difficult and controversial. In contrast, organic agriculture has quickly embraced a variety of innovative technologies, such ensilaging grass and cutting-edge equipment, since their potential to have unanticipated bad effects is limited, their usage is reversible, and the user is the one who will suffer the most if there are issues. The concept of care also extends to the ecosystem as a whole and future generations, which are often left out of risk management and cost-benefit calculations.

A holistic or whole system approach to land management and agricultural output is the foundation of organic agriculture. In contrast to industrial agriculture, where pests are seen in isolation and managed with pesticides, this is shown by the method to pest management, which relies on the design and interaction of the farm as a whole to control pests. In the early days of organic farming, the farm was considered as a single, self-managing organism rather than a collection of discrete elements. The idea that a farm is an organism is where the name "organic" comes from, and it is based on the same reasoning as James Lovelock's (1979) thesis that the whole world is one organism. The shared interchange of resources (labor, inputs, and product) between farms at the village or district size would have also looked natural to the early pioneers of organic agriculture. A farm worker from a third nation may now use inputs obtained from one country in a second country to generate food for a fourth country.

Humans are clearly seen as a part of nature in organic farming, not as something distinct or something to be dominated or controlled. This viewpoint highlights the need for people to cooperate with, rather than compete with, ecological and other natural processes. Using renewable energy, guaranteeing closed nutrient cycles, and avoiding pollution are a few examples. However, since organic agriculture is integrated into larger society, it can only accomplish these goals if society as a whole does as well. Working within closed nutrient cycles is challenging, for instance, when there is no practical way for the community that eats organic products to return the nutrients in the food to the farm.

While adopting a holistic perspective and desiring to engage with natural systems, organic agriculture considers the state of scientific knowledge and understanding of such systems to be insufficient. According to the ecological point of view, such systems are incredibly complex and, on certain scales, essentially unpredictable. When people intervene in and alter natural systems, this perspective of unpredictability is particularly relevant; the risk being that the adverse unanticipated impacts are likely to be far bigger than the anticipated advantages. This is an additional example of the precautionary principle in action since it may take decades or even centuries for the harmful impacts of changes to ecological and other natural systems to manifest, at which time it will be hard to reverse them.

CONCLUSION

The market for biofertilizers has expanded significantly, which is a reflection of the worldwide movement toward environmentally friendly agriculture. A thorough study of the market's size, growth potential, and effects on the agriculture sector has been offered in this report. The given data emphasize the critical function of biofertilizers in improving crop output, supporting soil health, and lowering dependency on chemical fertilizers. But there are still issues, such the need for further education, study, and infrastructure building in this area. Realizing the full potential of biofertilizers in sustainable agriculture requires cooperation between researchers, financiers, legislators, and agricultural experts. The agriculture sector may use biofertilizers to boost yields while simultaneously promoting environmental protection and long-term food security. In the end, the worldwide move to more environmentally friendly and sustainable agricultural techniques relies critically on the biofertilizers business.

REFERENCES:

[1] T. T. Win, G. D. Barone, F. Secundo, en P. Fu, “Algal Biofertilizers and Plant Growth Stimulants for Sustainable Agriculture”, *Industrial Biotechnology*. 2018. doi: 10.1089/ind.2018.0010.

[2] L. Schütz *et al.*, “Improving crop yield and nutrient use efficiency via biofertilization—A global meta-analysis”, *Front. Plant Sci.*, 2018, doi: 10.3389/fpls.2017.02204.

[3] S. Sarkar en K. K. Yadav, “Biofertilizers, Impact on Soil Fertility and Crop Productivity under Sustainable Agriculture”, *Environ. Ecol.*, 2018.

[4] P. Agarwal, R. Gupta, en I. K. Gill, “Importance of biofertilizers in agriculture biotechnology”, *Biol. Res.*, 2018.

[5] N. T. Khan en M. J. Khan, “Microbes as Biofertilizers”, *Open Access J. Biomed. Eng. Biosci.*, 2018.

[6] H. El-Ramady, A. El-Ghamry, A. Mosa, en T. Alshaal, “Nanofertilizers vs. Biofertilizers: New Insights”, *Environ. Biodivers. Soil Secur.*, 2018, doi: 10.21608/jenvbs.2018.3880.1029.

[7] Y. Mounika, G. Thanuja Sivaram, P. S. Sundar Reddy, en M. Ramaiah, “Influence of Biofertilizers and Micronutrients on Growth, Seed Yield and Quality of Coriander (Coriandrum sativum L.) cv. Sadhana”, *Int. J. Curr. Microbiol. Appl. Sci.*, 2018, doi: 10.20546/ijcmas.2018.701.253.

[8] K. Rani, A. Dahiya, J. C. Masih, en L. Wati, “Actinobacterial Biofertilizers: An Alternative Strategy for Plant Growth Promotion”, *Int. J. Curr. Microbiol. Appl. Sci.*, 2018, doi: 10.20546/ijcmas.2018.709.072.

[9] S. Stamenković, V. Beškoski, I. Karabegović, M. Lazić, en N. Nikolić, “Microbial fertilizers: A comprehensive review of current findings and future perspectives”, *Spanish Journal of Agricultural Research*. 2018. doi: 10.5424/sjar/2018161-12117.

[10] J. Lauriano-Barajas en R. Vega-Frutis, “Infectivity and effectivity of commercial and native arbuscular mycorrhizal biofertilizers in seedlings of maize (Zea mays)”, *Bot. Sci.*, 2018, doi: 10.17129/botsci.1855.

CHAPTER 12

INVESTIGATION OF SOIL FERTILITY IN ORGANIC FARMING SYSTEMS

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ABSTRACT:

In organic farming systems, where sustainable techniques strive to organically maintain and improve soil health, soil fertility is a key component. In this essay, soil fertility in organic farming systems is thoroughly examined with an emphasis on its importance, management techniques, and benefits to sustainable agriculture. The research examines the many facets of soil fertility by looking at organic agricultural practices, soil enrichment methods, and the function of organic matter. The study highlights the significance of organic farming in maintaining soil health, biodiversity, and the ecosystem by drawing on empirical evidence and practical ideas. The report also addresses issues with market access, production consistency, and pest control in organic agricultural systems. This study offers a comprehensive perspective that is a useful tool for academics, farmers, decision-makers, and environmentalists who want to comprehend the significance of soil fertility in organic agriculture and its potential for sustainable food production.

KEYWORDS:

Biodiversity, Organic Farming, Soil Enrichment, Soil Fertility, Soil Health, Sustainable Agriculture.

INTRODUCTION

For environmental and financial sustainability, all agricultural methods rely on maintaining soil fertility. Understanding the interactions between soil's chemical, physical, and biological components is essential for managing soil fertility effectively, yet historically soil chemical fertility has received more attention. The fundamental physical and chemical properties of soils, as well as their ability to sustain biological activity, vary widely. Of course, agricultural techniques also have an impact on soil fertility, but how much depends on the particular soil and environmental factors. In order to understand the impact of agricultural techniques on soil fertility, local knowledge is required. The term "soil biological fertility" refers to soil processes involving organisms that enhance plant growth indirectly through their effects on soil chemical fertility e.g., organic matter mineralization and mineral dissolution and physical fertility, such as symbioses with root nodule bacteria and mycorrhizal fungi. The size, activity, variety, and function of communities may be used to calculate the biological fertility of the soil. The complete effects of increasing numbers, activity, and variety of soil organisms on soil function and plant development are not understood, and there are no established criteria Because they react quickly to changes in soil conditions, signs of long-term changes in overall fertility may be found in soil biological fertility measurements. Developing sustainable agriculture systems may require managing beneficial soil biological activities Optimizing plant output by preserving a rich biological variety in the soil is a key component of organic farming [1], [2].

The ability of a soil to maintain biological fertility is influenced by its natural physical and chemical composition as well as management techniques. According to the Sustainable Agriculture Farming Systems Project (SAFS) trials, soil type, measurement time, specific management practice, management system, and spatial variation were ranked in order of relative importance for influencing the composition of microbial communities. Organic matter additions, increased plant variety, decreased tillage techniques, and specific soil amendments are management techniques that might be employed to maximize the advantages of soil organisms Neither organic nor conventional farming methods can hope to expand the size or activity of the soil biological community without additional inputs of organic matter The possible contribution of soil biological activities to preserving soil chemical fertility in organic farming systems is a topic of discussion. Theoretically, organic farming depends more on soil biological fertility than conventional farming systems do for chemical fertility and sustainability It could be feasible to use agricultural inputs to selectively raise the quantity and activity of certain soil organisms using the fertilizers allowed in organic farming. Simple organic chemicals like sugars and complex humic substances, for instance, may promote microbial activity, resulting in transient increases in biological activity and, perhaps, nutrient release and increased physical fertility bacteria and fungus grew more often on some silicate minerals than others. This finding is particularly important if selectively activated microbes have favorable impacts on soil fertility. All agricultural systems need a deeper knowledge of the dynamics and variety of soil biological processes, yet sometimes a soil has "too much" biological activity. This may happen if organic matter is repeatedly disturbed and subjected to fast disintegration, which results in the loss of the material's usefulness as a source of slow-release nutrients and a contributor to preserving or enhancing soil structure [3], [4].

The ability of organic management approaches to maximize the positive impacts of legumes while minimizing the possibility for N leaching is a necessary component of the sustainability of employing legumes to meet the N needs of crops. Legumes can be intercropped with other plants to increase the efficiency with which soil nutrients are utilized (advocated increased use of legumes in farming systems due to their positive effects on the environment, which include improved soil structure, erosion protection, increased biological diversity, stimulation of rhizosphere organisms, acidification of alkaline soils, and reduced energy use and carbon dioxide (CO_2) production on and off the farm. However, the acidifying action of legumes is harmful in acid soils because asynchrony between plant need for N and its release from organic matter may result in nitrate leaching, particularly after Nitrate leakage from conventional and organic farms was examined by Kirchmann and Bergström When the reduced intensity of N input in organic farming was taken into consideration, they came to the conclusion that there was no difference, even though the average nitrate leaching across a rotation was lower in the organic systems tested The study did not provide enough information to compare yield-based nitrate leaching. Well-managed organic systems have the capacity to utilize extra N via techniques like catch crops and intercropping, according to management choices [5], [6].

It might be helpful to quantify the relative efficiency of different nutrient sources in order to determine how successful they are as fertilizers The yield plateau of the response curve of the fertilizer in issue is often compared to a soluble source of the same nutrients to determine the relative efficacy of different nutrient sources. Due to their limited solubility in soil, minerals utilized as nutritional inputs in organic farming systems nearly invariably have a relative effectiveness of 1. The relative effectiveness of organic matter inputs can also be assessed based on their recalcitrance, but the degree to which they are physically shielded from degradation in soil aggregates which would vary depending on the type of soil is equally important. The methods described in the numerous organic standards that have been created and published in many nations form the foundation of organic crop husbandry.

The International Federation of Organic Agriculture Movements' published organic standards are the most widely accepted ones. To accomplish crucial soil fertility, nutrient management, and plant protection objectives, organic farming techniques place a focus on using on-farm inputs rather than inputs from outside sources. The basic concepts of organic farming that support the development of organic plants include self-regulation within an agroecosystem, multi-year management cycles, and an emphasis on prevention rather than response. The maintenance of a site-specific and market-focused crop rotation is the fundamental component of organic crop husbandry. By producing crops with a variety of profiles in nutrient need and supply, growth habit, and phytosanitary features, alternating a broad range of crops across time and area may promote effective use of the soil resource of a farm. Crop rotations are becoming more crucial for nitrogen management as stockless farming becomes more specialized locally and worldwide, and there is a growing dependence on manure sources that are not produced on the farm. Although the shift toward stockless systems may create concerns about sustainability in certain contexts, conflicts are more likely to develop as excellent organic agriculture practices are jeopardized the more crop husbandry is market-oriented or commercially driven. For instance, more components must be grown as cash crops rather than sacrificing enough soil fertility-building components in a cycle, whether it includes cattle or legumes [7], [8].

A variety of alternative cultural techniques utilized in organic farming to accomplish various farm management goals are covered in addition to crop rotations. Organic farming is essential to overall landscape management. Even small-scale farming may help to raise and improve a holding's percentage of non-productive land. It might be challenging to develop permanent elements like hedges, tree lots, or ponds in certain situations, particularly on rented farms. Instead, blooming field edges or corridors may be included as a yearly enrichment of the agroecosystem, boosting the quantity of faunal components for better self-regulation across neighboring fields mixed and stockless annual cropping systems, as opposed to strictly perennial agricultural systems, including tree and vine crops, are the primary topics.

Digging terraces is necessary for organic farming when the soil is barren and degraded on slopes. In order to create fanyajuu trenches are dug following contours and earth is thrown uphill to create embankments which are stabilized with multifunctional agroforestry plants and fodder grass like Napier Crops are grown in the area between the embankments, and the fanya juu eventually transform into bench terraces. They help gather and save water in semi-arid environments. Compost and green manures may also be utilized to improve soil structure and promote healthy crop harvests. Large concentrations of water-soluble salts in saline soils prevent seed germination and plant development. Particularly in dry and semi-arid areas, the overuse of irrigation water may have contributed to the salt buildup. By maintaining regular watering and improving the soil's structure with compost, one may gradually lower these salt levels and enable natural drainage of the surplus salts. Crops that can withstand salt may be cultivated in the beginning.

DISCUSSION

Crop rotation on mixed farms is primarily concerned with producing adequate feed for the various animal species. As a result, the rotating strategy will only partially respond to market needs. Contrastingly, farms with little or no animals may have a crop cycle where economically viable crops predominate. Most crops need careful N control to increase yields while reducing nitrogen loss. This transportable nutrient is often easy to provide in organic farming, whether via legumes or animal manures, but it is also simple to lose from the system. In particular at higher pH levels, phosphorus (P) is a particularly immobile nutrient, and sources of P that have received an organic certification often have limited solubility. lack of sustainability in current organic P management in many contexts has therefore been addressed by numerous recent studies) demonstrated that P and K were being depleted in certain systems, notably arable cropping, using farm-scale nutrient budgets. However, N was often not a concern. Dairy farms had low nutrient budgets because they relied so little on outside inputs, but horticulture farms had considerably higher budgets, perhaps as a consequence of significant outside manure inputs. brought attention to the longer-term reduction of P soil reserves in certain organic farms in Germany, where the older organic farms contain less P than the younger organic farms a tendency not seen in associated conventional farms.

Organic farmers may store nitrogen and other nutrients for use in subsequent crops while reducing the danger of environmental contamination by increasing the amount of carbon (C) inputs in the soil. As a matter of fact, claimed that enhanced soil structure was dependent on regular, and most likely substantial, inputs of fresh organic matte a typical practice in organic agriculture. The comparison of the impacts of fertilizers and manures (farmyard) over a long period of time (20–120 years) is made in Edmeades' 2003 study of various conventional field experiments. The usage of crop combinations designated for one-year set-aside is facilitated by particular initiatives within the European Union (EU). This is often handled within the framework of a biennial or longer grass clover crop, out of which one year is funded by subsidies and not used for animal feed. By removing the last cut as roughage and adding more biomass as C and organic N to the soil, a one-year forage crop may have similar benefits, although at a lesser level While the fast decomposed biomass of green manure offers more nutrients and energy sources for soil organisms and increases the fertility for the succeeding crop, the one-year green manuring is most important as a source of humus.

It will be more difficult to convert a farm to organic farming in a region with little rainfall, high temperatures, or strong winds than in an area with widespread rainfall and comfortable temperatures. The benefits of adopting organic methods will also be more apparent in dry environments than they would be in ideal humid environments. For instance, adding compost to the topsoil or planting holes would improve the soil's ability to retain water and raise the tolerance of the crop to water shortage. Water is lost via transpiration from plants and soil evaporation at significant rates in hot, dry climates. Strong winds may further increase these losses by accelerating soil erosion. Because biomass output is often low and the organic matter content of the soils is generally low, there is a significant reduction in the nutrients that are available to the plants. Protecting the soil from intense sun and wind, as well as boosting the amount of organic matter and water that the soil receives, are the keys to enhancing crop yield under these circumstances. Composting or growing green manure crops may both enhance the amount of organic matter in the soil. Increasing the output of plant biomass, which is required for compost manufacturing, is the issue in the case of compost production.

Farmers could start learning from their own experience on their farms after gathering information about the needs, opportunities, and key conversion strategies. Farmers are advised to gradually introduce organic techniques, choosing one practice at a time and testing them on single plots or single animals alone, to reduce chances of crop failure and animal losses and prevent frustrated overload. But which techniques ought one to choose first? Farmers should naturally begin by using techniques that are low risk, low investment, need minimal specialized expertise, involve little more labor, and have a strong short-term effect. Among the proposed interventions are: Most farmers may be unfamiliar with the technique of cultivating a type of leguminous plant for biomass generation and integration into the soil. In spite of this, this approach may significantly boost soil fertility. Improved fallows, seasonal green manures in crop rotation, or strips between crops are all possible ways to cultivate green manures. Knowledge of the suitable species is initially necessary for proper green manuring [9], [10].

judicious pairing and control of plants and animals to stop the spread of pest and disease. Although bio-control agents may be used at first, ecological methods that create a pest/predator balance are the most effective way to manage organic pests. While choosing resistant crop varieties is essential, there are other ways to prevent pest outbreaks, such as choosing sowing times that do not coincide with pest outbreaks, enhancing soil health to resist soil pathogens, rotating crops, encouraging natural biological agents for control of disease, insects, and weeds, using physical barriers to ward off insects, birds, and other animals, modifying habitat to encourage pollinators and natural enemies, and trapping pests in pheromone attractants. In general, farmers should choose crops that have a low chance of failing. Maize, sorghum, millet, beans, and peas are just a few examples of cereals and legumes that are particularly well suited for conversion since they are inexpensive to grow, often have modest nutritional requirements, and are resistant to pests and diseases. Many of the conventional crops may also be kept and sold in local marketplaces. Most vegetables are one example of a high-value short-term crop that is more delicate to develop and extremely vulnerable to pest and disease assault. Therefore, unless the farmer can tolerate certain harvest losses, they shouldn't be planted on a wider scale. Farmers often inquire about the length of time organic crops take to develop because they want to see results quickly. Crop growth speed is not a goal of organic farming. When growth circumstances are better than previously, crops will expand more quickly and broadly. Although excessive use of synthetic fertilizers and sprays may make crops cultivated in the usual manner grow more quickly. In order to be less vulnerable to pests and illnesses and to have a healthy physical and nutritional structure, organic crops are encouraged to grow at their normal, natural pace. However, organic farmers take great care to ensure that their crops develop healthily and offer high results.

Maintain soil moisture: During dry spells, certain soils are better equipped to provide crops with water than others. A soil's capacity to hold and absorb water is significantly influenced by its organic matter concentration and soil type. Up to three times as much water may be stored in clay-rich soils as compared to sandy soils. Like a sponge, soil organic matter serves as a reservoir for water. In order to preserve the soil, avoid crusting on the surface, and limit drainage, crop residue or a cover crop is used. Cracks and pores in the soil are kept open by roots, earthworms, and other soil life. Less water evaporates and more soaks into the ground. Evaporation may be significantly decreased by adding a thin layer of mulch to the soil. It shields the soil from the sun's rays and keeps it from being too hot. The drying out of the soil layers underneath may be slowed down by shallow digging of the dry top soil (capillary vessels are broken). The expense of irrigation is reduced via improved soil water retention. Utilize rainwater more effectively by ripping throughout the dry season so that farmers may plant as soon as the rains begin.

Because they both utilize water, green manure and cover crops are not always an effective approach to reduce soil evaporation. Consider applying other kinds of mulch in dry places, including crop waste or plant remnants brought in from outside the field. That will aid in preserving moisture in the soil so that the crop can utilise it. how hand-dug circular holes used as planting pits referred to as zai in Burkina Faso and tassa in Niger collect and store water for use by the crop. Each pit is 20 cm in width and 20 cm in depth.

The holes are partially left open after planting to allow for water collection. Digging planting trenches in dry soil is labor-intensive. However, they provide high yields in places where crops could ordinarily perish from a lack of water. The pits may be created once and then utilized season after season. Keep the dirt covered, and to improve the fertility of the pits, add compost or fertilizer. There may not be enough water in low-rainfall locations to cultivate crops over the whole region. Use of contour bunds and catchment strips is a possibility on easy slopes (less than 3%). Catchment strips are regions without any crops. When it rains on this terrain, the contour bund traps the water as it rushes downslope. To utilise this water, arrange rows of crops behind the bund. Even with very little rain, this may offer a good harvest. Apply crop leftovers as a mulch over the cultivated areas to stop erosion, promote water infiltration, and reduce evaporation. He subsoils these strips to a depth of 0.77 meters using a subsoiler driven by a tractor. In order to direct precipitation toward the crop, he contours the ground in between the strips so that it slopes in that direction. In each strip, he plants two rows of maize, and in the spaces between the strips, he plants a cover crop like cowpea. Since the strips are durable, crops may be grown on them year after year. The strips' soil progressively becomes more fertile as agricultural wastes build up there. Maize with a legume crop in rotation will boost the soil's fertility even further.

With less than 400 mm of rain every season, the farmer has been able to produce up to 6 t/ha of maize. During dry seasons, extra water from the rainy season may be used. There are several ways to store rainwater for irrigation, but the majority require a lot of work or are expensive. Pond storage provides the benefit of allowing for the growth of fish, although water is likely to be lost via infiltration and evaporation. These losses may be prevented by building water tanks, but doing so requires the right building supplies. The advantages and disadvantages of building water storage infrastructure, including the loss of agricultural land, should be considered before making a decision. The choice of crops and a suitable farming strategy are the main determinants of whether irrigation is required. It goes without saying that not all crops or even all kinds of a given crop need the same quantity of water, nor do they all need it for the same length of time. While some crops are very resistant to drought, others are quite vulnerable. Deep-rooted plants are less susceptible to brief droughts because they can draw water from deeper soil layers. Many crops may now be cultivated outside of their traditional agroclimatic zone with the use of irrigation. This might have some benefits in addition to the previously listed harmful effects. It could allow for the cultivation of land that would not otherwise be suitable for farming without irrigation. Alternately, sensitive crop production might be moved to regions with lower pest or disease load. There are irrigation methods with more or fewer negative effects and with better or lower efficiency. If irrigation is required, organic farmers should carefully choose a method that does not overuse the water supply, does not damage the soil, and has no detrimental effects on the health of the plants.

All farmers are aware that not all sorghum is created equal. Some types have a rapid growth rate and may yield soon. Others need more time till harvest. Some grow more leaves or are taller than others. Some are more resistant of drought or Striga, while others need more or fewer nutrients. Other crops have the same characteristics. For instance, certain cowpea cultivars may be harvested in only 55 days, while others need more than 100. Some people crawl on the ground, while others ascend. Pick a variety with the qualities you want. Be careful you get the appropriate seed. Consider making your own seed to plant in the future if you discover a kind you like. Mulches may be more difficult to cultivate and less successful to employ if they are used on a crop combination with distinct growth forms or developmental stages. Consequently, planting crops in different rows substantially streamlines management.

Crop rotation may also be hampered by intercropping. Given that one key premise of crop rotation is the separation of plant families over time, it could be challenging to transplant two plant families that are combined in the same area. A successful crop rotation might be maintained, nevertheless, with careful planning. Consider a farm where lettuce, tomatoes, squash, and other vegetables are grown. To keep certain diseases and pests under control, a straightforward rotation would place each of the crops in a separate year, with a three-year gap before a crop is repeated on the same bed. Cropping systems should be set up such that a canopy of plants covers the soil virtually constantly. When planting and spreading arable crops, proper scheduling might assist prevent exposed soil from being washed away during the rainy season. A green manure crop may be planted after the primary crops have been harvested Crops should be cultivated horizontally along contour lines rather than vertically on slopes. This has a significant impact on erosion prevention by slowing the flow of surface water. Intercropping of fast-growing species, such as beans or clover, may assist to protect the soil in the early stages of the primary crop in crops that require some time to create a protective canopy.

CONCLUSION

The foundation of organic farming systems is soil fertility, which is crucial for environmentally friendly agricultural practices and sustainable agriculture. This essay has offered a thorough review of the subject, highlighting its importance, management strategies, and contributions to the creation of sustainably produced food. The research put out emphasizes the crucial part that organic farming plays in preserving soil health, increasing biodiversity, and encouraging environmentally friendly behaviors. But problems still exist, especially when it comes to controlling pests, assuring reliable harvests, and getting organic goods to market. To solve these issues and foster the expansion of organic agricultural systems, cooperation between academics, farmers, politicians, and consumers is crucial. We can build a more resilient and sustainable food system that strikes an appropriate balance between the demands of agriculture, the environment, and public health by giving priority to organic farming techniques that increase soil fertility. In the end, organic farming methods' maintenance and improvement of soil fertility contribute to the worldwide endeavor to secure food security and environmental stewardship in the face of rising agricultural demands.

REFERENCES:

[1] W. F. Abd El-Gleel Mosa, L. S. Paszt, M. Frąc, P. Trzciński, W. Treder, en K. Klamkowski, "The role of biofertilizers in improving vegetative growth, yield and fruit quality of apple", *Hortic. Sci.*, 2018, doi: 10.17221/101/2017-HORTSCI.

[2] A. A. Al-Enazy, F. Al-Barakah, S. Al-Oud, en A. Usman, "Effect of phosphogypsum application and bacteria co-inoculation on biochemical properties and nutrient availability to maize plants in a saline soil", *Arch. Agron. Soil Sci.*, 2018, doi: 10.1080/03650340.2018.1437909.

[3] E. T. Alori en O. O. Babalola, "Microbial inoculants for improving crop quality and human health in Africa", *Frontiers in Microbiology*. 2018. doi: 10.3389/fmicb.2018.02213.

[4] J. feng Zhang *et al.*, "Effects of biofertilizers and super absorbent polymers on plant growth and soil fertility in the arid mining area of Inner Mongolia, China", *J. Mt. Sci.*, 2018, doi: 10.1007/s11629-017-4801-5.

[5] J. F. Aguirre-Medina, F. O. Mina-Briones, J. Cadena-Iñiguez, en R. M. Soto-Hernández, "Effectiveness of biofertilizers and brassinosteroids in Stevia rebaudiana Bert", *Agrociencia*, 2018.

[6] Y. Mounika, G. Thanuja Sivaram, P. S. Sundar Reddy, en M. Ramaiah, "Influence of Biofertilizers and Micronutrients on Growth, Seed Yield and Quality of Coriander (Coriandrum sativum L.) cv. Sadhana", *Int. J. Curr. Microbiol. Appl. Sci.*, 2018, doi: 10.20546/ijcmas.2018.701.253.

[7] T. Mahanty *et al.*, "Biofertilizers: a potential approach for sustainable agriculture development", *Environ. Sci. Pollut. Res.*, 2017, doi: 10.1007/s11356-016-8104-0.

[8] R. Chatterjee en S. Bandyopadhyay, “Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (Vigna unguiculata L. Walp.) in acid soil of eastern Himalayan region”, *J. Saudi Soc. Agric. Sci.*, 2017, doi: 10.1016/j.jssas.2015.11.001.

[9] S. Mukhtar, I. Shahid, S. Mehnaz, en K. A. Malik, “Assessment of two carrier materials for phosphate solubilizing biofertilizers and their effect on growth of wheat (Triticum aestivum L.)”, *Microbiol. Res.*, 2017, doi: 10.1016/j.micres.2017.08.011.

[10] R. W. Mukhongo, J. B. Tumuhairwe, P. Ebanyat, A. A. H. AbdelGadir, M. Thuita, en C. Masso, “Combined application of biofertilizers and inorganic nutrients improves sweet potato yields”, *Front. Plant Sci.*, 2017, doi: 10.3389/fpls.2017.00219.