STUDY MATERIAL FOR B.Sc MICROBIOLOGY

ORGANIC FARMING

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INDEX

UNIT -I

PRINCIPLES OF ORGANIC FARMING

The four principles of organic agriculture are as follows:

Principle of health

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This principle points out that the health of individuals and communities cannot be separated from the health of ecosystems - healthy soils produce healthy crops that foster the health of animals and people. Health is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health. The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings. In particular, organic agriculture is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

Principle of ecology

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling. Nourishment and well-being are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil; for animals it is the farm ecosystem; for fish and marine organisms, the aquatic environment. Organic farming, pastoral and wild harvest systems should fit the cycles and ecological balances in nature. These cycles are universal but their operation is site-specific. Organic management must be adapted to local conditions, ecology, culture and scale. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources. Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

Principle of fairness

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings.

This principle emphasizes that those involved in organic agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties - farmers, workers, processors, distributors, traders and consumers. Organic agriculture should provide everyone involved with a good quality of life, and contribute to food sovereignty and reduction of poverty. It aims to produce a sufficient supply of good quality food and other products. This principle insists that animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behavior and well-being. Natural and environmental resources that are used for production and consumption should be managed in a way that is socially and ecologically just and should be held in trust for future generations. Fairness requires systems of production, distribution and trade that are open and equitable and account for real environmental and social costs.

Principle of care

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions. Practitioners of organic agriculture can enhance efficiency and increase productivity, but this should not be at the risk of jeopardizing health and well-being. Consequently, new technologies need to be assessed and existing methods reviewed. Given the incomplete understanding of ecosystems and agriculture, care must be taken. This principle states that precaution and responsibility are the key concerns in management, development and technology choices in organic agriculture. Science is necessary to ensure that organic agriculture is healthy, safe and ecologically sound. However, scientific knowledge alone is not sufficient. Practical experience, accumulated wisdom and traditional and indigenous knowledge offer valid solutions, tested by time. Organic agriculture should prevent significant risks by adopting appropriate technologies and rejecting unpredictable ones, such as genetic engineering. Decisions should reflect the values and needs of all who might be affected, through transparent and participatory processes.

Benefits of Organic Farming on the Environment Cannot Be Ignored

Organic farming strives to improve the health of the environment and helps the environment. It relies on managing the ecosystem rather than depleting it. Farmers in the organic realm must abide by federal regulations to ensure the "organicness" of the products they're putting on the market.

The benefits of organic farming on the environment are immense, so this article will focus on just some of the most impactful.

1. Prohibits Use of Harmful Pesticides

For farming to be organic, harmful chemicals and pesticides are a no-go. Naturally, there are no pests. Humans labelled certain insects, animals or invasive plants as pests because they hinder the amount of food produced or are a general nuisance to humans. To manage pests, humans have created pesticides, which have harmful effects on the environment. Pesticides are used throughout the United States, whether it be in industrial farming or a backyard garden. They have lasting effects, including contamination of the soil, water and air. Therefore, organic farmers don't rely on harmful pesticides or chemicals to control pests. Instead, they aim to control pests through more natural methods like cover crops, composting and crop rotation.

2. Maintains a Healthy Soil

As previously stated, pesticides and chemicals contaminate the soil. Produce cannot be healthy if the ground isn't healthy to begin with. The soil must be able to survive on its own without the help of additives that will eventually deplete it. Organic farmers choose to use natural preventative fertilizers on their soils before they plant crops. One of the primary ways they maintain healthy soil is by using compost, which contains many helpful bacteria that build up the ground.

3. Reduces Erosion

Since organic farming builds healthy and strong soil, erosion naturally diminishes. When the soil is teeming with biodiversity and strengthened bonds, erosion has no chance. However, when harmful chemical fertilizers are used, the ground often compacts or dries out, and erosion takes over.

Erosion affects more than just the soil. When soil is swept away, the land is affected, and human food sources decrease. Further, organic farmers limit tillage on fields, keeping dirt from eroding because the soil isn't broken up so often.

4. Provides Cleaner Water

Water is necessary for survival for humans, animals and plants. When access to clean water is restricted, everyone suffers. Non-organic farming practices tend to contribute most to the water pollution problem. A lack of clean water is a real danger. Organic farming helps keep the water supply safe and clean because it doesn't use harmful chemicals. One of the primary sources of water pollution comes from agricultural soils when water runs off into rivers and streams.

Organic farmers mulch and amend soils to prevent runoff, which in turn conserves water. Additionally, they watch their water usage for irrigation.

5. Limits Non-Renewable Energy Use

Non-organic farming practices contribute to climate change. In each step of the process from farm to fork, greenhouse gases are likely emitted into the atmosphere. The fertilizers used directly put off emissions, the equipment to plant and harvest crops rely on fossil fuels, and agricultural animals eat food that contributes to climate change. In organic agriculture, non-renewable energy sources are highly regulated. Plus, it slows climate change by reducing carbon emissions.

6. Discourages Algae Blooms

Algal blooms can sometimes be harmful to the environment. They can affect the health of humans and the life in the water. Often, they occur when runoff from farms carry chemicals and fertilizers. They grow out of control and are difficult to get rid of. In addition to harming the environment, they damage the economy. Those who rely on marine or lake work for a living cannot work with algal blooms. Organic farming doesn't use those harmful fertilizers which feed and cause algae blooms.

7. Stimulates Biodiversity

The more diversity on a farm, the better — and organic farmers understand this principle. With more biodiversity, the farm is more stable and can ward off invasive species.A mixture of plants, animals and a microorganism promotes soil and animal health as well. This is because they can work together to prevent disease and erosion, which eradicates the need for chemical fertilizers and pesticides.

Benefits of Organic Farming on the Environment

Organic farming is just one of many practices that promote environmental health and conservation. By choosing organic, you're choosing the health of the environment, the economy, the future and your wellbeing.

Sustainable Agriculture | Definition, Importance & Practices

Common practices of sustainable agriculture are crop rotation, drip irrigation, Integrated Pest Management (IPM), planting cover crops, raising of heritage species, and small scale agriculture.

Sustainable agriculture is defined as engaging in farming practices that promote long-term food and livestock production while minimizing negative effects on the environment.

Sustainable farming is important because when performed correctly it uses less pesticides, industrial fertilizers, monocultures and feedlots. This in turn causes less water pollution, erosion, antibiotic use and loss of food diversity. It also is healthier for farm workers and consumers as they are exposed to less chemicals. Sustainable agriculture can be defined as producing food and livestock over the long term with minimal negative effects on the environment. It is undertaken by a society with the goal of producing the greatest quantity of food over the longest time in order to feed a growing human population while keeping the environment intact. Sustainable agriculture follows other sustainability practices where the long-term health of ecosystems and society are taken into consideration. The ideal in sustainable agriculture is to conserve water, lessen pesticide and fertilizer use, promote biodiversity in crops and livestock, and prevent soil erosion.

Historically, produce was grown and livestock was raised with very little concern for how farming practices affected the surrounding ecosystems. During the Green Revolution of the 1960s, increased pesticide and fertilizer use allowed farmers to produce larger crop yields on the same amount of land. This in turn leads to soil erosion, water pollution, and loss of crop diversity. As these new agrochemicals entered the environment, negative impacts were also noticed. This leads to environmentalists, consumers, and farmers shifting practices towards more sustainable practices.

Sustainable Farming

Sustainable agriculture, also known as sustainable farming, differs from conventional farming in multiples ways. As stated before, industrialized agriculture relied on the use of large quantities of pesticides and fertilizers to grow crops, the application of which allows more produce to be grown on the same amount of land. In addition, industrialized farming tends to use wasteful irrigation practices, large amounts of fossil fuels, and practices monoculture plantings. Each of these practices puts unnecessary pressure on the environment in with the produce is grown, as aquifers are depleted, CO_2 is released, and traditional crops are lost in favor of faster-growing ones.

Sustainable Agriculture

If you had to choose, which would you prefer to eat: food that is grown more naturally or food that is enhanced by spraying it with pesticides or applying chemical fertilizers? Most people would prefer the natural food that is free of chemicals and artificial enhancements. Unfortunately, the majority of food we consume is produced using industrialized agriculture, which is a type of agriculture where large quantities of crops and livestock are produced through industrial techniques for the purpose of sale. This type of agriculture relies heavily on a variety of chemicals and artificial enhancements, such as pesticides, fertilizers, and genetically modified organisms. This type of agriculture also uses a large amount of fossil fuels and large machines to manage the farm land. Although industrialized agriculture has made it possible to produce large quantities of food, due to the negative aspects of this technique, there has been a shift towards sustainable agriculture.

Sustainable agriculture is a type of agriculture that focuses on producing long-term crops and livestock while having minimal effects on the environment. This type of agriculture tries to find a good balance between the need for food production and the preservation of the ecological system within the environment. In addition to producing food, there are several overall goals associated with sustainable agriculture, including conserving water, reducing the use of fertilizers and pesticides, and promoting biodiversity in crops grown and the ecosystem. Sustainable agriculture also focuses on maintaining economic stability of farms and helping farmers improve their techniques and quality of life.

There are many farming strategies that are used that help make agriculture more sustainable. Some of the most common techniques include growing plants that can create their own nutrients to reduce the use of fertilizers and rotating crops in fields, which minimizes pesticide use because the crops are changing frequently. Another common technique is mixing crops, which reduces the risk of a disease destroying a whole crop and decreases the need for pesticides and herbicides. Sustainable farmers also utilize water management systems, such as drip irrigation, that waste less water.

Benefits of Sustainable Agriculture

There are many benefits of sustainable agriculture, and overall, they can be divided into human health benefits and environmental benefits. In terms of human health, crops grown through sustainable agriculture are better for people. Due to the lack of chemical pesticides and fertilizers, people are not being exposed to or consuming synthetic materials. This limits the risk of people becoming ill from exposure to these chemicals. In addition, the crops produced through sustainable agriculture can also be more nutritious because the overall crops are healthier and more natural.

Sustainable agriculture has also had positive impacts of the environment. One major benefit to the environment is that sustainable agriculture uses 30% less energy per unit of crop yield in comparison to industrialized agriculture. This reduced reliance on fossil fuels results in the release of less chemicals and pollution into the environment. Sustainable agriculture also benefits the environment by maintaining soil quality, reducing soil degradation and erosion, and saving water. In addition to these benefits, sustainable agriculture also increases biodiversity of the area by providing a variety of organisms with healthy and natural environments to live in.

Crop rotation

Crop rotation is the practice of planting different crops sequentially on the same plot of land to improve soil health, optimize nutrients in the soil, and combat pest and weed pressure.

For example, say a farmer has planted a field of corn. When the corn harvest is finished, he might plant beans, since corn consumes a lot of nitrogen and beans return nitrogen to the soil.

A simple rotation might involve two or three crops, and complex rotations might incorporate a dozen or more.

Different plants have different nutritional needs and are susceptible to different pathogens and pests.

If a farmer plants the exact same crop in the same place every year, as is common in conventional farming, she continually draws the same nutrients out of the soil. Pests and diseases happily make themselves a permanent home as their preferred food source is guaranteed. With monocultures like these, increasing levels of chemical fertilizers and pesticides become necessary to keep yields high while keeping bugs and disease at bay.

Crop rotation helps return nutrients to the soil without synthetic inputs.

The practice also works to interrupt pest and disease cycles, improve soil health by increasing biomass from different crops' root structures, and increase biodiversity on the farm. Life in the soil thrives on variety, and beneficial insects and pollinators are attracted to the variety above ground, too.

Intercropping

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making effective use of resources without affecting the yield of the main crop. Onion crop is best suited for intercrop with paired row planting of sugar cane (Nov.-Dec. Planting) under drip irrigation system. Ridges and furrows of 90 cm distance need to be prepared for planting sugar cane. Sugarcane sets with the single bud need to be planted at 30 cm apart in the bottom of the ridges. After every two rows of sugar cane, flat bed of 180 cm need to be prepared for planting onion crops. Onion seedlings should be planted at time of sugarcane planting. Additional fertilizer nutrients required for onion crop need to be calculated and applied as per requirement. Onion crop can be harvested after 120 DAT (Days after transplanting). Sugarcane-onion intercropping system with drip irrigation saves 25-30% water.

Ecosystem Services

An ecosystem is a group or community composed of living and non-living things and their interactions with each other. It is a dynamic complex of biotic components and abiotic components. These biotic and abiotic interactions maintain equilibrium in the ecosystem. We as humans are an integral part of it. The numerous benefits we obtain from the ecosystem are known by the term ecosystem services.

Ecosystem Services

The earth is home to millions of species. Every organism depends on one or another organism for energy, survival, and other life processes. This dependence of organisms on one another and their surroundings forge an interacting system called ecosystems. The interactions among different components of ecosystems are fundamental to a well-defined environment.

As a part of an ecosystem, humans derive lots of benefits from the biotic and abiotic components. These benefits are collectively termed as ecosystem services. Life and biodiversity on earth depend on these services.

Ecosystem services are classified into four types:

Provisioning Services

This includes the products/raw materials or energy outputs like food, water, medicines and other resources from ecosystems. Ecosystems are a source of food, water, medicines, wood, biofuels, etc. Also, they provide conditions for these resources to grow.

Regulating Services

This includes the services which regulate the ecological balance. For example, terrestrial environs like forest purify and regulates air quality, prevent soil erosion, and control greenhouse gases. Biotic components such as birds, rats, frogs, act as natural controllers and thus help in pest and disease control. Hence, ecosystems act as regulators.

Supporting services

Supporting services form the basis for other services. They provide habitat for different life forms, retain biodiversity, nutrient cycling, and other services for supporting life on the earth.

Cultural services

It includes tourism; provides recreational, aesthetic, cultural and spiritual services, etc. Most natural elements such as landscapes, mountains, caves, are used as a place for cultural and artistic purposes. Even a few of them are considered sacred. Moreover, ecosystems provide enormous economic benefits in the name of tourism.

The price tagging of the ecosystems and their services is quite unfeasible. Among all the ecosystem services, supporting services alone contribute about 50% and the rest of the services account for less than 10% in the same.

Biological Control

Biological control is the use by humans of beneficial insects such as predators and parasitoids, or pathogens such as fungi and viruses, to control unwanted insects, weeds, or diseases. Biological control dates back to 324 BC, when Chinese growers were recorded using ants to feed on citrus pests.

The State of New Jersey has long had the foresight to invest in biological control. Biological control offers tremendous social, environmental, as well as economic advantages. Biological control can become self-sustaining and integrated in the normal environment of the control area. Since such controls are expected to continue indefinitely, a high initial expense may prove to be a very low total cost. Biological control is particularly useful where chemical pesticides are not suitable or are impractical in environmentally sensitive areas, or on low-unit-value crops, such as alfalfa or soybeans, where complete control may not be required.

When pesticides were developed in the 1950's, they were potent and relatively inexpensive. However, in 1962, the book "Silent Spring," written by Rachel Carson, sounded a widespread warning about the persistence of certain pesticides in the environment and the environmental drawbacks of broad spectrum chemical use. Today's modern pesticides are not as persistent as past pesticides and are important tools in crop protection. These pesticides can be very expensive, warranting an integrated approach to pest management, which compliments and promotes the use of biological controls.

Eleven states currently maintain insect rearing laboratories for biological control: California, Colorado, Connecticut, Florida, Hawaii, Maryland, North Carolina, New Jersey, Oregon, South Carolina, and South Dakota. These facilities range greatly in size but carry out a wide variety of programs to control insect and weed pests of local or regional importance. The New Jersey Department of Agriculture's Phillip Alampi Beneficial Insect Rearing Laboratory supplies or has supplied beneficial insects to support programs in many of the Northeast and Mid-Atlantic states.

There are three types of biological control, conservation, classical and augmentative. Most of what is done at PABIL falls under the category of classical biological control and involves finding and working with associated natural enemies of the pest. The New Jersey Department of Agriculture partners with federal and other state departments of agriculture and university researchers in developing biological control programs for weed and insect pests. These researchers travel abroad locate and collect natural enemies in a pest's native area, which are maintained in a laboratory and evaluated for their effects on indigenous species of flora and/or fauna.

The natural predators and parasitoids must pass a rigorous quarantine process in federal facilities to ensure that no unwanted organisms (such as hyperparasitoids or microorganisms) are also introduced; and receive approval from the United States Department of Agriculture for introduction into the US. Only then do the beneficial insects come to the Phillip Alampi Beneficial Insect Rearing Laboratory for rearing. This process takes several years. Often when these beneficial insects come to the lab, they are relatively new to science, so a mass rearing protocol must be developed by the lab's entomologists.

The beneficial insects are then reared in the laboratory or in field insectaries, ideally in large numbers, and released.

The pest control program must also be compatible with current grower practices. A beneficial insect must have the ability to adjust to a new environment and, in the case of an augmentation approach, must lend itself to laboratory production.

The goal of biological control is to bring the pest population down below an economic threshold, not eradicate it. This process brings things into balance and allows native species to compete again. Classical biological control takes time. It will take a minimum of six to ten generations and possibly more before to evaluate the impact.

What is Soil?

It is the uppermost layer of Earth's crust, formed by the continuous weathering of mountains over thousands of years. It is made up of four basic constituents; minerals, organic materials, air, and water. The three main components responsible for its texture are; sand, silt, and clay. Depending upon these three constituents the mineral texture of the soil varies. Leaves and organic constituents decompose to form the upper organic layer, known as humus. The humus content in soils plays a very important role in its fertility.

Process of Soil Formation

Now let us look at the process of how soil formation happens.

Parent Material

The mineral from which the soil is formed is termed the parent material. Rocks are the source of all soil minerals. The parent material is chemically or physically weathered and transported which then deposits to form layers of soil. Usually, the bedrock is the parent material but there have been cases wherein soil gets transported due to factors like the wind and water.

Now the actual process of formation of soil is a cumulative combination of a number of processes. Soil formation also known as Pedogenesis is first kicked off by weathering and variations come according to the weather conditions.

Carriers or Weathering Agents

- **Glacier:**
  As glaciers move from one part to another, they push the soil further with them. The drifted material gets deposited miles away from the place of its formation. When the glaciers melt, huge mounds of soil are left behind, a part of which is carried by the stream.

- **Water:**
  As rivers flow, the soil particles are transported along with the water. The smallest particles travel the farthest. Heavier particles, such as sand and rock get settled earlier. Soils deposited along the river banks are termed alluvial soil, which is very rich in mineral content. Rainfall also plays an important role. Rainfall washes off the soils in exposed lands.

- **Wind:**
  Air plays the most important role as it transports a huge amount of soil from one place to another. Loose soils are carried away by the wind from one place to another.

Weathering Processes for soil formation

- **Freezing and Melting:**
  Repeated freezing and melting result in the formation of cracks and crevices in rocks. In the presence of the sun, the surface of rock expands. Upon coming in contact with a water body, these pores get filled with water. As we know, water expands when frozen, which pushes the particles further apart, breaking them down. When ice melts again, the rock breaks into loose soil particles.

- **Heating and Cooling:**
  In places with extreme climatic conditions, such as the Arctic Circle or the arid region, the rocks are subjected to sudden expansion and contraction, which results in the loosening of their particles and an increase in the air content. Over time, the effect significantly reduces rock to loose soil.

- **Wetting and Drying:**
  The rocks swell when they are wet and shrink back when dry. Regular wetting and drying of rocks result in the loosening of its grains.

- **Grinding or Rubbing:**
  As the sea waves pound the rocks along the seashore, abrasion of the uppermost layer occurs along with its fragmentation into smaller rocks and further into smaller particles.

- **Organisms:**
  The organisms such as earthworms live in the soil. They churn their way through it by eating it. This results in the production of nutrient-rich manure in the form of their excreta. Their movement in the soil helps in its mixing and aeration.

Nutrient Cycle Definition

"A nutrient cycle is defined as the cyclic pathway by which nutrients pass-through, in order to be recycled and reutilised. The pathway comprises cells, organisms, community and ecosystem."

In the process, nutrients get absorbed, transferred, released and reabsorbed. It is a natural recycling system of mineral nutrients.

Nutrients consumed by plants and animals are returned to the environment after death and decomposition and the cycle continues.

Soil microbes play an important role in nutrient recycling. They decompose organic matter to release nutrients. They are also important to trap and transform nutrients into the soil, which can be taken up by plant roots.

Nutrient cycling rate depends on various biotic, physical and chemical factors.

Examples of a nutrient cycle: carbon cycle, nitrogen cycle, water cycle, oxygen cycle, etc.

Nutrient Cycle

Nutrient recycling involves both biotic and abiotic components. The main abiotic components are air, water, soil.

Recycling of Carbon, Hydrogen, Nitrogen and Oxygen occurs in water, air and soil, whereas calcium, phosphorus, potassium, etc. are recycled mainly in soil and are available locally.

The 4 main nutrient cycles are:

1. Carbon Cycle

Carbon is the main constituent of all the living cells. All the organic matter and biomolecules contain carbon.

- Carbon is present mainly as carbon dioxide and methane in the atmosphere
- There is a continuous exchange of carbon between biotic and abiotic components by the process of photosynthesis and respiration
- Atmospheric carbon dioxide is fixed by plants in the process of photosynthesis
- All the living organisms release carbon dioxide during respiration
- Carbon is released into the atmosphere by burning of fossil fuels and auto emissions
- Organic carbon from dead and decaying organisms and waste products is released into the atmosphere after decomposition

2. Nitrogen Cycle

Nitrogen is also an essential component of life. Nitrogen cannot be directly utilised by living organisms and has to be converted to other forms.

- By the process of nitrogen fixation, nitrogen-fixing bacteria fix atmospheric nitrogen to ammonia and nitrifying bacteria convert ammonia to nitrate. It is then taken up by plants
- Atmospheric nitrogen is converted to nitrates directly by lightning and assimilated by plants
- Decomposers break down proteins and amino acids of dead and decaying organic matters and waste product
- Denitrifying bacteria convert ammonia and nitrates to nitrogen and nitrous oxide by the process of denitrification. In this way, nitrogen is released back into the atmosphere

3. Oxygen Cycle

Oxygen is essential for life. Aquatic organisms are dependent on oxygen dissolved in water. Oxygen is required for decomposition of biodegradable waste products.

- Photosynthesis is the main source of oxygen present in the atmosphere
- Atmospheric oxygen is taken up by living organisms in the process of respiration and release carbon dioxide which is used for photosynthesis by plants

4. Hydrologic or Water Cycle

Water is an essential element for life to exist on earth.

- Water from oceans, lakes, rivers and other reservoirs is continuously converted to vapour by the process of evaporation and transpiration from the surface of plants
- Water vapours get condensed and return by precipitation and the cycle continues
- The water falling on the ground is absorbed and stored as groundwater

Importance of Nutrient Cycling

All living organisms, biomolecules and cells are made up of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. These elements are essential for life. It is important to recycle and continuously replenish nutrients into the environment for life to exist.

Nutrient cycling is important for:

- It is required for the transformation of nutrients from one form to another so that it can be readily utilised by different organisms, e.g. plants cannot take atmospheric nitrogen and it has to be fixed and converted to ammonium and nitrate for uptake.
- Transfer of nutrients from one place to another for utilisation, e.g. air to soil or water
- Nutrient cycles keep the ecosystem in equilibrium and help in storing nutrients for future uptake
- Through nutrient cycling, living organisms interact with the abiotic components of their surroundings

UNIT - II

Organic Farming in Urban Spaces

Our food systems are facing tremendous difficulties due to the increased urbanization around the world. There is an urgent need for new and sustainable food production methods as cities grow and agricultural land is depleted. Urban organic farming has gained popularity as a potential answer to these problems. Urban organic farming uses small plots of land, rooftops, vertical gardens, and community areas to help people and communities reconnect with nature, encourage sustainable lifestyles, and help grow wholesome food.

In this blog post, we will examine the idea of organic farming in urban areas, consider its advantages, go through various strategies and efforts, and throw light on this practice's potential in the future.

What is organic farming in urban spaces?

Urban organic farming is cultivating crops and rearing livestock using organic methods within the boundaries of a city. It involves growing food in urban settings such as community gardens, rooftop gardens, vertical constructions, and other tiny urban parcels of land. Without synthetic fertilizers, pesticides, or genetically modified organisms (GMOs), the goal is to produce food sustainably. The practice is gaining popularity in countries with the problem of the need for more space and rising food demand. Urban farming in India is also flourishing due to these conditions. Additionally, various initiatives in India are promoting farming in urban spaces and managing the rising food demands.

Urban organic farming solves the problems caused by urbanization, including the scarcity of arable land, the distance between rural farming areas and urban populations, and the requirement for locally sourced, sustainable food. Individuals and communities can actively participate in food production, reducing carbon footprint and promoting a better and more sustainable way of life by utilizing urban spaces for organic farming.

Benefits of Urban Organic Farming

Food security: Food security is improved via urban organic farming, which lessens dependency on outside food supplies. Urban residents have more access to fresh, wholesome vegetables thanks to urban agriculture because there are fewer transportation and storage expenses for locally grown food.

Environmental Sustainability: By using fewer toxic chemicals that can contaminate soil, water, and air, organic farming practices encourage sustainable land management. Urban farms also aid in waste reduction and environmental protection by utilizing rainwater collection, composting, and recycling.

Health and nutrition: Urban organic farms make access to organic, pesticide-free, and locally-grown produce possible. This produce is recognized to have a higher nutrient content and superior flavour. This encourages healthy dietary practices, lessens exposure to dangerous substances, and benefits general Health.

Community engagement: Urban organic farms frequently function as community gardens or shared areas, promoting social ties and a sense of belonging. They provide chances for learning, developing skills, and community involvement, bringing people together to discover sustainable agriculture and nutritious food options.

Techniques and initiatives in urban organic farming

Rooftop farming: Urban regions with little ground space have increased interest in rooftop farming. To best use the available space and improve plant development, rooftop farms use various techniques such as container gardening, hydroponics, and green roofing. These farms can produce various fruits, vegetables, and herbs, adding to the local food supply and increasing urban aesthetics.

Vertical gardening is a productive approach to raising plants in constrained areas. Vertical gardens make the most of vertical space by utilizing walls, trellises, or other specially-made structures, enabling the production of various crops. In vertical farming systems, hydroponics, aeroponics, and aquaponics are frequently used to allow for year-round production and greater crop yields.

Gardens in communities: Gardens offer shared spaces where people and organizations can cultivate their plots and jointly manage common areas. These gardens foster a sense of ownership and responsibility while boosting community involvement, education, and social harmony. For urban dwellers studying sustainable agricultural techniques and gardening techniques, they can provide invaluable learning opportunities.

Indoor farming: This method of year-round crop production involves controlled conditions such as greenhouses, containers, or vertical racks. Indoor farming enables precise control over growth conditions, leading to increased crop output and less water use. It uses Technology like hydroponics, LED lighting, and climate control systems. This method is exceptionally well suited for year-round production in cities with harsh climates.

The future potential of urban organic farming

Urban organic gardening can completely transform our food systems. Integrating sustainable and regional food production becomes more important as cities expand. Several elements must be taken into account to realize this potential:

Policy Support: By putting policies that encourage and support urban organic farming initiatives in place, governments and local authorities may play a crucial role. This can entail offering incentives, assigning land for farming, and facilitating the transfer of information and resources.

Technology and innovation: Ongoing developments in these areas can boost the productivity and expandability of urban organic farming. Operations may be streamlined, prices can be decreased, and productivity can be increased with automation, integrating renewable energy sources, and data-driven farming methods.

Education and Awareness: For urban organic farming to be widely adopted, educating urban residents about its advantages and practices is essential. Communities can be enabled to participate in sustainable food production, creating a healthier and more stable urban environment, by raising awareness and offering training programs.

In the face of fast urbanization, urban organic farming offers a possible route to sustainable food production. People and communities can actively contribute to developing resilient, wholesome, and ecologically conscientious food systems by envisioning urban areas as productive agricultural zones. Suppose we adopt this transformative strategy, supported by cutting-edge practices, policies, and education. In that case, we can create a future where cities thrive as hubs of sustainable food production, feeding both people and the earth.

Sustainable Gardening

"Sustainable" is a term most associated with using eco-friendly practises in any industry. One might think, gardening is inherently anyway an eco-friendly activity, why there is a genre of landscaping called sustainable gardening

Sustainable gardening combines organic gardening practices with resource conservation. In general, sustainable gardening means to make as little negative impact on the earth as possible, and value ecosystem as a whole over simple aesthetics. Sustainable gardens should imitate natural ecosystems, such a forests, where there is no use of chemicals even in the form of pesticides and synthetic manures.

Before we dive into the different types of sustainable gardens, it is important to know the main 3 benefits of it. They are:

- **Reducing carbon emissions**: Modern gardening techniques use synthetic fertilisers, which often contain toxins that are destructive to the soil. The chemicals in these fertilisers are poisonous to humans, wildlife and marine life when they reach the nearby water bodies. These fertilisers may be good for the growth of plants in the moment, but overtime they cause more harm when the PH imbalance of the soil happens.
- **Creating less waste**: One of the significant principles of sustainable gardening is to use organic fertilisers, which are made from composting organic waste. A lot of the organic waste can be gathered from our own households that are often thrown away like - waste food items.
- **Supporting endangered species**: Planting local plants and flower species can attract a lot of local species like the bees. Bees help in pollination for the plants and flowers to grow better.

3 main types of sustainable gardening are:

1. Vegetable Garden

These gardens can be grown in your balcony or backyard. They don't have to take up a lot of space. You can grow your own food and be a little more self-sufficient. Most importantly, this way you get to grow your own seasonal vegetables like cucumber in summer months, and mustard in winter months. With the world becoming more global and with the use of modern technologies, we don't have specific seasons for vegetables anymore, most of the vegetables are not available throughout the year.

2. Indoor Herb Garden

Even if you don't have an outdoor space available, sustainable gardening can still be done by planting herbs. Herbs like coriander, mint, curry leaves, chilli, and so on, can be easily planted and maintained even indoors in compact spaces. This way you can consume essential herbs (which can be used as spices in Indian cuisines) fresh and in an organic way.

3. Pollinator Garden

These gardens are planted with flowers that provide nectar or pollen for insects that can pollinate. The space required for this type of garden can be as small as you prefer, even small balconies can be used. These gardens not only look aesthetic, but can be used for food, shelter and nesting sites for pollinating creatures like the bees. Blooms of lavender and oregano attract the bees and wasps.

Easy ways to start sustainable gardening practices:

1. Eliminate chemical use

Chemical fertisers and pesticides are only a “quick” solution, however, unfortunately, many of them also poison our soil, waterways, wildlife, and crops.

2. Start a compost pile

Compost piles take material that would typically go into the landfill and turn it into a valuable nutrient-dense material that our gardens love. A compost pile isn't just great for reducing waste; it also rejuvenates worn-out soil. With a compost pile, waste transforms into riches, and we all benefit. Compost is a natural fertiliser, and there are tons of compost bin options for apartments too.

3. Conserve water

Use drip sprinkler systems to avoid wasting water that would be done by over watering. These systems also help those that have limited free time on their hands or travel often.

4. Plant native

Non-native species usually require more water, effort, and nutrients than native species, meaning they use more resources overall. In addition to using fewer resources, native species also attract more native pollinators, providing shelter and food for them. Native plants are usually more drought-tolerant, meaning they need less water resources. Plus, so many native species are hardy to your environment without needing any extra help.

5. Reuse & repurpose

Instead of sending used materials off to the landfill, consider whether they can serve another purpose in the garden. Broken and imperfect bricks can be used to create row markers within your planter. Egg cartons can be used to initially plant plantlings.

6. Mulching

you can repurpose waste materials like lawn clippings, old leaves, wood chips, saw dust, etc. to make mulch. Mulch reduces water evaporation, so it assists in conserving water. It also prevents weeds from growing. Vegetables grow much more robust and happier when they have a layer of mulch protecting them from temperature swings.

Sustainable gardening practises are not that complicated to implement. Of course, it may be a bit of an effort at the start, but eventually they end up saving time and money in the long run. The actions of each gardener matter, even if you implement just one or two practices, it makes a difference. Although, when it comes to providing safe and healthy food for our family, no amount of effort is too little.

Importance of Backyard Gardening

A "Backyard Garden" simply refers to a home garden that can supply your family with fresh greens and vegetables daily.

Making a garden near your home can help you to:

- Have access to supply of fresh vegetables and fruits
- Saves time and money for not going to the market
- Have a healthy family -Lowers the cost of providing your family with healthy, organic vegetables. Organic produce means healthy produce, free of harmful pesticides and chemicals that are harmful to both health and environment.
- Provides wholesome activity and lasting memories for your children

In order to establish a backyard garden these are the following factors to consider

- Garden Layout: Setting and Size -Garden Size, Orientation to Sun and Shade, Proximity to Trees and Roots systems, Slopes, irrigation
- Garden Bed and Soil preparation
- Growing Your Garden: What to plant; Planting Basics
- Enjoying the Bounty: Simple Maintenance, harvesting and storing
- Backyard gardening is a way of addressing food security and health related issues.

By eating fresh fruits and vegetables grown near our homes, we are promoting a healthy lifestyle.

When using empty containers such as buckets, dishes, wheelbarrow, saucepan, plastic water bottles etc, it helps saves the environment because these materials can be recycled and not being wasted or dump into rivers.

Therefore, the information given out will be of benefit to those who put into practise home gardening

Square Foot Gardening

Square foot gardening is exactly what the name says: dividing a growing area into 1-foot x 1-foot sections. In a true square foot garden, an actual grid is placed on the growing area to divide up the space. What you grow in each section depends on the mature size of the crop. Some sections will house 16 small plants, like radishes, or only 1 plant, like a cabbage.

Benefits of Square Foot Gardening

For new gardeners, square foot gardening offers a simple vegetable garden layout that makes it easy to calculate exactly how many plants you need. It's also a handy solution for gardeners with limited room to grow, since the intensive planting style lets you plant more plants in less space. A square foot garden is also relatively low maintenance, since it leaves little room for weeds.

Drawbacks of Square Foot Gardening

Some crops, like large, indeterminate tomatoes, need more space than a single square foot—otherwise they'll start stealing nutrients and water from other plants. Plus, plants can deplete moisture and nutrients quickly in a square foot garden due to the intensive planting technique. Feeding your plants regularly with Miracle-Gro® Shake 'n Feed® Tomato, Fruit & Vegetable Plant Food will help provide the nutrition they'll need in order to produce a big harvest. Also, be sure to water whenever the top inch of soil is dry.

It's worth noting, too, that traditional square foot gardens are only 6 inches deep, which is too shallow for many plants. Vegetables need plenty of space to stretch their roots and absorb nutrients from the soil. If you choose to try this method, make your beds at least 12 inches deep to allow lots of room for the roots.

How to Tweak Your Square Foot Garden for Success

So, how can you benefit from the helpful aspects of square foot gardening while modifying the approach to fit your needs? Try one of these ideas:

Mix and match: Choose multiple plant types from the same category to give you more flexibility over what to grow in the space you have. For example, instead of planting a square with 4 lettuces, plant 2 lettuce plants and 2 marigolds, which not only attract pollinators but also add a pretty accent to the garden. Or, since you can fit 4 strawberry or 4 basil plants in one square foot, combine 2 of each of the plants in each of the outermost squares to create a lovely edible border around the inside perimeter of the bed.

Think small: Rather than planting a large tomato plant that would require more nutrients and water than are available in a single square foot, choose a smaller dwarf or bush variety, like Better Bush, that can flourish in less space.

Grow up: Adding a trellis to your square foot garden is a perfect way to increase available growing space and vines off the ground. Do this for peas, pole beans, cucumbers, melons, and squash. The easiest way is to attach the trellis to the back of the bed and use the back row of squares for the plants to be trellised.

So, no matter whether you appreciate a highly-organized planting plan for your raised bed or prefer a tad more creative approach, a little tweaking to the square foot gardening approach, plus some extra attention when it comes to watering and feeding, can lead to an impressive harvest. Enjoy your planning and planting!

Mini Farm is a small-scale agricultural operation proposal integrated with local businesses. Its compact size facilitates collaboration with other Mini Farms, fostering crop diversity and promoting a varied agricultural output. Spanning an area of $125m^2$, its modular structure spans three to four levels, optimizing sunlight exposure with its shallow depth.

This innovative farming model combines traditional outdoor vegetable crops with above-ground crops in greenhouses. Due to its spatial requirements, the Mini Farm thrives in clear urban areas such as urban wastelands or open islets, preferably located along traffic arteries like streets, platforms, canals, and tram tracks.

The design of the Mini Farm emphasizes verticality, featuring classic horticultural greenhouses stacked on multiple levels. Its compact layout maximizes solar input, necessitating exposure to light from all four facades. With a height comparable to tall trees, the Mini Farm blends seamlessly with its surroundings, contributing to urban greening.

Aside from its agricultural significance, the Mini Farm serves as a beacon of urban renewal, revitalizing neglected areas and fostering a symbiotic relationship between agriculture and suburban life. Its potential extends beyond mere cultivation, offering opportunities for business creation and social engagement.

Operationalizing a Mini Farm requires expertise in market gardening techniques and business management. However, acquiring these skills is feasible through practical and theoretical training programs. Additionally, the Mini Farm's proximity to public spaces provides educational opportunities, showcasing farming practices to the wider community. From an architectural standpoint, the Mini Farm's transparent design lends itself to modular and versatile construction methods. Its integration within the urban fabric underscores its role in fostering diversity, competition, and community engagement.

Ultimately, further research, including commercial studies, will determine the Mini Farm's viability as a standalone business or as part of a broader community-driven agricultural initiative.

How to Compost: Feeding Your Plants and Reducing Waste

Some people believe learning how to compost is too complicated, it smells bad, and it's messy. This may be true if you compost the wrong way, but learning how to compost the right way is actually quite simple. Start with a few layers of organic materials and kitchen scraps, add a dash of soil and a splash of water, and wait for your concoction to turn into humus (the best soil booster around!). This guide explains everything you need to know about how to compost successfully.

Types of Composting

Before you start learning about how to compost, it's important to know that there are a few different types of composting:

Cold composting is as simple as collecting yard waste or the organic materials in your trash (such as fruit and vegetable peels, coffee grounds and filters, and eggshells) to create a pile or fill a bin. Over the course of a year or so, the material will decompose.

Hot composting requires you to take a more active role, but the return is that it's a faster process; you'll get compost in one to three months during warm weather. Four ingredients are required for fast-cooking hot compost: nitrogen, carbon, air, and water. Together, these items feed microorganisms, which speed up the process of decay. During the growing season when garden waste is plentiful, you can mix one big batch of compost and then start a second one while the first one "cooks."

Vermicomposting is another type of composting that is made with the help of earthworms. When these worms eat your food scraps, they release castings, which are rich in nitrogen. You can't use just any old worms for this. You need redworms (also called "red wigglers"). Worms for composting can be purchased inexpensively online or at a garden supplier.

What Is Compost?

Compost is decomposed organic material that is added to soil to provide nutrients to sustain plant growth. Compost also helps to improve soil structure and water-holding capacity, and supports soil microbes that are integral to plant health.

What to Compost

Composting at home is a great way to use the things in your refrigerator that are a little past their prime, which helps reduce food waste. You can also compost certain kinds of yard waste rather than send them to the dump. Collect these materials to start off your compost pile right:

- Fruit scraps
- Vegetable scraps
- Coffee grounds
- Eggshells (though they can take a while to break down)
- Grass and plant clippings
- Dry leaves
- Finely chopped wood and bark chips
- Shredded newspaper
- Straw
- Sawdust from untreated wood

Never add meat scraps, dairy, cheese, fats/oils, pet waste, or chemically treated wood. These items either cause unpleasant odors or could contain harmful diseases or chemicals

Keeping a container in your kitchen is an easy way to accumulate composting materials as you prep meals. If you don't want to buy one, you can make your own indoor or outdoor compost bin. For kitchen scraps that could start spoiling quickly, another option is to store them in the freezer until you are ready to add them to your larger outdoor pile.

How to Make Hot Compost

1. Combine Green and Brown Materials

To make your own hot-compost heap, wait until you have enough materials to make a pile at least 3 feet deep with a combination of wet (green) items and dry (brown) items. Brown materials include dried plant materials, fallen leaves, shredded tree branches, cardboard, newspaper, hay, straw, and wood shavings. These items add carbon. Green materials include kitchen scraps, coffee grounds, animal manures (not from dogs or cats), and fresh plant and grass trimmings. These items add nitrogen.

For best results, start building your compost pile by mixing three parts brown materials with one part green material. If your compost pile looks too wet and smells unpleasant, add more brown items or mix your compost with a garden fork to aerate. If you see it looks extremely brown and dry, add green items and water to make it slightly moist.

2. Water Your Compost Pile

Sprinkle water over the compost pile regularly so it has the consistency of a damp sponge. Don't add too much water or the microorganisms in your compost pile will become waterlogged and drown. If this happens, your pile will rot instead of compost. You can monitor the temperature of your compost pile with a compost thermometer to be sure the materials are properly decomposing. Or, simply reach into the middle of the compost pile with your hand. Your compost pile should feel warm.
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3. Stir Your Compost Pile

During the growing season, you should provide the compost pile with oxygen by turning it once a week with a garden fork or other garden tools. The best time to turn the compost is when the center of the pile feels warm or when a thermometer reads between 130°F and 150°F. Stirring the compost pile will help it cook faster and prevents materials from becoming matted down and developing an odor. At this point, the brown and green layers have served their purpose so it's ok to stir thoroughly and intermix the two materials.

In addition to aerating regularly, chop and shred raw ingredients into smaller sizes to speed up the composting process.

4. **Feed Your Garden with Compost**

When the compost pile no longer gives off heat and becomes dry, brown, and crumbly, it's fully cooked and ready to feed to the garden. Add about 4 to 6 inches of compost to your flower beds and a thick layer to the top of pots at the beginning of each planting season.

Some gardeners make what's known as compost tea with finished compost. This involves allowing fully formed compost to "steep" in water for several days, then straining it to use as a homemade liquid fertilizer.

Vermicomposting Definition

“Vermicomposting is a process in which the earthworms convert the organic waste into manure rich in high nutritional content.”

Vermicomposting is the scientific method of making compost, by using earthworms. They are commonly found living in soil, feeding on biomass and excreting it in a digested form.

Vermiculture means "worm-farming". Earthworms feed on the organic waste materials and give out excreta in the form of "vermicasts" that are rich in nitrates and minerals such as phosphorus, magnesium, calcium and potassium. These are used as fertilizers and enhance soil quality.

Vermicomposting comprises two methods:

- **Bed Method:** This is an easy method in which beds of organic matter are prepared.
- **Pit Method:** In this method, the organic matter is collected in cemented pits. However, this method is not prominent as it involves problems of poor aeration and waterlogging.

Process of Vermicomposting

The entire process of vermicomposting is mentioned below:

This process is mainly required to add nutrients to the soil. Compost is a natural fertilizer that allows an easy flow of water to the growing plants. The earthworms are mainly used in this process as they eat the organic matter and produce castings through their digestive systems.

The nutrients profile of vermicomposts are:

- 1.6 per cent of Nitrogen.
- 0.7 per cent of Phosphorus.
- 0.8 per cent of Potassium.
- 0.5 per cent of Calcium.
- 0.2 per cent of Magnesium.
- 175 ppm of Iron.
- 96.5 ppm of Manganese.
- 24.5 ppm of Zinc.

Materials Required

- Water.
- Cow dung.
- Thatch Roof.
- Soil or Sand.
- Gunny bags.
- Earthworms.
- Weed biomass

- A large bin (plastic or cemented tank).
- Dry straw and leaves collected from paddy fields.
- Biodegradable wastes collected from fields and kitchen.

Procedure

1. To prepare compost, either a plastic or a concrete tank can be used. The size of the tank depends upon the availability of raw materials.
2. Collect the biomass and place it under the sun for about 8-12 days. Now chop it to the required size using the cutter.
3. Prepare a cow dung slurry and sprinkle it on the heap for quick decomposition.
4. Add a layer (2 – 3 inch) of soil or sand at the bottom of the tank.
5. Now prepare fine bedding by adding partially decomposed cow dung, dried leaves and other biodegradable wastes collected from fields and kitchen. Distribute them evenly on the sand layer.
6. Continue adding both the chopped bio-waste and partially decomposed cow dung layer-wise into the tank up to a depth of 0.5-1.0 ft.
7. After adding all the bio-wastes, release the earthworm species over the mixture and cover the compost mixture with dry straw or gunny bags.
8. Sprinkle water on a regular basis to maintain the moisture content of the compost.
9. Cover the tank with a thatch roof to prevent the entry of ants, lizards, mouse, snakes, etc. and protect the compost from rainwater and direct sunshine.
10. Have a frequent check to avoid the compost from overheating. Maintain proper moisture and temperature.

After the 24th day, around 4000 to 5000 new worms are introduced and the entire raw material is turned into the vermicompost.

Advantages Of Vermicomposting

The major benefits of vermicomposting are:

1. Develops roots of the plants.
2. Improves the physical structure of the soil.

3. Vermicomposting increases the fertility and water-resistance of the soil.
4. Helps in germination, plant growth, and crop yield.
5. Nurtures soil with plant growth hormones such as auxins, gibberellic acid, etc.

Disadvantages of Vermicomposting

Following are the important disadvantages of vermicomposting:

1. It is a time-consuming process and takes as long as six months to convert the organic matter into usable forms.
2. It releases a very foul odour.
3. Vermicomposting is high maintenance. The feed has to be added periodically and care should be taken that the worms are not flooded with too much to eat.
4. The bin should not be too dry or too wet. The moisture levels need to be monitored periodically.
5. They nurture the growth of pests and pathogens such as fruit flies, centipede and flies.

Vermicomposting turns the kitchen waste and other green waste into dark, nutrient-rich soil. Due to the presence of microorganisms, it maintains healthy soil.

Vermicomposting is an eco-friendly process that recycles organic waste into compost and produces valuable nutrients.

UNIT - III

Biofertilizers Definition

"Biofertilizers are substances that contain microorganisms, which when added to the soil increase its fertility and promotes plant growth."

Biofertilizers are substance that contains microbes, which helps in promoting the growth of plants and trees by increasing the supply of essential nutrients to the plants. It comprises living organisms which include mycorrhizal fungi, blue-green algae, and bacteria. Mycorrhizal fungi preferentially withdraw minerals from organic matter for the plant whereas cyanobacteria are characterized by the property of nitrogen fixation.

Nitrogen fixation is defined as a process of converting di-nitrogen molecules into ammonia. For instance, some bacteria convert nitrogen to ammonia. As a result, nitrogen becomes available for plants.

Types of Biofertilizers

Following are the important types of biofertilizers:

Symbiotic Nitrogen-Fixing Bacteria

Rhizobium is one of the vital symbiotic nitrogen-fixing bacteria. Here bacteria seek shelter and obtain food from plants. In return, they help by providing fixed nitrogen to the plants.

Loose Association of Nitrogen-Fixing Bacteria

Azospirillum is a nitrogen-fixing bacteria that live around the roots of higher plants but do not develop an intimate relationship with plants. It is often termed as rhizosphere association as these bacteria collect plant exudate and the same is used as food by them. This process is termed associative mutualism.

Symbiotic Nitrogen-Fixing Cyanobacteria

Blue-Green algae or Cyanobacteria from the symbiotic association with several plants. Liverworts, cycad roots, fern, and lichens are some of the Nitrogen-fixing cyanobacteria. Anabaena is found at the leaf cavities of the fern. It is responsible for nitrogen fixation. The fern plants decay and release the same for utilization of the rice plants. Azolla pinnate is a fern that resides in rice fields but they do not regulate the growth of the plant.

Free-Living Nitrogen-Fixing Bacteria

They are free-living soil bacteria that perform nitrogen fixation. They are saprotrophic anaerobes such as Clostridium beijerinckii, Azotobacter, etc.

Among all the types of biofertilizers, Rhizobium and Azospirillum are most widely used.

Components of Biofertilizers

The components of biofertilizers include:

Bio Compost

It is one of the eco-friendly product composed of waste material released from sugar industries which are decomposed. It is magnified with human-friendly bacteria, fungi, and various plants.

Tricho-Card

It is an eco-friendly and nonpathogenic product used in a variety of crops as well as in horticultural and ornamental plants, such as paddy apple, sugar cane, brinjal, corn, cotton, vegetables, citrus, etc. It acts as a productive destroyer and antagonistic hyper parasitic against eggs of several bores, shoot, fruit, leaves, flower eaters and other pathogens in the field.

Azotobacter

It protects the roots from pathogens present in the soil and plays a crucial role in fixing atmospheric nitrogen. Nitrogen is a very important nutrient for the plant and about 78% of the total atmosphere comprises nitrogen.

Phosphorus

Phosphorus is one of the essential nutrients for plants growth and development. Phosphate solubilizing microorganisms, hydrolyze insoluble phosphorus compounds to the soluble form for uptake by plants. Many fungi and bacteria are used for the purpose such as Penicillium, Aspergillus, Bacillus, Pseudomonas, etc.

Vermicompost

It is an Eco-friendly organic fertilizer that comprises vitamins, hormones, organic carbon, sulfur, antibiotics that help to increase the quantity and quality of yield. Vermicompost is one of the quick fixes to improve the fertility of the soil.

Importance of Biofertilizers

- Biofertilizers are important for the following reasons:
- Biofertilizers improve the soil texture and yield of plants.
- They do not allow pathogens to flourish.
- They are eco-friendly and cost-effective.
- Biofertilizers protect the environment from pollutants since they are natural fertilizers.
- They destroy many harmful substances present in the soil that can cause plant diseases.
- Biofertilizers are proved to be effective even under semi-arid conditions.

Applications of Biofertilizers

Following are the important applications of biofertilizers:

Seedling root dip

This method is applicable to rice crops. The seedlings are planted in the bed of water for 8-10 hours.

Seed Treatment

The seeds are dipped in a mixture of nitrogen and phosphorus fertilizers. These seeds are then dried and sown as soon as possible.

Soil Treatment

The biofertilizers along with the compost fertilizers are mixed and kept for one night. This mixture is then spread on the soil where the seeds have to be sown.

Future perspective of biofertilizers

Uncontrolled over-application of chemical fertilizers by farmers during intensive agricultural practices has led to excess nutrients (particularly P) accumulation in soils, which, as a result, makes the soils dead. That is why, nowadays, the production of efficient and sustainable biofertilizers for crop plants, wherein inorganic fertilizer application can be reduced significantly to avoid further pollution problems, represents major research interest. It comprises undertaking short-term, medium and long-term research programmes combining the efforts and scientific potential of soil microbiologists, agronomists, plant breeders, plant pathologists, nutritionists and economists to work together.

What should be done for better sustainable future?

The applicable regulatory bodies, the policy makers, the scientific community, the product proponents, and the farmer associations/organizations should concentrate their efforts to:

- Develop and/or review existing fertilizer and pesticide policies to include biofertilizers and biopesticides;
- Enact and/or review laws on fertilizers and pesticides to include biofertilizers and biopesticides;
- Review of existing regulations on fertilizers and pesticides to include biofertilizers and biopesticides;
- Develop standards for biofertilizers and biopesticides. These should include Standards Operating Procedures (SOPs) and norms on quality, safety, efficacy, testing, labeling and registration;
- Establish institutions, facilities and human resources to facilitate the production and testing;
- Encourage regional integration efforts for harmonization of policies, laws, regulations and standards;
- Disseminate information to stakeholder groups and ensure access to approved biofertilizers and biopesticide products.

- **Biofertilizer**
- Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants' uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants.
- Very often microorganisms are not as efficient in natural surroundings as one would expect them to be and therefore artificially multiplied cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil.
- Use of biofertilizers is one of the important components of integrated nutrient management, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms

and their association with crop plants are being exploited in the production of biofertilizers. They can be grouped in different ways based on their nature and function.

S. No.	Groups	Examples
N2 fixing Biofertilizers		
1.	Free-living	Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc,
2.	Symbiotic	Rhizobium, Frankia, Anabaena azollae
3.	Associative Symbiotic	Azospirillum
P Solubilizing Biofertilizers		
1.	Bacteria	Bacillus megaterium var. phosphaticum, Bacillus subtilis Bacillus circulans, Pseudomonas striata
2.	Fungi	Penicilliumsp, Aspergillusawamori
P Mobilizing Biofertilizers		
1.	Arbuscularmycorrhiza	Glomussp.,Gigasporasp.,Acaulospora sp., Scutellospora sp. & Sclerocystis sp.
2.	Ectomycorrhiza	Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.
3.	Ericoid mycorrhizae	Pezizellaericae
4.	Orchid mycorrhiza	Rhizoctoniasolani
Biofertilizers for Micro nutrients		
1.	Silicate and Zinc solubilizers	Bacillus sp.
Plant Growth Promoting Rhizobacteria		
1.	Pseudomonas	*Pseudomonas fluorescens*

SUSTAINABLE CROP PRODUCTION

Introduction

Sustainable crop production depends much on good soil health. Soil health maintenance warrants optimum combination of organic and inorganic components of the soil. Repeated use of chemical fertilizers destroys soil biota. In nature, there are a number of useful soil micro organisms which can help plants to absorb nutrients. Their utility can be enhanced with human intervention by selecting efficient organisms, culturing them and adding them to soils directly or through seeds. The cultured micro organisms packed in some carrier material for easy application in the field are called bio-fertilisers.

Bio-fertilisers are living microorganisms of bacterial, fungal and algal origin. Their mode of action differs and can be applied alone or in combination. By systematic research, efficient strains are identified to suit to given soil and climatic conditions. Such strains have to be mass multiplied in laboratory and distributed to farmers. They are packed in carrier materials like peat, lignite powder in such a way that they will have sufficient shelf life.

LIST OF COMMONLY PRODUCED BIO-FERTILIZERS IN INDIA

NAME	CROPS SUITED	BENEFITS USUALLY SEEN	REMARKS
Rhyzobium strains	Legumes like pulses, groundnut, soybean	10-35% yield increase, 50-200 kg N/ha.	Fodders give better results. Leaves residual N in the soil.
Azotobacter	Soil treatment for non- legume crops including dry land crops	10-15% yield increase-adds 20-25 kg N/ha	Also controls certain diseases.
Azospirillum	Non-legumes like maize, barley, oats, sorghum, millet, Sugarcane, rice etc.	10-20% yield increase	Fodders give higher/enriches fodder response. Produces growth promoting substances. It can be applied to legumes as co-inoculant
Phosphate Solubilizers* (*there are 2 bacterial and 2 fungal species in this group)	Soil application for all crops	5-30% yield increase	Can be mixed with rock phosphate.
Blue-green algae and Azolla	Rice/wet lands	20 -30 kg N/ha, Azolla can give biomass up to 40-50 tonnes and fix 30-100 kg	Reduces soil alkalinity, can be used for fishes as feed. They have growth promoting

		N/ha	hormonal effects. TNAU has developed high yielding Azolla hybrids.
Microhizae (VAM)	Many trees, some crops, and some ornamental plants	30-50% yield increase, enhances uptake of P. Zn, S and Water.	Usually inoculated to seedlings.

Major advantages of Biofertiliser

Biofertilisers enhance the nutrient availability to crop plants (by processes like fixing atmosphere N or dissolving P present in the soil) ; and also impart better health to plants and soil thereby enhancing crop yields in a moderate way. It is a natural method without any problems like salinity and alkalinity, soil erosion etc.. In the vast areas of low input agriculture and oil seeds production, as also in crops like sugarcane, etc, these products will be of much use to give sustainability to production. In view of the priority for the promotion of organic farming and reduction of chemical residues in the environment, special focus has to be given for the production of biofertilisers.

Commercial prospects

Thebiofertilisers are mainly purchased by State Agriculture Departments and distributed to the farmers at concessional rates. About 200 to 500 grams of carrier material is only needed per acre, costing about Rs.10/- to 25/-. In view of the above, if the units are selected carefully, there can be assured business. The benefits usually obtained by the use of biofertilizers will not be as visible as that of chemical fertilizers. As the results are not dramatic, many farmers are not aware of the significance, excepting in States like Maharashtra, Gujarat, parts of Karnataka and Tamil Nadu, these are more commonly used with Government's support. In the context of increasing awareness about the use of natural products and organic agriculture, these products will have good scope. Further, the organically grown produces fetch higher prices both in domestic and export markets.

It is estimated that the production of biofertilisers in the country by the existing units is about 7500 to 9000 TPA. This is far below the potential requirement of 7.6 lakh TPA by the year 2000-2001 as estimated by the National Biofertiliser Development Centre (NBDC) Ghaziabad. So far, the Ministry of Agriculture has supported establishment of 67 biofertiliser units in different parts of the country.

Difference between Azotobacter and Azospirillum

Azotobacter and Azospirillum are two genera of bacteria that are important for nitrogen fixation. They are both gram-negative, free-living bacteria that promote plant growth. The chief difference between the two bacteria genera is that *Azotobacter* is an aerobic, soil-dwelling bacteria, whereas Azospirillum is microaerophilic and surface colonising bacteria.

Azotobacter

Domain: Bacteria

Phylum: Proteobacteria

Class: Gammaproteobacteria

Order: Pseudomonadales

Family: Pseudomonadaceae

Genus: *Azotobacter*

Azotobacter is free-living, motile, spherical bacteria that form cysts. They are aerobic and play a large role in nitrogen fixation.

They are used as model organisms in the study of diazotrophs, and also for the production of food additives, biopolymers and some biofertilisers.

They are mostly found in neutral and alkaline soils, in association with plants. They are oval, 2-4 µm in diameter and can form clusters or chains of varying lengths. They are mobile due to the presence of numerous flagella. The cells of *Azotobacter* are resistant to environmental stresses because they secrete a thick mucus-like layer, forming a cyst.

Some of the species produce pigments that range from yellow-green to purple colours.

Azospirillum

Kingdom: Bacteria

Phylum: Proteobacteria

Class: Alphaproteobacteria

Order: Rhodospirillales

Family: Azospirillaceae

Genus: *Azospirillum*

Azospirillum is a plant growth-promoting diazotroph. It is a free-living, gram-negative bacteria. They are oblong-rod shaped and do not produce spores. They are microaerophilic, i.e., they are aerobic but can survive under low oxygen conditions as well.

They are found in freshwater and in close association with plant roots in soil habitats. It is the plant growth-promoting bacteria (PGPB) and does so in the following ways:

- They secrete plant hormones that make the root grow more branches and root hairs.
- It makes nutrients such as nitrogen and phosphorus more available to the plants.
- It also produces antioxidants that protect the plants in stressful conditions.
- It competes with disease-causing microbes, making the plant less susceptible to diseases.

AzotobactervsAzospirillum

Azotobacter	**Azospirillum**
Description	
Azotobacter is an aerobic, soil-dwelling bacteria.	*Azospirillum* is microaerophilic and surface colonising bacteria.
Oxygen Requirement	
They are aerobic bacteria and require high oxygen concentration for them to function.	They are aerobic, but are also microaerophilic and can survive in low oxygen conditions.
Shape of Bacteria	
Oval or spherical shape.	Oblong-rod shaped.
Formation of Cysts	
They form cysts to protect themselves from harsh environmental conditions.	No formation of cysts.
Functions	

It functions mainly as a nitrogen fixer, also useful in the production of biofertilisers and biopolymers.	It is mainly useful as a plant growth-promoting bacteria.
Family of the Bacteria	
Pseudomonadaceae	Azospirillaceae
Temperature for Growth	
20°C to 30°C	5°C to 42°C

Rhizobium

"Rhizobium is a soil bacteria that fixes atmospheric nitrogen once it finds a base inside the roots of the leguminous plants"

Rhizobium is the bacteria that live in symbiotic association with the root nodules of the leguminous plants. Fixation of nitrogen cannot be done independently. That is why rhizobium requires a plant host. Rhizobium is a vital source of nitrogen to agricultural soils including those in arid regions. They convert dinitrogen into ammonia. Ammonia, being toxic in nature. is rapidly absorbed into organic compounds.

Nitrogen fixation helps in increasing soil productivity and soil fertility. The various behavioural factors such as drought stress, nutrient deficiency, salt stress, fertilizers, and pesticides of nitrogen-fixing systems are reviewed.

Classification of Rhizobium Bacteria

Rhizobium can be classified on the basis of the types of the plant they are associated with and also the rate of growth. Few species of Rhizobium bacteria include:

- Rhizobium leguminosarum
- Rhizobium alamii
- Rhizobium lantis
- Rhizobium japonicum
- Rhizobium trifolii
- Rhizobium phaseolii
- Rhizobium smilacinae

Nitrogen Fixation

Nitrogen fixation is the essential biological process and the initial stage of the nitrogen cycle. In this process, the free nitrogen available in the atmosphere is converted into ammonia (another form of nitrogen) by certain bacterial species like Rhizobium, Azotobacter, etc. and the complete process is carried on by natural phenomena.

Role of Rhizobium

Rhizobium plural form rhizobia are prokaryotes whose main function involves the conversion of stable nitrogen gas in the atmosphere to a biologically useful form. Nitrogenase is an enzyme complex that reduces dinitrogen to ammonia.

A huge amount of energy is consumed during the nitrogen fixation and the nitrogenase enzymes are irreversibly inactivated by oxygen. Acetylene reduction assay is used to measure the nitrogenase activity. A very less portion of species is capable of carrying out nitrogen fixation. That is around two genera of archaea, twenty genera of cyanobacteria and much more.

A symbolic amount of nitrogen remains after the harvesting of grains even though a large amount of nitrogen is removed at the time of harvesting. It is mainly taken into account when there is no usage of nitrogen fertilizers. It is usually seen in less industrialized countries.

Nitrogen is one of the most supplied plant nutrients as it is one of the common deficiency found in soils. Several environmental concerns are raised regarding the supply of nitrogen to the soil.

Rhizobium infects the roots of leguminous plants. They are usually found in the soil and produce nodules after infecting the roots of the leguminous plants. As a result, nitrogen gas is fixed from the atmosphere. This nitrogen is made available to the plants that help in their development. When the legume dies there will be a breakdown of nodules. As a result, Rhizobium is released back to the cell where it can infect a new host.

Specific strains of Rhizobium are required to make the nodules functional in order to carry out the process. This increases the yield of the crops. Legume inoculation has been an agricultural practice for several years and has constantly improved over time.

Diseases Caused by Rhizobium Bacteria

Rhizobium can be pathogenic as well as non-pathogenic. The pathogenic Rhizobium bacteria species include:

- Rhizobium rhizogenes– It is also known as Agrobacterium rhizogenes and is responsible for infectious hairy roots in dicotyledonous plants.

- Rhizobium radiobacter– It is also known as Agrobacterium tumefaciens and is responsible for crown gall disease.

Pseudomonas

Domain: Bacteria

Phylum: Pseudomonadota

Class: Gammaproteobacteria

Order: Pseudomonadales

Family: Pseudomonadaceae

Genus: *Pseudomonas*

The genus Pseudomonas comprises 140 species, most of which are saprophytic. 25 of those species are related to humans. It is a free-living bacteriumthat is ubiquitous in nature. It is mostly found in moist environments. It is a gram-negative bacterium.

It measures roughly 0.5 to 0.8, µm by 1.5 to 3.0 µm. It is aerobic, rod shaped and possesses a flagellum. The flagella provides motility to the bacterium. The standard temperature for the growth of Pseudomonads is 25° C to 37° C.

Pseudomonas aeruginosa and *Pseudomonas maltophilia* are the most infectious species, causing about 80% of the diseases caused by Pseudomonads. A *Pseudomonas* infection is very common in hospital patients suffering with cystic fibrosis, cancer and burns. It infects the urinary tract, open wounds, eyes, ears and skin. It also causes bacteremia (the presence of bacteria in the bloodstream). The spread of these organisms can be prevented by repetitive cleaning and disinfection.

Bacillus Bacteria

Bacillus, meaning “stick”, is a genus of rod-shaped, Gram-positive bacteria, a member of the Bacillota phylum, with 266 identified species. The term refers to the shape (rod) of other similarly shaped bacteria, and the plural name of the bacteria class is Bacilli.

Bacillus species can either be facultative anaerobes, which can exist with or without oxygen, or obligate aerobes, which require oxygen to survive.

Pseudomonas aeruginosa and Escherichia coli are two examples of rod-shaped bacteria that do not belong to the class Bacilli. These two Gram-negative bacteria are common in the environment and can harm people. Bacillus anthracis is an example of a rod-shaped bacteria from the Bacilli class.

Examples of Bacillus Bacteria

There are several Bacillus species, and they all serve a variety of purposes in both the environment and the human body. B. anthracis is one of these bacteria that produce the toxin that results in anthrax disease in individuals.

Pathogens of certain types of insects include Bacillus larvae, B. popilliae, B. lentimorbus, B. thuringiensis, and B. sphaericus. Although a few other species, such as B. cereus, occasionally cause disease in humans and animals, most Bacillusspecies are non-pathogenic saprophytes.

Scientific Classification

Domain	Bacteria
Phylum	Bacillota
Class	Bacilli
Order	Bacillales
Family	Bacillaceae
Genus	*Bacillus*
Species	See the list

Structure

The Bacillus cell wall is an external component of the cell that serves as the second line of protection between the organism and its surroundings, supports the rod-like shape of the cell, and withstands pressure imposed by the turgor of the cell. Teichoic and teichuronic acids make up the cell wall.

Bacillus species are rod-shaped, Gram-positive, aerobic or facultatively anaerobic bacteria that produce endospores. In some species, cultures have the potential to mature into Gram-negative species. The diverse species of the genus have a wide range of physiological capabilities that enable them to survive in various types of natural environments. Each cell produces a single endospore. The spores are resilient to radiation, desiccation, heat, cold, and disinfectants.

Oxygen is required for Bacillus anthracis to sporulate; this restriction significantly affects epidemiology and control. B. anthracis forms a polypeptide or polyglutamic acid capsule in vivo to protect it from phagocytosis. The family Bacillaceae includes the genera *Bacillus* and *Clostridium*. Biochemical and morphological factors are used to classify species.

Characteristics

General characteristics of *Bacillus* spp. are as follows:

- Bacillus consists of bacilli producing heat resistant pores.
- They are Gram-positive but are susceptible to decolourisation, appearing Gram-negative.
- The spores are resistant to cold, heat, desiccation, radiation, and disinfectants.
- Extreme environmental conditions, such as high temperature (B. thermophilus), high pH (B. alcalophilus), and high salt concentrations (B. halodurans), can support the growth of Bacillus.
- Some Bacillus species are naturally capable of transforming DNA.

Key characteristics of Bacillus anthracis include the following:

- Gram-positive, large, box-car-shaped rod in long or short chains.
- Oval, non-swelling spores developed during culture media growth.
- Clinical specimens may contain encapsulated rods.
- Colonies have a ground-glass look.
- Non-hemolytic on sheep blood agar.
- Non-motile.
- MacConkey agar shows no growth.
- Positive for catalase test.
- Penicillin susceptible
- Positive for lecithinase test.

Bacillus Species List

- B. acidocaldarius
- B. aerius
- B. anthracis
- B. cereus
- B. fastidiosus
- B. subtilis
- B. thermoaerophilus
- B. thuringiensis

Significance

There are many different types of Bacillus in nature, including in soil. Extreme conditions like high temperature (B. thermophilus), high pH (B. alcalophilus), and high salt concentration (B. halodurans) can all lead to their occurrence. In plants, they are also frequently found as endophytes, which can be extremely important for the health of the plant's immune system, capacity to absorb nutrients, and ability to fix nitrogen.

An important insect pathogen, B. thuringiensis, is usually employed to eradicate insects and pests. B. subtilis serves as a valuable model organism. Additionally, a well-known food spoiler makes bread and other foods ropy. Also capable of producing and secreting antibiotics is B. subtilis.

Some commercial and environmental B. coagulansstrains may lead to the deterioration of extremely acidic tomato-based products.

Frankia

Frankia is a genus of nitrogen-fixing, bacteria that live in symbiosis with actinorhizal plants, similar to the Rhizobium bacteria found in the root nodules of legumes in the family Fabaceae. Frankia also initiate the forming of root nodules with actinorhizal plant are known as Actinorhizalsymbiosis.

The term actinorhiza and actinorhizal plants is derived from "action" for the actinomycete Frankia named after its discover Frank in the 1880s and "rhiza" for the plant root bearing the nodules formed by symbiosis.

Alder trees are known to recuperate soil nitrogen in temperate forest ecosystem. Field estimates have shown that alder trees increase the nitrogen content content of soil. Casurina trees release nitrogen indicate the importance of root nodule bearing non-leguminous plants in the overall nitrogen economy of soil.

Isolation

1. Clear the nodules of extraneous organic matter, soil and dirt under running water by frequent examination under a dissecting microscope.
2. Fragment the nodule into individual lobes, sterilize the lobes by immersion into 3.0 % aqueous solution of osmium tetroxide for 1-4 min.
3. According to nodule mass and age, wash in sterile distilled water several times and cut the nodule lobes into 0.1-0.5 mm^3 pieces with the help of a sterile scalpel.

4. Transfer these nodule pieces into bottom layer of 1.5 per cent of Yeast Extract Dextrose Medium (YEMA) or Q mod medium with activated charcoal/tween 80.

5. Addition of cycloheximide at the concentration of 50μg/ml may be useful for preventing fungal contamination.

6. Pour 3ml of the same medium over the layer containing nodule pieces, thereby providing microaerphilic conditions and facilitate Frankia growth which can be periodically checked under a dissecting microscope.

7. Seal the pertiplate with paraffin and incubate at 28-30°C.

8. After 4 weeks, colonies of Frankia generally appear at the edge of nodule pieces.

Cultural Characteristics of Frankia

1. Exhibit polymorphism of colonies ranging from starfish, diffuse or compact shapes.

2. The hyphae are poorly branched, may be colourless or pigmented depending upon the nature of the medium.

3. Round, cylindrical, stipitate vesicles are formed in nitrogen free medium. These swollen tips of hyphae (vesicles) assume various shapes ranging from pear, club or filamentous types and are regarded as site of nitrogen fixation. Vesicles in general possess an intrinsic oxygen protection mechanism to sustain continued nitogenaseactivity.

UNIT-IV

Anabaena

Anabaena is the genus of filamentous cyanobacteria. These bacteria can form colonies composed of either single cells or filamentous groups of cells. The cells are photosynthetic; as a byproduct of photosynthesis, they generate oxygen gas. It has been proven that several Anabaenaspecies work well as natural fertilisers by being utilised on rice paddies.

One of four cyanobacterial genera, Anabaena, produces neurotoxins that are toxic to domestic animals, farm animals, and pets in addition to the local fauna. It is believed that the production of these neurotoxins contributes to its symbiotic interactions, which protect the plant against grazing stress.

Scientific Classification

Domain	**Bacteria**
Phylum	**Cyanobacteria**
Class	**Cyanophyceae**
Order	**Nostocales**
Family	**Nostocaceae**
Genus	***Anabaena***

Anabaena Variabilis

Among the filamentous cyanobacteria species is one called Anabaena variabilis. It is a photosynthetic prokaryote that fixes atmospheric nitrogen gas and transforms it into a form that plants can utilise. It can be found in many aquatic habitats including soil, freshwater, and saltwater. It develops colonies that are either spherical or filamentous.

As a nitrogen-fixing bacteria, Anabaena variabiliscan transform atmospheric nitrogen into a form that plants can utilise. It is necessary to convert nitrogen gas into a format that plants can utilise, as they cannot use it directly.

Structure

The structure of Anabaena is filamentous. Its filament is similar to Nostoc's filament. Nostoc and Anabaena trichomes can often be hard to distinguish from one another. However, mucilage covers the Nostoc filaments, combining to form a colony, while in Anabaena, it is not present.

Anabaena has a filament made up of a string of beaded cells. There are several intercalary heterocysts in the trichome. Heterocysts have a vegetative cell-like morphology. Typically, the filaments are straight. However, they could be uneven or circinate. A sheath contains only one filament at a time. Hyaline and watery gelatinous sheaths are always present.

Occurrence

Anabaena is observed as plankton. It is notable for its capacity to fix nitrogen. They develop symbiotic bonds with some plants such as the mosquito fern. There are some endophytic Anabaena species. They reside in the Cycas and Azolla roots.

Anabaena is present in all forms of water. Nutrient-rich waterways can support large-scale growths or blooms. When the cells of these blooms decompose, the water becomes discoloured, and a foul smell is released.

Nitrogen Fixation

The process of turning atmospheric nitrogen (N_2) into ammonia (NH_3) is known as nitrogen fixation (NH_3). Specific bacteria known as nitrogen-fixing bacteria are responsible for this process.

One Anabaena cell out of every ten will develop into a heterocyst when the ambient nitrogen level is low. Heterocysts then exchange the byproducts of photosynthesis for fixed nitrogen, which they supply to nearby cells. These nitrogen-fixing cells can no longer engage in photosynthesis. Nitrogenase is the enzyme that heterocysts use to fix nitrogen. Nitrogenase reduces N_2 into two molecules of ammonia (NH_3).

The blue-green algae Anabaena azollae and fern Azolla maintain a symbiotic relationship where the fern provides the alga with a habitat, and the alga provides the nitrogen. Since it can quickly colonise freshwater environments and develop rapidly, this has led to the plant being referred to as a "super-plant." Phosphorus generally keeps it from growing, and an oversupply of it from chemical runoff frequently causes Azolla blooms.

Nostoc

Nostoc is a genus of blue-green algae or cyanobacteria. They are prokaryotic and perform photosynthesis. They are found mainly in freshwater as free-living colonies or attached to rocks or at the bottom of lakes. They are also found on tree trunks. They are also found as an algal component of lichens in certain bryophytes (Anthoceros). They are capable of nitrogen-fixing and perform photosynthesis. They are also present as an endosymbiont to fungus.

Nostoc Classification

Nostoc are prokaryotic and are grouped with bacteria. The cell lacks membrane-bound organelles and genetic material is found dispersed in the cytoplasm. They are kept in cyanobacteria as they are photosynthetic.

Domain	Bacteria
Phylum	Cyanobacteria
Class	Cyanophyceae
Order	Nostocales
Family	Nostocaceae
Genus	*Nostoc*

Some of the commonly found Nostoc species are:

1. Nostoc commune is eaten as a salad
2. Nostocazollae forms symbiotic association with water fern
3. Nostocpunctiforme form symbiotic relationship with Anthceros and other higher plants
4. Nostocflagelliforme is known as Fat choy. It is used as a vegetable in China

Nostoc Structure

- Nostoc are filamentous and unbranched. Numerous filaments are found in a gelatinous mass as a colony. The colonies may be as big as an egg. The filament consists of a chain of cells, which appear like a bead. They are called trichomes
- Cells are oval, spherical or cylindrical
- Some of the cells in the filament are differentiated, they are called heterocyst. They are sites for nitrogen fixation. Nitrogenase enzyme fixes nitrogen

- Each filament is covered in a mucilaginous sheath, which is a protective layer. It absorbs and retains water. The gelatinous sheath is made up of polysaccharides and also contains proteins
- Colonies are of different shapes, sizes and colours. They are mostly greenish or bluish-green in colour and also have red-brown or yellow-green colour
- Extracellular pigments are also found, e.g. nostocine, scytonemin. These pigments along with some amino acids protect the cells from UV radiation
- Each cell has a thick cell wall made up of peptidoglycan
- The cytoplasm of a cell is differentiated into outer coloured due to peripherally arranged chromoplast and inner clear cytoplasm
- Cells have various pigments. Cells contain chlorophyll (green pigment). Phycocyanin (blue) and phycoerythrin (red) are also present
- Inner cytoplasm contains incipient nucleus or a nuclear body, DNA is without histones

Nostoc Reproduction

Nostoc reproduce vegetatively or asexually by spore formation. The vegetative reproduction is by fragmentation. Small colonies can grow attached to a large colony and later form separated colonies.

Hormogonia are short and free filaments. They are formed when a filament breaks. It retains the gelatinous sheath. New trichomes are developed inside the colony.

Asexual reproduction is by the formation of resting spores known as **akinetes.** Some of the cells become thick-walled due to accumulation of food. They can withstand unfavourable conditions for many years. Under favourable conditions, they germinate to form a new filament.

Nostoc also reproduce by heterocysts. Heterocysts separate from the filament. They divide and germinate into a new filament.

Ecological Importance

- Nostoc are important for their nitrogen-fixing ability. They are used in paddy fields and are also used to increase the nutrient value of soil
- They are rich in proteins and vitamin C and are used as a delicacy in various Asian countries, e.g. N. flagelliforme, N. commune, etc.
- N.muscorum has shown to accumulate polyhydroxy butyrate, which is a precursor of plastic. It may have useful application in the industry
- Cyanobacteria can convert CO_2 to biofuels. Nostoc have shown to produce hydrogen
- They can be used for bioremediation of wastewater and degrade environmental pollutants
- Various species, e.g. N. muscorum, N. commune, N. insulare, etc. extracts have shown antibacterial or antiviral activity and may be used in future to prepare drugs

MYCORRHIZAE

A mycorrhiza is a symbiotic relationship between a fungus and a root system. A network of fungus filaments surrounds the developing root or reaches the root cells directly. The hyphae possess a relatively broad surface area, which allows them to collect water and mineral ions from a significantly more amount of soil than the root. The roots receive water and minerals from the fungus, and the mycorrhizae receive sugars and N-containing components from the roots.

Certain plants require an association with mycorrhizae. For example, mycorrhizae are necessary for the germination and establishment of Pinus seeds.

When two organisms form a mycorrhizal relationship, the fungus colonises the host plant's root tissues either intracellularly like in arbuscularmycorrhizal fungi (AMF or AM), or extracellularly like in ectomycorrhizal fungi. Mycorrhizae may associate parasitically with host plants depending on the species or the environment. Often the association is mutualistic.

Types of Mycorrhiza

The two main types of mycorrhizae are ectomycorrhizae and endomycorrhizae. They are categorised according to where the fungi colonise on the plants.

Ectomycorrhiza

Ectomycorrhiza, also known as EcM, usually develops connections between woody plants (like beech, birch, willow, oak, pine, fir and spruce) and fungi belonging to the Ascomycota, Basidiomycota, and Zygomycota. About 10% of plant families have ectomycorrhizal relationships.

Ectomycorrhizas comprise a Hartig net of hyphae encircling the plant cells in the root cortex and a mantle or hyphal sheath covering the root tip. The term "ectendomycorrhiza" refers to a mycorrhiza in which the hyphae have the potential to enter the plant cells.

Springtails are attracted to and killed by the ectomycorrhizal fungus Laccaria bicolour to extract nitrogen, some of which may be passed to the mycorrhizal host plant.

Endomycorrhiza

Alternatively, endomycorrhizae are present in more than 80% of plant families, including greenhouse and crop plants such as vegetables, flowers, grasses, and fruit trees. The production of vesicles and arbuscules by the fungus and their penetration of the cortical cells are characteristics of endomycorrhizal relationships.

There are several types of endomycorrhizas including arbuscular, arbutoid, ericoid, monotropoid and orchid mycorrhizas.

ARBUSCULAR MYCORRHIZA

In an arbuscularmycorrhiza, also known as an AMF, the symbiotic fungus reaches the cortical cells of the roots of a vascular plant to produce arbuscules. Only members of the division Glomeromycota of fungi can produce arbuscularmycorrhizas.

Ericoid Mycorrhiza

Ericaceae plants and various mycorrhizal fungal lineages come together to produce the mutualistic association known as the ericoid mycorrhiza. It has also been demonstrated that ericoid mycorrhizas are highly saprotrophic, allowing plants to obtain nutrients from still-in-decomposition materials through the decomposing activities of their ericoid companions.

Monotropoid Mycorrhiza

This kind of mycorrhiza can be found in various genera of the Orchidaceae and the Ericaceae subfamily Monotropoideae. These plants get their carbon from the fungal companion and are heterotrophic or mixotrophic. Thus, this type of mycorrhizal relationship is parasitic and non-mutualistic.

Orchid Mycorrhiza

Every orchid undergoes myco-heterotrophic growth at some point in its life cycle, forming orchid mycorrhizas with various basidiomycete fungi. Their hyphae enter the root cells and create pelotons (coils) to exchange nutrients.

Uses & Benefits

Soil fungi called mycorrhizae provide the soil with numerous advantages. For a water-wise landscape, healthy soil is essential. The fertility and health of the soil and the plants that grow there are influenced by drainage, organic matter, and plant nutrients.

Mycorrhizae, meaning “fungus root,” refers to a mutualistic relationship between fungi and plant roots in most plants. While the fungus assists the plant by expanding its root surface area, the plant benefits the fungus by supplying the carbohydrates necessary for fungal growth.

Mycorrhizae may provide the following benefits:

- Increased absorption of nutrients and water
- Reduced need for irrigation
- Reduced demand for fertiliser

- Enhanced resistance to drought
- Improved resistance to pathogens
- Enhanced plant health and resistance to stress
- Improved transplant success.

UNIT - V

Microbes as Biofertilizers

Organic farming is increasing the production of pollutant-free crops. It involves the use of biofertilizers and biopesticides which increases the nutrient quality of the crop and controls any kind of pest and pathogen.

Biofertilizers are microorganisms that add to the nutrient quality of the soil. Bacteria, fungi, and algae are some of the beneficial microorganisms that help in improving the fertility of the soil.

Biofertilizers are classified as:

- Free-living nitrogen-fixing bacteria like Azotobacter, and Rhodospirillum.
- Free-living nitrogen-fixing Cyanobacteria like Anabaena, and Nostoc.
- Loose association of nitrogen-fixing bacteria like Azospirillum.
- Symbiotic nitrogen-fixing bacteria like Rhizobium, and Frankia

Microbes as Biofertilizers

The following microorganisms are used as biofertilizers:

- **Rhizobium:** They form root nodules in leguminous plants and fix the atmospheric nitrogen into an organic form. Rhizobium also has no negative effect on soil quality and improves the quality, nutrient content, and growth of the plant.
- **Azotobacter:** These are free-living nitrogen fixers found in all types of upland crops. These not only fix nitrogen but also provide certain antibiotics and growth substances to the plant.
- **Azospirillum**: Unlike Azotobacter, these can be used in wetland areas. They are found inside the roots of the plant (non-free-living) where they fix the atmospheric nitrogen.
- **Blue-green algae:** These are free-living nitrogen-fixing Cyanobacteria that are present only in wet and marshy lands. However, they do not survive in acidic soil.
- **Mycorrhiza:** It is a symbiotic association between the fungi and the roots of a plant. The mycorrhizal fungi play an important role in binding the soil together and improves the activity of the microbes. The fungi draw water and nutrients from the soil thereby

increasing the plant productivity. It also helps the plant to survive under various environmental stresses.

How are Biofertilizers Important?

- Biofertilizers are eco-friendly and are not harmful to the environment.
- These improve the soil quality thereby increasing plant productivity.
- The farmers can prepare the inoculum of these microbes and inject them into the plants when required.
- They produce growth-promoting substances in the soil.
- Biofertilizers can be used in semi-arid areas also.

Biofertilizers are the perfect alternative to chemical fertilizers. The chemicals not only harm the soil and its productivity but also harm the living organisms consuming the crops grown on that soil. Therefore, the scientists had discovered the use of microorganisms as fertilizers.

They have gained recognition over the years and are being implemented on a large scale to increase agricultural productivity without harming human health.

Classification of Biofertilizers

Biofertilizers play a crucial role in maintaining soil health and required plant nutrients. They are classified for their effective application and utilisation in farming.

Share

Biofertilizers contain microorganisms that are necessary for plant growth. The microorganisms help in absorbing nutrients from the soil. A plant or crop requirement is identified, and a suitable fertiliser is employed. It is necessary to classify biofertilizers as every individual species of crop requires certain amounts of specific nutrients. The appropriate bio fertilizer will help in improving the yield and quality of the crop. Classification is done on the basis of the type of microorganism present or the basis of the function of the biofertiliser.

Classification on the Basis of Microorganisms

The classification on the basis of microorganisms is done by identifying which type of microorganisms, such as algae, fungi or bacteria, is present in the biofertiliser. For example, a bacterial bio fertilizer contains Rhizobium, and a fungal biofertilizer contains Mycorrhiza. The different types of biofertilizers with examples are explained below.

Bacterial biofertilizer

This classification of biofertilizers contains bacteria. They are further classified on the basis of the function of bacteria:

- **Nitrogen Fixer**

As the name suggests, this classification of biofertilizers contains bacteria that can fix nitrogen. The bacteria associate themselves with the nodules present in the roots of the leguminous plants and perform nitrogen fixation in the soil. On the other hand, free-living bacteria exist as free microorganisms and fix the nitrogen of the atmosphere. These types of biofertilizers with examples are given below:

- **Symbiotic**

Bradyrhizobium, mesorhizobium, azorhizobium, sinorhizobium, allorhizobium, rhizobium, etc.

- **Associative**

Herbaspirillum, azospirillum, etc.

- Non-symbiotic

Azotobacter, derxia, rhodospirillum, rhodopseudomonas, chromatium, beijerinckia, acetobacter, etc.

- **Phosphate Solubilized**

This classification of biofertilizers contains bacteria that fix and help absorb another important nutrient, phosphorus. The fixed phosphorus present in the soil is converted into a soluble form by organic acids and enzymes. Generally, this classification of biofertilizers is called phosphorus solubilising microorganisms (PSM).

- **Non symbiotic**

Pseudomonas striata, bacillus pseudomonas, bacillus circulans, etc.

Fungal Biofertilizer

This classification of biofertilizers contains fungi. They are further classified on the basis of the function of the fungi:

- **Phosphate solubilizer**

This classification of biofertilizers contains fungi. The rest of the mechanism is the same as the phosphate solubilizer of bacterial biofertilizer.

- **Non-symbiotic**

Species of penicillium, species of aspergillus, species of Trichoderma, etc.

- **Nutrient Mobilised**

This classification of biofertilizers helps transfer nutrients such as phosphorus from the soil to cortical cells of the roots of a crop. Therefore, they act as a carrier of nutrients and must not be confused with solubilizers. The fungi present in the bio fertilizer help absorb nutrients into the root system. An example of this type of biofertiliser is given below:

- **Symbiotic**

Vesicular ArbuscularMycorrhiza or VAM.

Algal Biofertilizer

This classification of biofertilizers contains algae. They are further classified on the basis of the function of the algae:

- **Nitrogen fixer**

As the name suggests, this classification of biofertilizers contains algae that can fix nitrogen. The algal biofertilizers have the same mechanism of action as that of bacterial biofertilizers.

Examples of these types of biofertilizers are given below:

- **Symbiotic:** Blue-green algae or cyanobacteria
- **Non-symbiotic:** Azolla

Classification on the Basis of Function

Fertilisers are classified based on the function of micro-organisms and their effect on plant growth. For example, a bio fertilizer that promotes the growth of a plant is classified under plant growth-promoting rhizobacteria or PGPR. The different types of biofertilizers with examples are explained below.

Nitrogen-fixing (NBF)

As discussed before, this classification of biofertilizers contains microorganisms that can fix nitrogen. The microorganisms either live in a symbiotic manner or freely in a non-symbiotic way. The microorganisms associate themselves with the nodules present in the roots of the leguminous plants and perform nitrogen fixation in the soil. They are further classified as:

- **Nitrogen fixer for legumes:** This type of fertiliser is employed for fixing nitrogen in legumes; some examples are discussed below
- **Rhizobium:** The protein requirements of leguminous plants can only be fulfilled with the help of this bacteria
- **Cyanobacteria:** This is also known as blue-green algae, which helps in increasing the growth of a plant
- **Nitrogen fixer for non-legumes:** This type of biofertilizer is employed for fixing nitrogen in non-legumes; some examples are discussed below:
- **Azotobacter:** Substances released from this bacteria promote the growth of roots and strengthen them by inhibiting root pathogens.
- **Azolla:** It excretes organic nitrogen in the water.

Phosphate Mobilising (PMBF)

This classification of biofertilizers is concerned with the transportation and absorption of phosphorus by the roots of the crop. They are further differentiated on the basis of their solubilising or absorbing nature.

Phosphate solubilizer:

- This classification of biofertilizers contains bacteria that fix and help absorb phosphorus
- The fixed phosphorus present in the soil is converted into a soluble form by organic acids and enzymes
- Some examples are pseudomonas, nitrobacter, escherichia, bacillus, serratia, and others

Phosphate Absorbers or Mobilisers:

- This classification of biofertilizers helps in transferring phosphorus from the soil to cortical cells of the roots of a crop

- They act as a carrier of nutrients rather than a solubilizer and, therefore, must not be confused with solubilizers
- The microorganism present in the bio fertilizer helps in absorbing nutrients into the root system
- Some examples are aspergillusawamori, aspergillusniger, penicilliumdigitatum, and others

Organic Matter Decomposers (OMD)

This classification of biofertilizers is concerned with the decomposition of organic matter, as the name suggests. They are further classified on the type of organism, such as:

- Cellulolytic organisms: An example of this category is Cellulomonas
- Lignolytic organisms: An example of this category is Arthobacter

Biofertilisers play an important role in agriculture. The rhizosphere of crop soil is affected by biofertilizers and helps in promoting the growth of the crop. Biofertilizers are different from usual fertilisers because they do not contain harmful chemicals that may be toxic for crops and consumption. Biofertilisers work on the principle of natural interconnection between flora and fauna. With their help, humans utilise and improve naturally occurring processes such as nitrogen fixation by microorganisms, mobilising and solubilising nutrients with the help of microorganisms, intaking micronutrients and macronutrients, or stimulating natural growth hormones of plants or phytohormones. Therefore, it is important to understand the classification to identify how many types of biofertilisers are there.

Bio-fertilisers are living microorganisms of bacterial, fungal and algal origin. Their mode of action differs and can be applied alone or in combination.

- Biofertilizers fix atmospheric nitrogen in the soil and root nodules of legume crops and make it available to the plant.
- They solubilise the insoluble forms of phosphates like tricalcium, iron and aluminium phosphates into available forms.
- They scavenge phosphate from soil layers.
- They produce hormones and anti metabolites which promote root growth.
- They decompose organic matter and help in mineralization in soil.

- When applied to seed or soil, biofertilizers increase the availability of nutrients and improve the yield by 10 to 25% without adversely affecting the soil and environment.

Types and features of biofertilizers

Based on type of microorganism, the bio-fertilizer can also be classified as follows:

- **Bacterial Biofertilizers:** e.g. Rhizobium, Azospirilium, Azotobacter, Phosphobacteria.
- **Fungal Biofertilizers:** e.g. Mycorrhiza
- **Algal Biofertilizers:** e.g. Blue Green Algae (BGA) and Azolla.
- **ActinimycetesBiofertilizer**: e.g. Frankia.

Bio-fertilizer are mostly cultured and multiplied it the laboratory. However, blue green algae and azolla can be mass-multiplied in the field.

Characteristics Features of common Biofertilizers

- **Rhizobium** : Rhizobium is relatively more effective and widely used biofertilizer. Rhizobium, in association wit legumes, fixes atmospheric N. The legumes and their symbiotic association with the rhizobium bacterium result in the formation of root nodules that fix atmospheric N. Successful nodulation of leguminous crop by rhizobium largely depends on the availability of a compatible stain for a particular legume. Rhizobium population in the soil is dependent on the presence of legumes crops in field. In the absence of legumes the population of rhizobium in the soil diminishes.
- **Azospirillum** :Azospirillum is known to have a close associative symbiosis with the higher plant system. These bacteria have association with cereals like; sorghum, maize, pearl millet, finger millet, foxtail millet and other minor millets and also fodder grasses.
- **Azotobacter** : It is a common soil bacterium. A. chrococcum is present widely in Indian soil. Soil organic matter is the important factor that decides the growth of this bacteria.
- **Blue Green Algae (BGA**) : Blue green algae are referred to as rice organisms because of their abundance in the rice field. Many species belonging to the genera, Tolypothrix, Nostic, Schizothrix, Calothrix, Anoboenosois and Plectonema are abundant in tropical conditions. Most of the nitrogen fixation BGA are filamenters, consisting of chain of vegetative cell including specialized cells called heterocyst which function as a micronodule for synthesis and N fixing machinery.

Biofertilizer Production

Biofertilizer production is necessary for the agricultural lands that have been deprived of soil minerals and nutrients essential for plant growth and development. Thus, soil minerals are required for the plant's growth. But, due to the excessive burden on agricultural land by the increasing population, the land area for farming is limited.

Thus, it becomes necessary to utilize the agricultural lands economically to obtain the maximum yield. Nitrogen is a major element important for plant growth. The demand for nitrogen is generally fulfilled by employing chemical fertilizers, though they impose serious health hazards and reduce soil fertility.

However, the use of biofertilizers that contain living microorganismsincreases crop yield by improving soil fertility. Biofertilizers are different from chemical fertilizers that negatively impact the soil quality and the people consuming those crops.

Besides, chemical fertilizers are quite expensive, and cost production is also high. Thus, biofertilizers are recommended over chemical fertilizers as they improve the soil structure and texture and enrich the soil with essential nutrients required for plant growth. This post describes the definition, purpose and steps involved in biofertilizer production.

Definition of Biofertilizer

Biofertilizer is the formulation of living microbes that fix the atmospheric nitrogen either by living freely in the soil or by associating symbiotically with the plant. Its commercial production is cost-effective and relatively inexpensive to buy.

It enriches the soil with dormant (metabolically inactive) or living microorganisms that neither degrade the soil quality nor harm the growing plants. Biofertilizers are easily biodegradable products that do not cause soil pollution. The organisms that are prevalently used in the bio-inoculant preparation are:

- Nitrogen-fixing soil bacteria (*Azotobacter* and *Rhizobium species*)
- Nitrogen-fixing cyanobacteria (*Anabaena species*)
- Phosphate-solubilizing bacteria (*Pseudomonas species*)
- AM fungi

Biofertilizers significantly enhance the microbial process to increase the bioavailability of nutrients in the forms that the plants can assimilate. Biofertilizers have a low cost and play an essential role in supporting soil health and minimizing environmental pollution.

Purpose

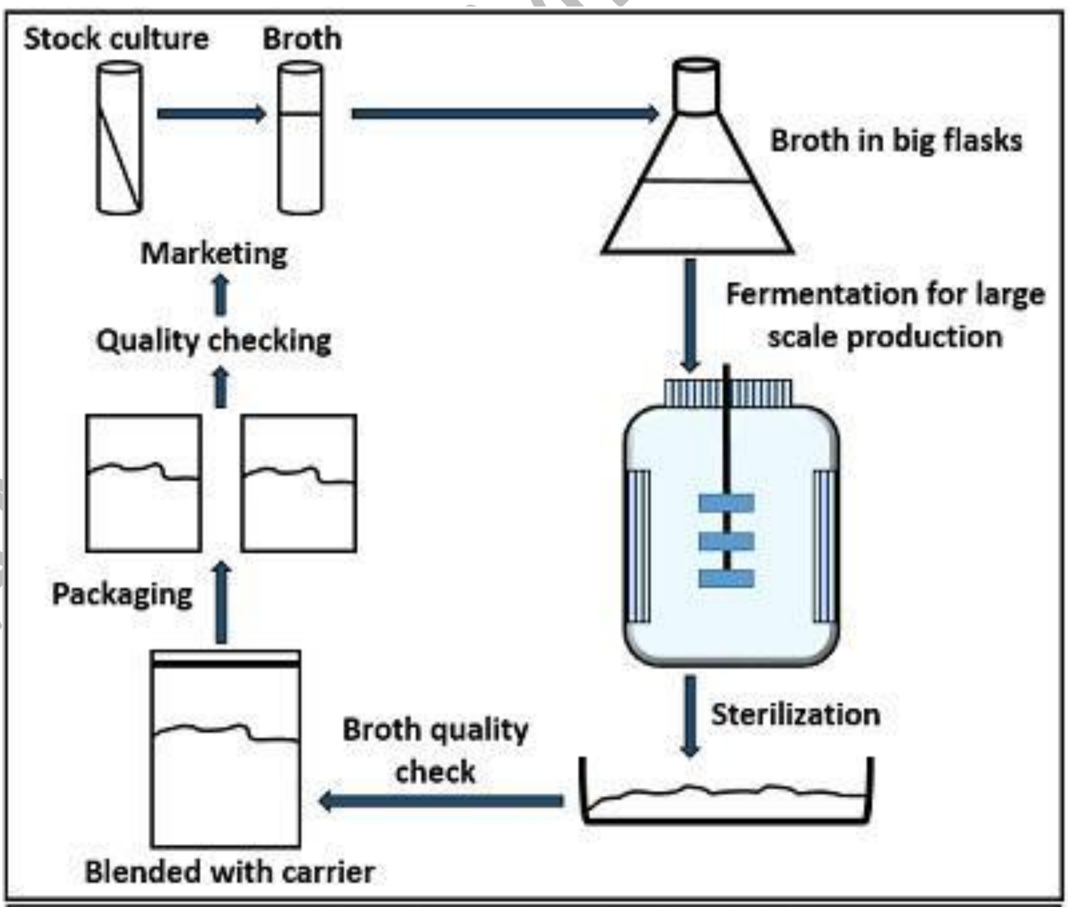
A plant requires a balanced amount of nutrients and minerals to grow. It will be shocking to know that only a small portion of soil produces nutrients through biological or chemical methods every year.

Therefore, biofertilizer production aims to supplement the soil with the essential nutrients that already exists in it. It also aims to control soil-borne diseases. The production and use of biofertilizers aim to improve soil health and soil properties and result in higher yield rates.

Production

Biofertilizers are the biological preparations with live dormant strains of microbes, which positively impact soil rhizosphere and helps in plant development. Biofertilizers are formulated with living or dormant (inactive metabolically) microbial cells. An efficient nitrogen-fixing strain is selected, and later the inoculum is prepared to produce a bio-fertilizer of good quality.

An inoculum is a form in which the strain is inoculated in the seed or soil. Besides strain selection, maintenance, storage and packing are other aspects of bio-fertilizer production. During the biofertilizer production, the product manufactured must fulfil the quality standards laid down by BIS.



Commercial Production: To produce inoculum, you must inoculate the isolated strain in small flasks containing a suitable medium. The starter culture should have a volume that must produce at least 1×109 cells/ml. Then, add culture to the carrier for the preparation of bio-inoculant.

Carriers carry nitrogen-fixing organisms. Primarily, sterilize the carrier and then inoculate it into the seed or soil. But in a few cases, the carrier is inoculated first and later subjected to sterilization via UV irradiation. Then, package the inoculum or biofertilizer with a standard quantity of 109-1010 viable cells/gram.

As per the quality standards, the final moisture content of the biofertilizer must be 40-60%. For large scale biofertilizer production, use large culture fermenters rather than big flasks. The production

Process Of Biofertilizer Includes The Following Sequential Steps:

Strain Selection

First, select the efficient nitrogen-fixing strains and later maintain the culture of strains artificially in the laboratory on the nutrient-rich medium before inoculating them in the seed or soil.

Seed Pelleting

Then, prepare the inoculum of the desired strain. After that, inoculate the seeds using either of the seed coating methods (direct coating or slurry method). The direct seed coating method uses gum arable or sugary syrup. The slurry seed coating method uses efficient nitrogen-fixing strains (coating of rhizobia over specific host legume seeds).

Then, add calcium carbonate to the sticky seeds right away after seed coating. Sometimes, root nodule bacteria are absent in soil, necessary to fulfil the plant’s nitrogen requirements. Therefore, we should inoculate the soil with inadequate nodule bacteria with seed pellets of highly effective rhizobia.

Inoculant Carriers

Inoculants are simply the mixture of the starter culture and a finely milled carrier material. The ideal properties of the carrier should have the properties:

- Non-toxicity
- Good moisture absorption capacity
- Free of lump forming material

- Easy to sterilize
- Inexpensive
- Easily available
- Good buffering capacity

Therefore, the carrier material with these properties can prolong the growth of microbial strains. Peat is the most standard carrier used in bioinoculant preparation. The application of peat is not common in few countries such as India due to its unavailability.

Therefore, peat as a carrier can be substituted with various alternative carriers like lignite, coal, charcoal, vermiculite, polyacrylamide etc. The production of inoculant involves carrier processing, in which the carrier material is subjected to the following stages:

- **Mining**: Carrier like peat is mined, drained and cleared off stones, roots, etc.
- **Drying**: Then, the carrier material is shredded and dried.
- **Milling**: After that, pass the peat through heavy mills. Peat is generally used as a soil inoculant, with a preferable particle size (0.5-1.5 mm).
- **Neutralization**: Then, neutralize the carriers by treating them with precipitated $CaCO_3$, which maintains the pH between 6.5 and 7.0.
- **Sterilization**: At last, sterilize the carriers so that they can be used as inoculants.

Quality Standards for Inoculants

During the production of biofertilizers, it should be kept in mind that the product must make up the quality standards. The inoculant should be carrier-based. There should be a minimum of 108 viable cells per gram (dry mass) of the carrier in the inoculant. The inoculant must have an expiry period of at least 12 months from DOM.

Packaging

Finally, pack the bio-inoculant in polyethene bags of low density (50-75 µ). Label each packet with the product information like name of the product, type of carrier, batch number, DOM, DOE, net quantity and storage instructions etc. Each packet should be ISI (BIS) certified.

Storage

Store the bio-inoculant in a cool and dry place. Keep the bio-inoculant ideally at a temperature of 15°C and a pH between 6.0 and 7.5.

Inoculation into the Field

Seed inoculation and soil inoculation are the two standard inoculation methods that are prevalently used. The soil inoculation involves direct mixing of the bio-inoculant into the sowing furrow along with the seeds. Seed inoculation is a more popular technique that involves seed pelleting or coating with an inoculant.