WHY BIOFERTILIZERS?

Contents

INTRODUCTION

"Despite the many accomplishments of mankind, we owe our existence to six-inch of top soil and fact that it rains." – Confucius

Sustainable agriculture *is the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural* **environment***, the* **social and economic conditions** *of farmers, their employees and local communities, and safeguards the* **health and welfare** *of all farmed species.*

For a sustainable agriculture system, it is essential to use renewable inputs (fertilizer, pesticides, water etc.) which benefit the plant and cause no or minimal damage to the environment. One possible way is to reduce the use of chemical fertilizers and pesticides. Chemical fertilizers are being used in increasing amounts in order to increase the output in high yielding varieties of crop plants. Chemical fertilizers are industrially manipulated substances composed of known quantities of nitrogen, phosphorus and potassium, and their exploitation causes air and groundwater pollution by eutrophication of water bodies.

However, chemical fertilizers cause pollution of water bodies as well as groundwater, besides getting stored in crop plants.

Modern agriculture is becoming more and more dependent upon the steady supply of synthetic inputs, mainly chemical fertilizers, which are products of fossil fuel (coal+ petroleum). Adverse effects are being observed due to the excessive and imbalanced use of these synthetic inputs. The soils have now become biologically dead. This situation has led to identifying harmless inputs like biofertilizers and biopesticides.

Environmentalists worldwide are pressing the market and society for a switch over **to *organic farming and biofertilizers***. ***Organic farming*** aims to be a more environmentally sustainable form of agricultural production, combining best environmental practices, and emphasizing biodiversity protection and the preservation of natural resources. It also emphasizes high animal welfare standards and the avoidance of synthetic chemical inputs such as fertilizers and pesticides and genetically modified organisms (GMOs).

Organic farming is one such strategy that not only ensures food safety, but also adds to the biodiversity of soil.

Organic farming is the raising of unpolluted crops through the use of manures, *biofertilizers* and *biopesticides* that provide optimum nutrients to crop plants, keeping pests and pathogens under control.

WHAT ARE BIOFERTILIZERS?

Generally, the term "fertilizer" is used for "fertilizing material or carrier", meaning any substance which contains one or more of the essential elements (nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, chlorine, sodium, cobalt, vanadium and silicon). Thus, fertilizers are used to improve the fertility of the land.

The term “biofertiliser” has been defined in different ways over the past 20 years, which derives from the improved understanding of the relationships occurring between the rhizosphere microorganisms and the plant. Biofertilizers may be defined as “substances which contain living microorganisms that colonize the rhizosphere or the interior of the plants and promote growth by increasing the supply or availability of primary nutrients to the target crops, when applied to soils, seeds or plant surfaces”. According to Vessey, the term biofertiliser is associated to “a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant". In 2005, biofertilizer was defined as "a product that contains living microorganisms, which exert direct or indirect beneficial effects on plant growth and crop yield through different mechanisms". The definition was extended as the bacteria were used to control plant pathogens. Nevertheless, microorganisms which promote plant growth by control of harmful organisms, such as biofungicides, bionematocides, bioinsecticides, or any other products with similar activity favoring plant health, are generally defined as biopesticides, not as biofertilizers.

Biofertilizers have an ability to mobilize nutritionally important elements from non-usable to usable form. These microorganisms require organic matter for their growth and activity in soil and provide valuable nutrients to the plant. The microorganisms in biofertilizers restore the soil's natural nutrient cycle and build soil organic matter. Through the use of biofertilizers, healthy plants can be grown while enhancing the sustainability and the health of soil. Thus, the term *biofertilizer means the product containing carrier based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop.* Although at present biofertilizers are available for nitrogen and phosphorus only, efforts are on to identify the organisms which can solubilize or mobilize other minerals or nutrients. Recently, K-biofertilizer and Zn-biofertilizers have also been developed but these products are yet to be commercialized.

Biofertilizers are also living or biologically active products or microbial inoculants of bacteria, algae and fungi (separately or in combination) which are able to enrich the soil with nitrogen, phosphorus, organic matter etc. Biofertilizers act as a compound that enriches the nutrient quality of the soil by using microorganisms that establish symbiotic relationships with the plants.

Biofertilizers are low-cost renewable sources of plant nutrients which supplement chemical fertilizers. Biofertilizers generate plant nutrients like nitrogen and phosphorous through their activities in the soil or rhizosphere and make them available to the plants on the soil.

The use of biofertilizers is gaining importance because of the proper maintenance of soil health, the minimization of environmental pollutions and the cut-down in the use of chemicals.

Biofertilizers are one of the important components of integrated nutrient management, as they are a cost-effective and renewable source of plant nutrients to supplement and/or replace the chemical fertilizers for sustainable agriculture. These are preparations containing living cells or latent cells of efficient strains of microorganisms that help the uptake of nutrients in crop plants 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.

WHAT ARE BIOPESTICIDES?

Biopesticedes are certain types of pesticides derived from such natural materials as animals, plants, bacteria and certain minerals. Biopesticides are pest management agents based on living microorganisms or natural products. They have proven potential for pest management and they are being used across the world. Biopesticides are living organisms (natural enemies) or their products (phytochemicals, microbial products) or byproducts (semiochemicals) which can be used for the management of pests that are injurious to plants. They are living organisms which are cultivated in the laboratory on a large scale and are used and exploited experimentally for the control of harmful organisms. Examples include insects, viruses, bacteria, fungi, protozoa and nematodes.

Biopesticides have an important role in crop protection, although most commonly in combination with other tools including chemical pesticides as part of Biointensive Integrated Pest Management. Biopesticides or biological pesticides pose less threat to the environment or to human health because they are specifically targeted to a single pathogenic pest.

The three main types of biopesticides are microbial pesticides, biochemical and plant-incorporated protectants.

Microbial Pesticides

Microbial pesticides contain active ingredients of specific types of microorganisms, such as a fungus, bacterium or protozoan. Each active ingredient can be utilized to target a specific type of pest. For example, some fungi can suppress certain weeds, while certain types of bacteria can control different species of insect larvae, such as mosquitoes, moths or flies. The most commonly utilized microbial pesticides come from strains of the bacteria *Bacillus thuringiensis* (Bt). The bacterial strains manufacture different protein mixes that can target specific insect larvae and will not affect other organisms.

Biochemical Pesticides

Biochemical pesticides use natural substances like insect sex pheromones, which can disrupt mating, thus controlling the insect population. Other types of biochemical pesticides can include the use of hormones, enzymes and scented plant extracts to attract and trap certain pests. These are good alternatives to conventional pesticides because the latter often contain synthetic toxic material to destroy insects.

Plant-Incorporated Protectants

By introducing genetic material into plants, scientists can make plants produce pesticide substances which can target and kill specific pests. In some cases, the addition of a gene with a particular Bt protein can produce these plant incorporated protectants, or plant pesticides.

There are considerable potential benefits to agriculture and public health programmes through the use of biopesticides. The interest in biopesticides is based on the advantages associated with such products, as follows:

1) They are less toxic and inherently less harmful and cause less environmental load;

2) Designed to affect only one specific pest or, in some cases, a few target organisms;

3) Often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems.

4) When used as a component of Integrated Pest Management (IPM) programmes, biopesticides can contribute greatly.

5) They are safer for humans and the environment.

However, for the effective use of biological pesticides, it is important to have extensive knowledge of pest management.

WHY ARE BIOFERTILIZERS USED?

In recent years, a microbial green revolution is underway. Biofertilizers have their own advantages over chemical fertilizers and are economically and environmentally friendly as well. With the increasing demand in agriculture, it has become important for scientists and society to increase the productivity of the sector by using various fertilizers, insecticides and pesticides. However, with the tremendous use of these products, the soil has been badly affected because of the depletion of the essential minerals of the soil. Therefore, to overcome this problem, it has become important to use a different remedy for the production of various biofertilizers. They have the best economic value.

The following basic reasons to explore biofertilizers are outlined:

WHY BIOFERTILIZERS?

- The demand is much higher than the availability. It is estimated that by 2020, to achieve the targeted production of 321 million tonnes of food grain, the requirement of nutrients will be 28.8 million tonnes, while their availability will be only 21.6 million tonnes, leaving a deficit of about 7.2 million tonnes.

- Depleting feedstock/fossil fuels (energy crisis) and increasing cost of fertilizers. This is becoming unaffordable by small and marginal farmers.

- Depleting soil fertility due to widening the gap between nutrient uptake and supplies.

- Growing concerns about environmental hazards.

- Increasing threat to sustainable agriculture. Besides the above facts, the long-term use of biofertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers.

Bio-fertilizers, also known as microbial inoculants, have great potential as a supplementary, renewable and environmentally friendly source of plant nutrients and are an important component of Integrated Plant Nutrient System (IPNS).

HOW DO BIOFERTILIZERS WORK?

1) Biofertilizers fix atmospheric nitrogen in the soil and root nodules of legume crops and make them available to the plants.

2) They solubilize the insoluble forms of phosphate, such as tricalcium, iron and aluminum phosphates, into available forms.

3) They scavenge phosphates from soil layers.

4) They produce hormones and anti-metabolites which promote root growth.

5) They decompose organic matter and help in the mineralization of soil.

6) When applied to the soils or seeds, these biofertilizers increase the availability of nutrients and improve the yield by 10% to 20% without adversely affecting the soil and the environment.

WHY BIOFERTILIZERS?

Biofertilizers are ready-to-use live formulates of such beneficial microorganisms, which upon application to seeds, roots or soil, mobilize the availability of nutrients by their biological activity in particular, and help build up the microflora and, in turn, the soil health in general, which consequently benefits crops. Biofertilizers are designed to improve the soil fertility in N and P. They provide growth promoting substances.

WHAT ARE THE BENEFITS OF USING BIOFERTILIZERS?

- *Increasing harvest yields*
  - ✓ An average increase in crop yields by 20 to 37 percent.
  - ✓ Algae-based fertilizers give improved yields in rice at rates ranging between 10 and 45 %.
- *Improving soil structure*
  - ✓ The use of microbial biofertilizers improves the soil structure by influencing the aggregation of the soil particles
- *Better water relation*

  Arbuscular mycorrhizal colonization induces drought tolerance in plants by:
  - ✓ Improving leaf water and turgor potential,
  - ✓ Maintaining stomatal functioning and transpiration,
  - ✓ Increasing root length and development.
- *Lowering production costs*
  - ✓ Made from easily obtained organic materials such as rice husks, soil, bamboo and vegetables etc.
  - ✓ Reduce the input expenses by replacing the cost of chemical fertilizers.
- *Providing protection against drought and some soil-borne diseases*
  - ✓ Aquatic cyanobacteria provide natural growth hormones, proteins, vitamins and minerals to the soil.
  - ✓ *Azotobacter* infuse the soil with antibiotic pesticide and inhibit the spread of soil-borne pathogens like *Pythium* and *Phytophthora*.
- *Suppressing the incidence of insect pests and plant diseases*

Biofertilizers strengthen the soil profile, leave water sources untainted and improve plant growth without detrimental side effects.

WHY BIOFERTILIZERS?

WHAT ARE THE ADVANTAGES AND DISADVANTAGES?

We can list the basic *advantages* of using biofertilizers:

They help to achieve high yields of crops by enriching the soil with nutrients and useful microorganisms necessary for plant growth.

They replace the chemical fertilizers, as the latter are not beneficial for plants. Chemical fertilizers decrease the plant growth and pollute the environment by releasing harmful chemicals.

Plant growth can be increased because biofertilizers contain natural components which do not harm the plants but do the opposite.

- *They are eco-friendly due to the fact that they protect the environment against pollutants.*
- If the soil is free of chemicals, it will retain its fertility, which will be beneficial for the plants as well as the environment, because the plants will be protected against diseases and the environment will be free of pollutants.
- Biofertilizers destroy those harmful components from the soil which cause diseases in plants. By using biofertilizers, plants can also be protected against drought and other restrictive conditions.
- Biofertilizers are cost effective. They are not costly and even low-income farmers can make use of them.

As disadvantages, using biofertilizers:

- Gives much lower nutrient density – it requires large amounts to get enough for most crops;
- Requires a different type of machinery to apply from that used for chemical fertilizers;
- Sometimes is hard to locate in certain areas; odour; difficult to store;
- Specific to the plants;
- Requires skills in production and application.
- There is inadequate awareness about the use and benefits of biofertilizers.

TYPES OF BIOFERTILIZERS

Biofertilizers add nutrients through the natural processes of fixing atmospheric nitrogen, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances. They can be categorised in different ways based on their nature and function.

One simple broadly disseminated classification is as follows:

A. Nitrogen Biofertilizers

This group fixes nitrogen symbiotically. Nitrogen biofertilizers help to correct the nitrogen levels in the soil. Nitrogen is a limiting factor for plant growth because plants need a certain amount of nitrogen in the soil to thrive. Different biofertilizers have an optimum effect for different soils, so the choice of nitrogen biofertilizer to be used depends on the cultivated crop. Rhizobia are used for legume crops, *Azotobacter* or *Azospirillum* for non-legume crops, *Acetobacter* for sugarcane and blue-green algae and *Azolla* for lowland rice paddies.

B. Phosphorus Biofertilizers

Just like nitrogen, phosphorus is also a limiting factor for plant growth. Phosphorus biofertilizers help the soil to reach its optimum level of phosphorus and correct the phosphorus levels in the soil. Unlike nitrogen biofertilizers, the usage of phosphorus biofertilizers is not dependent on the crops cultivated on the soil. Phosphatika is used for all crops with *Rhizobium*, *Azotobacter*, *Azospirillum* and *Acetobacter*.

C. Compost Biofertilizers

Biofertilizers are also used for enrichment of your compost and for enhancement of the bacterial processes that break down the compost waste. Suitable biofertilizers for compost use are cellulolytic fungal cultures and Phosphotika and *Azotobacter* cultures. A 100% pure eco-friendly organic fertilizer is **Vermi Compost**: this organic fertilizer has nitrogen, phosphorus, potassium, organic carbon, sulphur, hormones, vitamins, enzymes and antibiotics, which helps to improve the quality and quantity of yield. It is observed that, due to continuous misuse of chemical fertilizers, the soil looses its fertility and becomes saline day by day. To overcome such problems, natural farming is the only remedy and Vermi compost is the best solution.

Another eco-friendly organic fertilizer which is prepared from sugar industry waste material that is decomposed and enriched with various plants and human-friendly bacteria and fungi is **Biocompost**. Biocompost consists of nitrogen, phosphate-solubilizing bacteria and various beneficial fungi like the decomposing fungus *Trichoderma viridae*, which protects plants from various soil-borne diseases and also helps to increase the soil fertility, resulting in a good quality product for farmers.

A more detailed classification of biofertilizers is as follows:

Classification of Biofertilizers

S.N	Groups		examples
A	N_2 fixing Biofertilizer		
	1.	Free-living	Azotobacter, Clostridium, Anabaena, Nostoc,
		Symbiotic	Rhizobium, Anabaena azollae
	3.	Associative Symbiotic	Azospirillum
B	P Solubilizing Biofertilizer		
	1.	Bacteria	*Bacillus subtilis, Pseudomonas striata*
	2.	Fungi	*Penicillium sp, Aspergillus awamori*
C	P Mobilizing Biofertilizers		
	1.	Arbuscular Mycorrhiza	*Glomus sp. , Scutellospora sp..*
	2.	Ectomycorrhiza	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
	3.	Ericoid Mycorrhiza	*Pezizella ericae*
D	Biofertilizer for Micro nutrients		
	1.	Silicate and Zinc solubilizers	*Bacillus sp.*
E	Plant Growth Promoting Rhizobacteria		
	1.	Pseudomonas	*Pseudomonas fluorescence*

Just to remind, biofertilizers are defined as biologically active products or microbial inoculants of bacteria, algae and fungi (separately or in combination), which may facilitate the biological nitrogen fixation for the benefit of plants. Biofertilizers also include organic fertilizers (manure, etc.), which are rendered in an available form due to the interaction of microorganisms or due to their association with plants.

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

The various biofertilizers are as follows:

(i) *Nitrogen-fixing biofertilizers* Nitrogen-fixing bacteria function under two types of conditions, symbiotically and as free-living (non-symbiotic) as well as associative symbiotic bacteria.

Free-Living Nitrogen-Fixing Bacteria:

They live freely in the soil and perform nitrogen fixation. Some of them are saprotrophic, living on organic remains, e.g., *Azotobacter*, *Bacillus polymyxa*, *Clostridium*, *Beijerinckia*. They are further distinguished into aerobic and anaerobic forms.

The property of nitrogen fixation is also found in photoautotrophic bacteria, e.g., *Rhizobium, Rhodopseudomonas, Rhodospirillum, Chromatium*. Inoculation of soil with these bacteria helps in increasing the yield and cutting down on nitrogen fertilizers. For example, *Azotobacter* occurring in fields of cotton, maize, jowar and rice not only increases the yield, but also cuts down on nitrogen fertilizer to about 10–25 kg/ha. Its inoculant is available under the trade name of Azotobactrin.

Rhizobia are soil bacteria which are able to colonize the legume roots and fix the atmospheric nitrogen symbiotically. The morphology and physiology of rhizobia will vary from free-living conditions to the bacteroid of nodules. They are the most efficient biofertilizer as per the quantity of fixed nitrogen. There are seven genera that are highly specific in forming nodules in legumes, referred to as a cross-inoculation group.

Azotobacter is a genus of heterotrophic free-living nitrogen-fixing bacteria present in alkaline and neutral soils. It is aerobic in nature, recommended for non-leguminous crops like paddy, millets, cotton, tomato, cabbage and other monocotyledonous crops. *Azotobacter* also produces growth-promoting compounds. *Azotobacter* performs well if the soil organic matter content is high. Response to *Azotobacter* has been seen in rice, maize, cotton, sugarcane, pearl millet, vegetable and some plantation crops.

(ii) *Free-Living Nitrogen-Fixing Cyanobacteria:*

A number of free-living cyanobacteria, or blue-green algae, have the property of nitrogen fixation, e.g., *Anabaena, Nostoc, Aulosira, Totypothrix, Cylindrospermum, Stigonema*. Cyanobacteria are photosynthetic microorganisms. Therefore, they add organic matter as well as extra nitrogen to the soil. These chlorophyll-containing prokaryotic organisms fix atmospheric nitrogen.

Aulosira fertilissima is considered to be the most active nitrogen fixer of rice fields. *Cylindrospermum licheniforme* grows in sugarcane and maize fields. Cyanobacteria are extremely low-cost biofertilisers. Phosphate, molybdenum and potassium are supplied additionally.

(iii) *Loose Association of Nitrogen-Fixing Bacteria:*

This bacterial group live partly within the root and partly outside. There is a fair degree of symbiosis between the host and the bacteria. Hence, they are called associative symbiotic bacteria. *Azospirillum* is an important bacterium in this group, recommended for millets, grass, wheat, maize, sorghum, rice etc.

(iv) *Symbiotic Nitrogen-Fixing Bacteria:*

They form a mutually beneficial association with the plants. The bacteria obtain food and shelter from plants. In return, they give to the plants part of their fixed nitrogen. The most important group of symbiotic nitrogen-fixing bacteria are rhizobia (Sg. rhizobium). They form nodules on the roots of legume plants. There are about a dozen *Rhizobium* species which form associations with the roots of different legumes, e.g. *R. leguminosarum*, *R. lupini*, *R. trifolii*, *R. meliloti*, *R. phaseoli*.

These bacteria, also called rhizobia, can live freely in the soil but cannot fix nitrogen except for a strain of cowpea *Rhizobium*. They develop the ability to fix nitrogen only when they are present inside the root nodules. In the nodule cells, bacteria (bacteroids) lie in groups surrounded by the membrane of the host cells, which is lined by a pink-red pigment called leghemoglobin. Presently cultures of *Rhizobium* specific for different crops are raised in the laboratory.

Frankia, a nitrogen-fixing mycelial bacterium (actinomycete), is associated symbiotically with the root nodules of several non-legume plants like *Casuarina*, *Alnus* (*Alder*) *Myrica*, *Rubus* etc. The leaves of a few plants (e.g., *Ardisia*) develop special internal cavities for providing space to symbiotic nitrogen-fixing bacteria, *Xanthomonas* and *Mycobacterium*. Such leaves are a constant source of nitrogen fertilizer to the soil.

(v) *Symbiotic Nitrogen-Fixing Cyanobacteria*:

Nitrogen-fixing cyanobacteria (blue-green algae) form symbiotic associations with several plants, e.g. cycad roots, liverworts, *Azolla* (fern), and lichenized fungi. *Azolla* is an aquatic floating fern, found in temperate climate suitable for paddy cultivation. The fern appears as a green mat over water, which becomes reddish due to excess anthocyanin pigmentation. The blue-green algae, cyanobacteria (*Anabaena azollae*), present as a symbiont with this fern in the lower cavities actually fixes atmospheric nitrogen.

Azolla pinnata is a small free-floating fresh water fern which multiplies rapidly, doubling every 5–7 days. The fern can coexist with rice plants because it does not interfere with their growth.

Anabaena azollae resides in the leaf cavities of the fern. It fixes nitrogen. A part of the fixed nitrogen is excreted in the cavities and becomes available to the fern. The decaying fern plants release this nitrogen for utilization by the rice plants. When a field is dried up at the time of harvesting, the fern functions as green manure, decomposing and enriching the field for the next crop.

(vi) *Microphos Biofertilizers:*

They release phosphate from bound and insoluble states, e.g., *Bacillus polymyxa*, *Pseudomonas striata*, *Aspergillus* species.

(vii) *Mycorrhiza (Pl. Mycorrhizae, Frank, 1885):*

WHY BIOFERTILIZERS?

The mycorrhiza is a mutually beneficial or symbiotic association of a fungus with the root of a higher plant. The most common fungal partners of mycorrhiza are *Glomus* species. Mycorrhizal roots show a sparse or dense wooly growth of fungal hyphae on their surface. Root cap and root hairs are absent.

Mycorrhiza is a potential biofertilizer which mobilizes P, Fe, Zn, B and other trace elements. It supplies moisture from far-off inches and is ideal for long duration crops. It can be stored up to 2 years and is dry powder resistant.

Depending upon the residence of the fungus, mycorrhizae are of two types—ectomycorrhiza and endomycorrhiza.

(a) *Ectomycorrhiza (= Ectotrophic Mycorrhiza):*

The fungus forms a mantle on the surface of the root. Internally, it lies in the intercellular spaces of the cortex. The root cells secrete sugars and other food ingredients into the intercellular spaces that feed the fungal hyphae. The exposed fungal hyphae increase the surface of the root to several times. They perform several functions for the plant as follows:

(i) Absorption of water,

(ii) Solubilisation of organic matter of the soil humus, release of inorganic nutrients, absorption and their transfer to root,

(iii) Direct absorption of minerals from the soil over a large area and handing over the same to the root. Plants with ectomycorrhiza are known to absorb 2–3 times more of nitrogen, phosphorus, potassium and calcium,

(iv) The fungus secretes antimicrobial substances which protect the young roots from attack of pathogens. Ectomycorrhiza occurs in trees such as Eucalyptus, oak (*Quercus*), peach, pine, etc. The fungus partner is generally specific. It belongs to Basidiomycetes.

(b) *Endomycorrhiza (Endotrophic Mycorrhiza):*

Fewer fungal hyphae lie on the surface. The remaining live in the cortex of the root, mostly in the intercellular spaces with some hyphal tips passing inside the cortical cells, e.g., grasses, crop plants, orchids and some woody plants. At the seedling stage of orchids, the fungal hyphae also provide nourishment by forming nutrient-rich cells called pelotons. Intracellular growth occurs in order to obtain nourishment because, unlike ectomycorrhiza, the cortical cells do not secrete sugars in the intercellular spaces.

Vesicular Arbuscular Mycorrhizal (VAM) fungi possess special structures known as vesicles and arbusculars. VAM fungi are intercellular, obligate endosymbionts and, on establishment on the root system, act as an extended root system. Besides harvesting moisture from deeper and faraway nitches in the soil, they also harvest various micronutrients and provide them to the host plants. VAM facilitates the phosphorus nutrition by not only increasing its availability, but also increasing its mobility. VAM are obligate symbionts and improve the uptake of Zn, Co, P and H_2O. Its large-scale application is limited to perennial crops and transplanted crops. A single fungus may form a mycorrhizal association with a number of plants, e.g., *Glomus*.

The different types of biofertilizers are preparations made from natural beneficial microorganisms. They are safe for all plants, animals and human beings. Being beneficial to crops and natural nutrient cycles, they not only are environmentally friendly, but also help in saving of chemical inputs.

MAIN ROLES OF BIOFERTILIZERS

- ✓ Make nutrients available.
- ✓ Make the root rhizosphere livelier.
- ✓ Growth-promoting substances are produced.
- ✓ More root proliferation.
- ✓ Better germination.
- ✓ Improve the quality and quantity of produce.
- ✓ Improve the fertilizer use efficiency.
- ✓ Higher biotic and abiotic stress tolerance.
- ✓ Improve soil health.
- ✓ Residual effect.
- ✓ Make the system more sustainable.

Liquid Biofertilizers

At present, biofertilizers are supplied to the farmers as carrier-based inoculants. As an alternative, liquid formulation technology has been developed which has more advantages than the carrier inoculants.

Benefits:

The advantages of liquid biofertilizer over conventional carrier-based biofertilizers are listed below:

a. Longer shelf-life – 12–24 months;
b. No contamination;
c. No loss of properties due to storage up to 45º C;
d. Greater potential to fight with native population;

e. Easy identification by typical fermented smell;
f. Better survival on seeds and soil;
g. Very easy to use by the farmer;
h. High commercial revenues;
i. High export potential.

CHARACTERISTICS OF DIFFERENT LIQUID BIOFERTILIZERS

Rhizobium

Physical features of liquid *Rhizobium* biofertilizer:

a) Dull white in colour;
b) No bad smell;
c) No foam formation, pH 6.8–7.5

Azospirillum

Physical features of liquid *Azospirillum* biofertilizer:

a. The colour of the liquid may be blue or dull white.
b. Bad odour confirms improper liquid formulation and may be considered as mere broth.
c. Production of yellow gummy colour materials confirms the quality product.
d. Acidic pH always confirms that there are no *Azospirillum* bacteria in the liquid.
e. Role of liquid *Azospirillum* under field conditions:
f. Stimulates growth and imparts green colour which is a characteristic of a healthy plant.
g. Aids utilization of potash, phosphorous and other nutrients.
h. Enhances the plumpness and succulence of fruits and increases the protein content.

Azotobacter

Physical features of liquid *Azotobacter* biofertilizer:

The pigment that is produced by *Azotobacter* in aged culture is melanin, which is due to oxidation of tyrosine by a copper-containing enzyme, tyrosinase. The colour can be seen in liquid forms. Some of the pigmentations are described below:

a) Produces brown-black pigmentation in liquid inoculum;
b) Produces yellow-light brown pigmentation in liquid inoculum;
c) Produces green fluorescent pigmentation in liquid inoculum;
d) Produces green fluorescent pigmentation in liquid inoculum;
e) Produces, pink pigmentation in liquid inoculum;
f) Produces less, gum-less, greyish-blue pigmentation in liquid inoculum;
g) Produces green-fluorescent pigmentation in liquid inoculum.

Acetobacter

These are sacharophillic bacteria associated with sugarcane, sweet potato and sweet sorghum plants. *Acetobacter* fixes 30 kg N/ha/year. This bacterium is mainly commercialized for sugarcane crops. It is known to increase the yield by 10–20 t/acre and sugar content by about 10–15 percent.

ADVANTAGES OF THE PRODUCTION TECHNOLOGY OF BIOFERTILIZERS

Carrier-based	**Liquid-based**
Cheap	Longer shelf-life
Easier to produce	Easier to produce
Less investment	Temperature tolerant
	High cell counts
	Contamination-free
	More effective
	Product can be 100% sterile
Disadvantages	
Low shelf-life	High cost
Temperature sensitive	Higher investment for production unit
Contamination prone	
Low cell counts	
Less effective	
Automation difficult	

CONSTRAINS OF BIOFERTILIZERS

a) Hard to find in some areas;
b) Sensitive to humidity and temperature;
c) Slower effect on plant growth;
d) Some biofertilizers need special types of machines or sprayers to use;
e) Difficult to store.

There are three main ways of using biofertilizers (liquid and carrier).

APPLICATION OF BIOFERTILIZERS

1. Seed treatment or seed inoculation;
2. Seedling root dip;
3. Main field application.

Seed treatment

One package of the inoculant is mixed with 200 mL of rice kanji to make a slurry. The seeds required for an acre are mixed in the slurry so as to have a uniform coating of the inoculant over the seeds and then shade-dried for 30 minutes. The shade-dried seeds should be sown within 24 hours. One package of the inoculant (200 g) is sufficient to treat 10 kg of seeds.

Seedling root dip

Suspend 1 to 2 kg each of nitrogen-fixing (*Azotobacter*/*Azospirillum*) and phosphate-solubilizing biofertilizer into just sufficient quantity of water (5–10 L depending upon the quantity of seedlings to be planted in one acre). Dip the roots of seedlings in this suspension for 20–30 min before transplanting. In case of paddy, make a bed of sufficient size (2 m x 1.5 m x 0.15 m) in the field, fill it with 5 cm of water and suspend 2 kg each of *Azospirillum* and phosphate-solubilizing biofertilizer and mix thoroughly. Now dip the roots of seedlings in this bed for 8–12 hours (overnight) and then transplant.

CONSTRAINTS IN BIOFERTILIZER TECHNOLOGY

Although the biofertilizer technology is a low cost, eco-friendly technology, several constraints limit the application or implementation of the technology. The constraints may be environmental, technological, infrastructural, financial, human resources, unawareness, quality, marketing, etc. The different constraints, in one way or another, affect the technique at production or marketing or usage.

Technological constraints

- Use of improper, less efficient strains for production;
- Lack of qualified technical personnel in production units;
- Production of poor quality inoculants without understanding the basic microbiological techniques;
- Short shelf-life of inoculants.

Infrastructural constraints

- Non-availability of suitable facilities for production;
- Lack of essential equipment, power supply, etc.;
- Space availability for laboratory, production, storage, etc.;
- Lack of facilities for cold storage of inoculant packages.

Financial constraints

- Non-availability of sufficient funds and problems in getting bank loans;
- Less return by sale of products in smaller production units.

Environmental constraints

- Seasonal demand for biofertilizers;
- Simultaneous cropping operations and short span of sowing/planting in a particular locality;
- Soil characteristics like salinity, acidity, drought, water logging, etc.

Human resources and quality constraints

- Lack of technically qualified staff in the production units;
- Lack of suitable training on the production techniques;
- Ignorance on the quality of the manufactured product;
- Non-availability of quality specifications and quick quality control methods;
- No regulation or act on the quality of the products;
- Awareness on the technology;
- Unawareness on the benefits of the technology;

- Problems in the adoption of the technology by the farmers due to different methods of inoculation;
- No immediate visual difference in the crop growth like that of inorganic fertilizers.

Biofertilizers have a great role in increasing the crop production. They improve the soil health status and provide different growth-promoting hormones and phytohormones to the plant. Moreover, they do not leave residual effects like those of chemical fertilizers. Thus, the use of biofertilizers could be the proper option for sustainable agriculture.

WHAT PRECAUTIONS SHOULD ONE TAKE BEFORE USING BIOFERTILIZERS?

- Biofertilizer packages need to be stored in a cool and dry place away from direct sunlight and heat.
- The right combinations of biofertilizers have to be used.
- Other chemicals (fertilizers and pesticides) should not be mixed with the biofertilizers.
- Seed treatment chemicals like Bavistine etc. should be mixed 3 days prior to mixing with biofertilizer treatment.
- Sow the treated seeds (with biofertilizer) immediately, preferably in the morning or afternoon avoiding scorching sunlight.
- The package has to be used before its expiry, only for the specified crop and by the recommended method of application.

SPECIAL LEGISLATIVE ACTS ARRANGING FERTILIZERS ACTIVITIES IN BULGARIA AND EC

- LAW on plant protection (promulgated in State Gazette 91/10.10.1997, amended in State Gazette 18/5.3.2004); Art. 1 2a of the Plant Protection Law as well as Ordinance 22 regulate the strict rules for production of plants, plant products and foodstuffs of plant origin and indications referring thereto on them. Through these legislative acts, the EC Regulations on organic plant growing or production of organic plant food products are harmonized. Such plant products are organic only in case the requirements of the Ordinance are followed – for soil fertility preservation and improvement, for utilization of plant protection materials and for usage of organic seed material.

- Ordinance No 36/18 August 2004 for the conditions and order of bio-provision and control of fertilizers (State gazette No 87/2004);
- LAW on animal husbandry (promulgated in State Gazette 65/8.8.2000, amended in State Gazette 18/5.3.2004);
- LAW on foodstuff (promulgated in State Gazette 90/15.10.1999, amended in State Gazette 70/10.8.2004).
- ORDINANCE No 22 of 4 July 2001 on organic production of plants, plant products and foodstuffs of plant origin and indications referring thereto on them (promulgated in State Gazette 68/3.8.200 1);
- ORDINANCE No 35 of 30 August 2001 on organic production of livestock, livestock products and Food stuffs of animal origin and indications referring thereto on them (promulgated in State Gazette 80/18.9.2001).

The above-mentioned acts laid down the basis for development of organic farming compliant with the sustainable development requirements in the agricultural sector and its contribution to biodiversity conservation.

In the EU, microorganisms (bacteria, viruses and fungi) are included as possible inputs in the EU Commission Regulation n. 889/2008 on organic production, but only for the biological control of pests and diseases. As such, they are thus listed within the legal framework dealing with plant protection products, as biocontrol agents.

Another document is the **EU Landfill Directive,** which currently is the primary driver for initiatives on biodegradable waste. Its implementation at a national level often also includes separate collection of organic waste, and composting/AD as its primary destination. Anyway, no general provision is included for the destination of biodegradables; hence, the way that composting and anaerobic digestion shall be combined with incineration will be a matter of local strategies, and they factually vary widely from country to country.

REGULATIONS **Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91**

CONCLUSION

Biofertilizers increase the availability of plant nutrients and can help in maintenance of the soil fertility over a long period. As discussed earlier, some microorganisms have the beneficial role of biological nitrogen fixation to supply nitrogen to crops, solubilizing insoluble phosphates to plant-available (soluble) forms and synthesizing biomass for manuring of crops like rice. Biofertilizers are, therefore, economical, renewable and eco-friendly, but they cannot totally replace chemical fertilizers. Biofertilizer use is an important component of Integrated Nutrient Management and organic farming. These technologies are becoming vital in modern-day agricultural practices. The changing scenario of agricultural practices and environmental hazards associated with chemical fertilizers demand a more significant role of biofertilizers in coming years.

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