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11. Bio-Fertilizer

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11.1 Introduction:

Bio-fertilizers provide an overview of these microbial agents' role in sustainable agriculture, emphasizing their benefits over traditional chemical fertilizers. Bio-fertilizers consist of beneficial microorganisms such as bacteria, fungi, and algae, which colonize the plant rhizosphere or soil and enhance nutrient availability and uptake by plants. Unlike chemical fertilizers, which can degrade soil health and pollute water bodies, bio-fertilizers offer a natural and environmentally friendly alternative. Their use promotes soil fertility, improves crop yield and quality, and reduces dependency on synthetic inputs. This introduction sets the stage for discussing the specific types, mechanisms, applications, and advantages of bio-fertilizers in modern agricultural practices.

Definition:

We know that "bio" means living. So, the bio-fertilizer is a substance which contains active strains of certain micro-organisms or inoculation of micro-organisms which are used to increase plant growth or crop production by enhancing biological activity in the root zone.

11.2 Advantage:

- **Renewable Source of Nutrients**: Bio-fertilizers utilize living organisms like bacteria, fungi, and algae to fix atmospheric nitrogen, solubilise phosphorus, and produce growth-promoting substances. They are renewable and can be produced continuously.
- **Improvement of Nutrient Status and Soil Quality**: Bio-fertilizers enhance the nutrient availability in soil and improve soil structure, leading to better water retention and aeration.

- **Long-Term Soil Fertility and Sustainability**: By promoting beneficial microbial activity in the soil, bio-fertilizers contribute to sustainable agriculture practices that maintain soil fertility over the long term.
- **Increase in Yield**: Different types of bio-fertilizers have been shown to increase crop yields through improved nutrient availability and enhanced plant growth.
- **Reduction in Chemical Fertilizer Use**: Effective use of bio-fertilizers can reduce the dependency on chemical fertilizers, which helps mitigate environmental pollution and reduce production costs.
- **No Adverse Effects on Plants or Soil**: Bio-fertilizers work naturally with plants and soil microbes, posing no harm to plant growth or soil fertility. They do not leave harmful residues or contribute to soil degradation.
- **Eco-Friendly**: Bio-fertilizers are environmentally friendly as they reduce the risk of chemical runoff into water bodies, minimize soil pollution, and support sustainable agricultural practices.
- **Lower Energy Requirement for Production**: Compared to the energy-intensive processes involved in manufacturing chemical fertilizers, the production of bio-fertilizers generally requires less energy.
- **Cost-Effectiveness**: Bio-fertilizers are often cheaper to produce than chemical fertilizers, making them a cost-effective option for farmers, especially when considering long-term soil health and productivity.
- **Farmers' Independence**: Some bio-fertilizers like Blue-Green Algae (BGA) and Azolla can be easily multiplied by farmers themselves in their own fields, reducing dependency on external inputs.

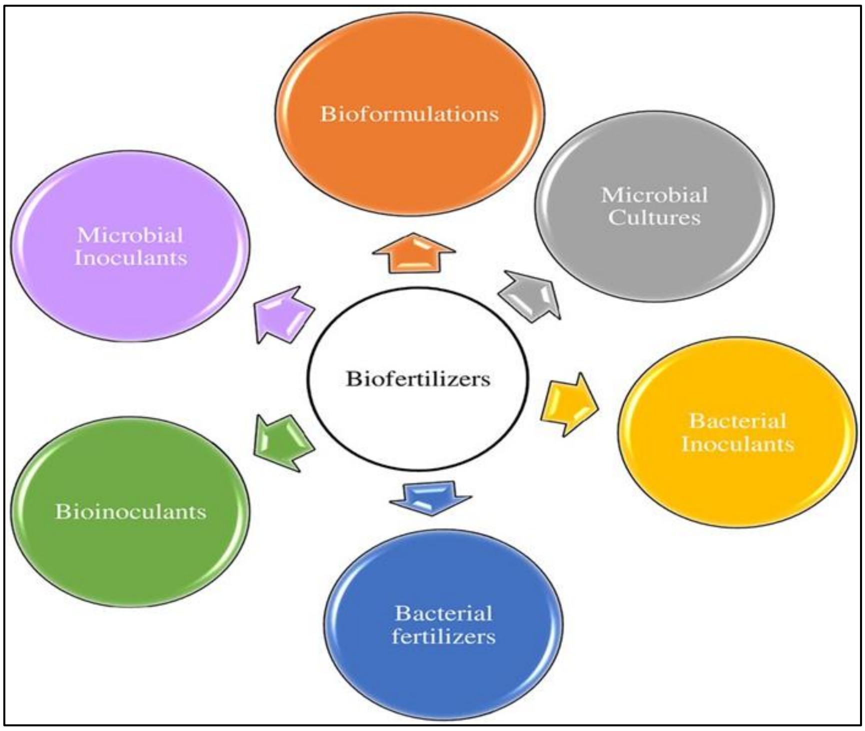

Figure 11.1: Terminologies Used Interchangeably with Microbial Biofertilizers.

11.3 Constraints and Required Steps to Overcome:

To effectively address the constraints in bio-fertilizer technology and promote its widespread adoption, it is essential to consider targeted strategies across various domains:

1. **Technological Constraints:**

- **Strain Selection and Quality**: Invest in research to identify and develop efficient strains suitable for different crops and soil types.
- **Training and Capacity Building**: Provide technical training for personnel involved in bio-fertilizer production to improve their understanding of microbiological techniques and ensure quality production.
- **Shelf-life Improvement**: Research and implement methods to extend the shelf-life of inoculants through better packaging or storage techniques.

2. **Infrastructural Constraints:**

- **Facility Improvement**: Advocate for investments in infrastructure such as production facilities, laboratories, and cold storage facilities for maintaining inoculants viability.
- **Equipment and Power Supply:** Ensure availability of essential equipment and reliable power supply to support production and storage needs.

3. **Financial Constraints:**

- **Financial Support**: Facilitate access to funds through government subsidies or easier loan processes to support bio-fertilizer production units.
- **Market Development**: Explore avenues for enhancing market opportunities and improving returns for bio-fertilizer producers to make the venture financially viable.

4. **Environmental Constraints**:

- **Adaptation Strategies**: Develop bio-fertilizer formulations that are resilient to seasonal variations and adverse soil conditions like salinity, acidity, or water-logging.
- **Educational Campaigns**: Conduct awareness campaigns among farmers about the benefits of bio-fertilizers and educate them on proper application methods.

5. Human Resources and Quality Constraints:

- Capacity Building: Offer training programs to enhance the technical skills of personnel engaged in bio-fertilizer production.
- **Quality Assurance:** Establish quality standards and regulatory frameworks for bio-fertilizers to ensure consistency and efficacy.
- **Awareness and Adoption**: Educate farmers about the advantages of bio-fertilizers through demonstrations, farmer field schools, and extension services.

6. Promotion of Benefits:

- **Demonstration Farms:** Set up demonstration plots or farms where farmers can observe the benefits of using bio-fertilizers firsthand.
- **Incentives:** Provide incentives or subsidies to encourage farmers to adopt bio-fertilizers as part of sustainable agriculture practices.

Table 11.1: Difference between Biofertilizer and Chemical fertilizer

Topic	Biofertilizer	Chemical fertilizer
Composition	These are living organisms (bacteria, fungi, or algae) that enrich the soil nutrient content naturally. They fix atmospheric nitrogen, solubilize phosphorus, or produce growth-promoting substances.	These are synthetic or inorganic fertilizers manufactured through chemical processes. They contain specific concentrations of nutrients (nitrogen, phosphorus, potassium, etc.) in forms readily available for plant uptake.
Mode of Action:	They work symbiotically with plants or directly in the soil. Example, nitrogen-fixing bacteria convert atmospheric nitrogen into ammonium, for plant use.	They deliver nutrients to plants directly in forms that are immediately available, such as nitrate or ammonium ions.
Nutrient Release	Nutrients are released slowly.	Nutrients are released quickly.
Environmental Impact	They have a lower environmental impact because they improve soil health.	It causes soil degradation, water pollution and greenhouse gas emissions.
Long-term Effects	Improve soil fertility and structure over the long term by promoting microbial activity and organic matter accumulation.	May lead to soil acidification, reduced microbial activity.
Application and Use	We can use it in organic farming and sustainable agriculture practices.	Widely used in conventional agriculture for their quick and reliable nutrient supply.

By systematically addressing these constraints through policy support, research and development, infrastructure improvements, financial incentives, and educational initiatives, the adoption of biofertilizers can be enhanced. This approach not only promotes sustainable agricultural practices but also contributes to improved soil health and reduced environmental impact over the long term.

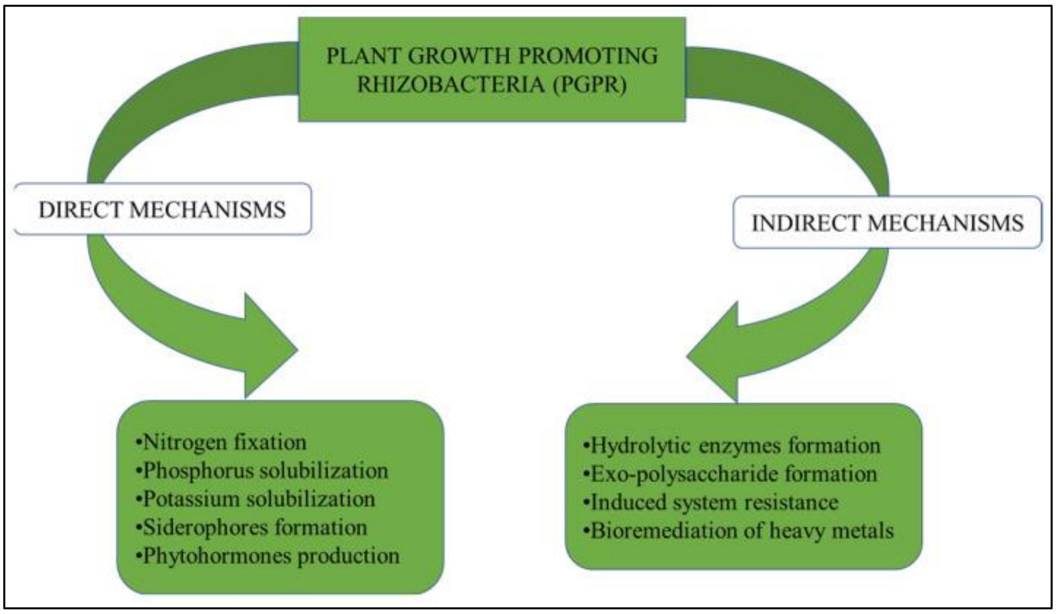

Figure 11.2: Plant Growth Promoting Bio-Fertilizer

11.4 Improvement of Efficacy of Biofertilizer:

To effectively manage and utilize biofertilizers while ensuring their efficacy, the following precautions should be taken before using biofertilizers:

1. Storage Conditions: Store biofertilizer packages in a cool, dry place away from direct sunlight and heat. This helps maintain the viability of the microorganisms present in the biofertilizer.

2. Correct Combination and Compatibility: Use the correct combinations of biofertilizers suitable for the specific crop and soil conditions. Ensure compatibility among different biofertilizers if using multiple types.

3. Avoid Mixing with Chemicals: Do not mix biofertilizers with chemical fertilizers or pesticides. This can affect the viability and effectiveness of the biofertilizers.

4. Pre-treatment of Seeds: If using seed treatment chemicals (e.g., Bavistin) along with biofertilizers, ensure that these treatments are done at least 3 days prior to mixing with biofertilizer treatments. This allows time for the seed treatment to settle and avoids any adverse interactions.

5. Timing of Application: Sow the treated seeds (those treated with biofertilizers) immediately after treatment, preferably in the morning or afternoon to avoid exposure to intense sunlight, which can affect seed viability and germination.

6. Expiry Date and Specific Use: Use the biofertilizer package before its expiry date. Ensure that it is used only for the specified crop and by the recommended method of application (e.g., seed coating, soil application, foliar spray). Following manufacturer's instructions is crucial to achieve optimal results.

7.Application of bio-Fertilizer Mixing with FYM: Carbon is the feed of microorganism and FYM is a source of carbon. So, application of FYM mixing with biofertilizer, supplies energy to microorganism and enhance efficacy of biofertilizer.

By following these precautions, farmers can maximize the benefits of biofertilizers, improve soil health, and enhance crop productivity effectively and sustainably.

11.5 Different Types of Bio Fertilizer:

1) **Bacteria:**
   a) **Symbiotic**: Nitrogen is fixed by *Rhizobium* in different legume species. *Rhizobium* is generally divided into two genera.
      i) Rhizobium: It grows fast and contains sub-polar flagella eg. *Rhizobium leguminoserum* biovar *phaseoli*
      ii) Brady-rhizobium: It grows slow and contains sub-polar flagella. Eg. *Bradyrhizobium japonicum.*

Table 11.2: Symbiotic Nitrogen Fixation by *Rhizobium* in Different Legumes:

Legumes	Nitrogen fixed (kg/ha/year)
Alfalfa	125 – 335
Red clover	85 – 190
Peas	80 – 150
Soybean	65 – 115
Cowpea	65 – 130

***Table 11.3: Rhizobium sp.* and Legumes (Host Plant):**

Rhizobium sp	**Legumes**
Alfalfa	*Rhizobium meliloti*
Clover	*Rhizobium trifolii*
Pea	*Rhizobium leguminosarum*
Soybean	*Bradyrhizobium japonicum*
Lupin	*Rhizobium lupini*
Cowpea	*Bradyrhizobium sp.*

***Acetobacter** is a nitrogen fixing bio-fertilizer, used in **sugarcane** crop. As it provides higher nitrogen requirement like urea so it is known as **“black urea”.**

- b) **Non-symbiotic**: *Azotobacter chroococcum, A. beijerinckii, Bijerinckia sp.* etc. These are used in several cereal & vegetables.
- c) **Root associative**: *Azospirillum lipoferum, A. brasilense* etc. These are mainly used for C_4 plants.

2) **Blue green algae (BGA) or Cyanobacteria:**
   - *a)* **Symbiotic:***Anabaena azollae* is used for rice.
   - *b)* **Non-symbiotic:***Nostoc, Aulosira* are non-symbiotic cyanobacteria

3) **Phosphate Solubilizing Microbes:** Bacteria like *Bacillus megatherium, Pseudomonas striata, P. fluorescens, Micrococcus* and fungi like *Penicillium rugulosum, Aspergillus niger, Penicillium digitatum, Fusarium oxysporum,*etc. produce organic acids like formic acid, oxalic acid, lactic acid, citric acid, malic acid and other some organic acids. Bacteria like *Nitrosomonas* and *Thiobacillus* produce nitric acid & sulphuric acid(inorganic). Those acids alter pH and increase solubility of inorganic phosphate compounds.

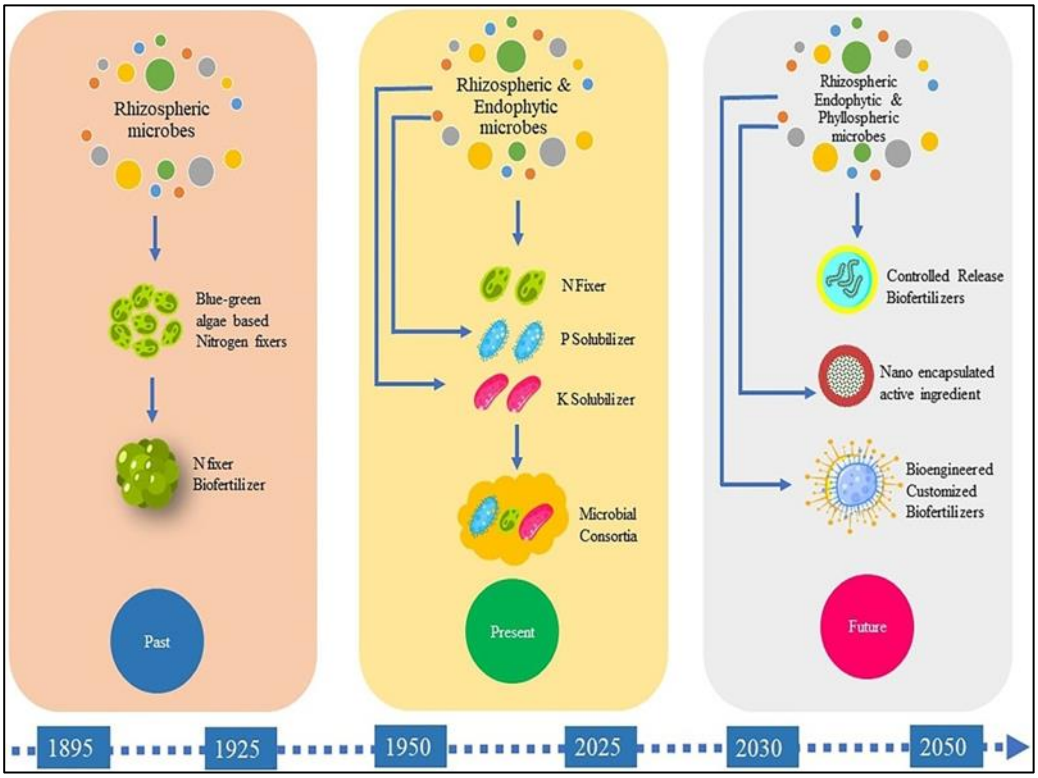

Figure 11.3: Schematic Representation of The Past Present and Future of Bio-Fertilizer Development

Mycorrhizal Association and Mobilization of P: Mycorrhiza indeed represents a fascinating symbiotic relationship where both the roots of higher plants (woody plants mainly) and certain fungi benefit from each other's presence. Mycorrhizal fungi enhance phosphorus (P) uptake in plants through several mechanisms:

- **Physical Exploration and Penetration:** Mycorrhizal fungi extend their hyphae into the soil, exploring a larger volume than plant roots can alone. This allows them to access P sources that are farther away from the root zone.
- **Increased Surface Area:** The extensive network of fungal hyphae provides a larger surface area for absorption of nutrients, including phosphorus.
- **Higher Affinity Towards P:** Mycorrhizal fungi have specific mechanisms that allow them to efficiently take up phosphorus from the soil solution.
- **Transport Beyond the Root Depletion Zone:** Fungal hyphae can transport phosphorus from areas in the soil where it might be less accessible to the plant root, effectively extending the nutrient capture range.
- **Promotion of P-Mineralizing and Solubilizing Bacteria:** Mycorrhizal fungi enhance the growth of bacteria that can mineralize organic phosphorus and solubilize inorganic phosphorus. These bacteria produce enzymes like acid phosphatase and organic acids, which help release phosphorus from organic and inorganic compounds, making it available for uptake by the plant.

Mycorrhizal fungi can be divided into two types:

- **Ectomycorrhiza or extra-cellular:** Plant roots are not being penetrated by ectomycorrhizal fungi.
- **Endomycorrhiza or intra-cellular:** Arbuscular mycorrhizae (AM), formerly known as vesicular-arbuscular mycorrhizae (VAM), are widespread in nature and form associations with a wide range of plant species, including many agricultural crops and wild plants and it is most common endomycorrhizal form.

4) K-Mobilizer microbes:

Potassium is indeed one of the three primary nutrients essential for plant health, alongside nitrogen (N) and phosphorus (P). It plays a vital role in various physiological processes within plants. However, potassium deficiency can be a significant issue. A lot of micro-organisms can mobilize unavailable K from minerals.

Bacteria like *Bacillus mucilaginosus, B. edaphicus, B. subtilis, Pseudomonas, Klebsiella, Acidithiobacillus ferrooxidans* and fungus like *Aspergillus niger, A. fumigates, Penicillium sp.*Release of K is in the order**: Illite > Feldspar > Muscovite**

5) **Plant Growth Promoting Rhizobacteria (PGPR):** *Rhizobium leguminosarum, Pseudomonas putida, P. flurescens, R. leguminismarum* etc bacterias releases growth stimulating phytohormones.

11.6 Liquid Bio-Fertilizer:

Liquid biofertilizers are indeed a specialized form of fertilizer that differs from traditional chemical or organic fertilizers. Liquid biofertilizers contain specific strains of beneficial microorganisms such as bacteria, fungi, or algae. These microorganisms can fix atmospheric nitrogen, solubilize phosphorus, or promote plant growth through other mechanisms such as producing growth-promoting substances. Various other substances may be included to improve shelf life and enhance the effectiveness of the biofertilizer under different environmental conditions. These could include stabilizers, surfactants (to aid in penetration of plant roots), and substances that improve adhesion to plant surfaces. Liquid biofertilizers typically utilize liquid materials as carriers to effectively deliver beneficial microorganisms, nutrients, and other additives to plants and soil. These carriers can be in various forms such as water,oil,emulsions.

11.7 Quality Control of Biofertilizers:

1. Microbial Count and Identification:

- **Quantitative Analysis:** Determining the number of viable microorganisms (bacteria, fungi, or other beneficial organisms) per gram or milliliter of biofertilizer.
- **Qualitative Analysis:** Identifying specific strains or species present using techniques like PCR (Polymerase Chain Reaction) or sequencing.

2. Viability and Shelf Life:

- Testing the viability of microorganisms over time to determine shelf life and storage conditions that maintain effectiveness.

3. Contamination Screening:

- Checking for contaminants such as pathogenic bacteria or fungi that could be harmful to plants, animals, or humans.
- Screening for heavy metals, pesticides, or other pollutants that may have unintended adverse effects.

4. Nutrient Content Analysis:

- Determining the concentration of essential nutrients (nitrogen, phosphorus, potassium, etc.) that the biofertilizer provides to plants.
- Ensuring consistency in nutrient content batch-to-batch.

5. Compatibility Testing:

- Assessing compatibility with other agricultural inputs (pesticides, fungicides) to avoid negative interactions.

6. Field Trials:

- Conducting trials in real agricultural settings to evaluate the biofertilizer's effectiveness in improving crop yield and health.

7. Certification and Regulatory Compliance:

- Meeting regulatory standards for biofertilizer production and distribution in terms of safety, efficacy, and environmental impact.

8. Documentation and Record Keeping:

- Maintaining detailed records of production processes, testing results, and batch histories to ensure traceability and quality consistency.

9. Packaging and Labeling:

- Ensuring proper packaging materials that maintain microbial viability and prevent contamination.
- Accurate labeling with ingredient lists, microbial species/strains, application rates, and safety precautions.

10. Continuous Improvement:

- Implementing feedback mechanisms from field trials and customer feedback to improve product quality and efficacy over time.

By implementing rigorous quality control measures at each stage of production, biofertilizer manufacturers can provide farmers with reliable products that enhance soil fertility, crop productivity, and sustainability.

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