OPEN ACCESS

DOI: https://doi.org/10.52756/boesd.2022.e01.001

Chapter- 1

Application of biofertilizers in polyculture: a way towards sustainability

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Keywords: Biofertilizers, Polyculture, Sustainable Agriculture.

Abstract:

The rate of population growth in the world is worrying. This sharp rise has led to increased demand for food resources, creating immense pressure in the agricultural sector. In order to increase crop yields, farmers rely on using fertilizers. Chemical based fertilizers, which are mostly utilize, negatively impact the environment. The production of crops using those chemical fertilizers are generally not fit for human consumption. Moreover, they cause harmful effects to other living beings. To reduce the harmful effects caused by chemical fertilizers, several alternatives are being preferred. Biofertilizers may prove to be decent alternative for the chemical based fertilizers since they promote growth of the plant without causing any environmental issues. Biofertilizer is an organic substance, containing beneficial microorganisms that enhance the growth and yield of the plant by producing various growth stimulants and hormones without causing any potential damage to the environment. The main components of biofertilizers include *Azospirillum*, *Rhizobium*, *Azolla*, blue-green algae and *Azotobacter*, which promote plants' growth by various mechanisms like nitrogen fixation, iron sequestration and phosphorus solubilization. Therefore, biofertilizers are rapidly gaining importance in the agricultural sector. Along with monoculture; polyculture is also becoming popular nowadays. This technique involves the culture of different species in a single environment simultaneously. Crop-based polyculture is a common practice in recent days. Polyculture in the aquatic sector is gaining rapid importance since it enhances productivity of the pond and increases the biomass of the fish. Scientifically using biofertilizers in polyculture may improve manifold production and promote sustainable agricultural practices.

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Nithar Ranjan Madhu & Biplab Kumar Behera (eds.), A Basic Overview of Environment and Sustainable Development. ISBN: 978-81-957954-2-0
Published online: 22nd August, 2022

Introduction:

"A biofertilizer is a substance which contains living microorganisms which when applied to seeds, plants, or soil, colonises the rhizosphere or the interior of the plants and promotes plant growth by increasing the supply of nutrients to the host plant"(Malusa and Vassilev, 2014; Bardi and Malusà, 2012; Vessey, 2003; Kar et al., 2022). Biofertilizers are able to solubilize insoluble phosphates, fix nitrogen present in the atmosphere. They produce such chemicals which can encourage the rapid growth and development of the plant. Thus, they improve soil fertility and have the extensive potential for enhancing crop production. Biofertilizers also supply sufficient amounts of nutrients to the crops (Mazid and Khan, 2015; Kundu, 2022). By boosting the protein, vitamins, nitrogen and vital amino acids, biofertilizers can increase crop output by roughly 10% to 40% (Bharadwaj et al., 2014). Through the process of nitrogen fixation, mobilisation of fixed micronutrients and macronutrients and the transformation of insoluble form of phosphorus present in the soil into soluble form, biofertilizers can ensure soil sustainability and fertility in long terms. Additionally, it is also claimed that biofertilizers exhibit characteristics that promote proper growth of the plant and also increases its yield by the mechanisms that involve nitrogen fixation, phosphorus solubilization, phosphorus mobilisation, potassium solubilization, micronutrient solubilization, plant growth promotion, and preventing the loss of organic matter present in the soil (Jeyabal and Kuppuswamy, 2001; De and Dey, 2021). Phosphorus is solubilized and fixed by phosphorus-solubilizing bacteria (PSB) which are present in the soil, including *Bacillus megaterium*, fungi, Pseudomonas putida, and including *Penicillium* species and *Aspergillus* species (Bagchi, 2021, 2020).

Therefore, its use in agricultural purposes, declines the cost of manufacturing of phosphate-based fertilisers and promotes mobilisation of the insoluble fertilizer present in the soil (Chang and Yang, 2009). Under microaerobic conditions, the *Azospirillum* sp. present in the biofertilizer can aid in the fixation of 20–40 kilos of nitrogen. *Azospirillum amazonense*, *A. brasilense*, *A.lipoferum* and *A. trikense* are significant species (Steenhoudt and Vanderleyden, 2000). The use of *Azolla* sp. significantly increased rice output by 0.5 to 2000/hectare (Gupta, 2004). For fixing the proper amount of N2, *Rhizobium* is considered most effective; especially if this fixation is in the leguminous plants (Jehangir et al., 2017; Banerjee et al., 2021). As biofertilizers may be added to the soil manually, it can assist in increasing the yield of the crop. Certain agricultural practices, such as mono-cropping and a few nature based process can result in the decreased load of microbes in the crops' root zone (Itelima et al., 2018). To reduce the excess use of chemical fertilizers and their cost of production, strains of *Azotobacter chroococcum* were used in the fish ponds with less organic wastes and organic fertilizers. Two strains of Azotobacter (Mac-27, and PS-21) were inoculated, and the effects on pond water physicochemical properties, nutrient status, plankton productivity, and fish biomass were assessed. It was observed that these Azotobacter strains increased fish productivity in still-water ponds (Gordon and Jacobson, 1983; Gaind and Gaur, 1991).

A more sophisticated type of agriculture, polyculture, involves simultaneously cultivating multiple species. It is also known as integrated agriculture or multitrophic aquaculture (Bunting 2008). Aquatic polyculture alters productivity, decomposition, and nutrient cycling, which increases yield and thereby improves the pond environment. As a result, it is consistent with sustainable cultural approaches. In South East Asian nations like Thailand, Indonesia, Cambodia, Myanmar, and Vietnam, IAA farming practices for tilapia are heavily integrated with agriculture (Dey et al., 2001).

IAA, on a modest scale in Africa, Polyculture outperformed traditional cultural norms in terms of the economic appeal (Jamu, 2001). Polyculture using African catfish (*Clarias gariepinus*), Nile Tilapia (*Oreochromis niloticus*) and Chinese cabbage (*Brassica rapa*) showed greater yield (Wang and Lu, 2015). Vegetables and integrated aquaculture of *C. gariepinus* and *Oreochromis niloticus* increased productivity, income, yield, production of food and nutrients for the farmers working on small-scale (Pant et al., 2004). With biofertilizers, polyculture will enable the production of numerous food species in a small amount of land, enhancing food security (Adnan et al., 2018).

So, the sustainable method of agriculture could be attained by the right use of biofertilizers in polyculture practices. Higher income and employment prospects may result from it. Everyone from small-scale farmers to large-scale agricultural companies can use these scientific culture techniques to fulfil the increased requirement of vegetables, fish and other crops. If those ideas are applied on a broad scale with ideal conditions & suitable managerial abilities, large nations like India and others may benefit.

Components of Biofertilizers:

Biofertilizers include PGPR, *Azospirillum, Azotobacter,* N2 fixing bacteria, blue green algae and also endophytes, *Azolla* and mycorrhizae.

Endophytes:

Fungi and bacteria called endophytes thrive without hurting the plant tissue. Bacterial endophytes and fungal endophytes are the two types of endophytes (Ganley et al 2004). There have been reports of the bacteria *Azoarcus, Azospirillum, Pseudomonas, Gluconacetobacter, Achromobacter, Harpophora, Rhizoctonia/ Ceratobasidium* complex, *Periconia macrospora*, etc (Jumpponen, 2001). Endophytes can contribute to increase the plant growth and output. Their use promotes healthy nutrient cycling and can potentially reduce pathogen impacts.

Plant growth promoting *Rhizobacterium* (PGPR):

It is a bacterial group which is present in the rhizosphere. A narrow, enclosed area which surrounds the root of the plant and functions as home to a variety of microbes. (Ahemad and Khan, 2012). Plant root nodules contain internal PGPR, PGPR existing in the extracellular portion. PGPR is non-symbiotic bacterial species (Martinez-Viveros et al 2010). PGPR can boost the release of chemicals like ethylene, auxin, cytokinin and giberellin, and also function in the up taking of micronutrients, potassium solubilization, and phosphorus solubization by plants (Klopper et al., 1992). Adding to this, plant development under stress may be enhanced by PGPR (Egamberdieva and Kucharova, 2004).

Mycorrhizae:

Plants and mycorrhizal fungi coexist in a symbiotic relationship. To take up nutrients, the fungi enter the plant roots. For minerals, primarily phosphorus, mycorrhizal fungi provide around 90% of terrestrial plants (Bhatt et al., 2019, Sharma and Bhatt, 2016). Mycelia networks connect different trees in lowland forests. These networks are used by the seedlings of the tree and the tree themselves, for the communication of various chemical messages. (Bhatt et al. 2019d; Sharma et al. 2016; Gangola et al., 2018a). Endomycorrhiza and ectomycorrhizal are two forms of mycorrhizae that have been identified. While endomycorrhizal is primarily found on crops, ectomycorrhiza is found in trees (Bhandari and Bhatt, 2020; Bhatt et al., 2020).

N_2 fixing bacteria

Because the nitrogen present in the atmosphere is unsuitable for plants, it must be transformed into ammonia. The nitrogenase enzyme, produced by microorganisms, is used in the BNF process to convert a significant amount of atmospheric nitrogen into ammonia. These microbes make up a large portion of the biofertilizer. The nitrogenase enzymes can transmit nitrogen into ammonia and then protein. Nitrogen or dinitrogen fixation is the name of this process. Among the nitrogen-fixing microbes found in biofertilizers are:

Azotobacter:

A. chroococcum, A. nigricans, A. beijerinckii, A. paspali, A. vinelandii, and *A. amerniacus,* all belong to the genus *Azotobacter*. A rhizospheric bacteria causes it. When chemicals are applied, the cysts of these bacteria do not burst or become dessicated. In general, non-leguminous plants employ azotobacter. Cereals benefit specifically from *A. Chroococcum.*

Rhizobium:

Leguminous plants and rhizobium bacteria work together symbiotically to fix nitrogen. *Rhizobium*, *Mesorhizobium*, *Sinorhizobium*, *Azorhizobiu*m, and *Bradyrhizobium* are some of the genera of rhizobia (Mutch and Young, 2004; Keet et al., 2017).

Blue- Green algae:

BGA are non-symbiotic, single-celled species that fix nitrogen of the paddy fields and can consist of branched or unbranched filaments.

Azospirillum:

Azospirillum belong to the family of gram-negative, motile, vibrioid bacteria which can grow in anaerobic, aerobic, and microaerophilic environments. It includes polyhydroxy butyrate granules and has peritrichous flagella. A wide range of plants can have Azospirillum colonising both their roots and their uppermost parts, creating a symbiotic association (Cassan and Diaz–Zorita, 2016). *Azospirillum is used* in sorghum, wheat, pearl millet, barley corn and finger millet, (Verse Oglou and Menexes, 2010).

Azolla:

Azolla is a nutrient-rich plant that fixes nitrogen. The fern gains a protective leaf cavity from *Azolla*, which also fixes nitrogen. Due to its ability to grow in still water, quick growth capacity, and high nitrogen content, *Azolla* is most often used as a rice fertiliser (Singh et al., 1984, Prasanna et al., 2008).

Mode of action of biofertilizers:

✔ **Direct mechanism**

- Fixation of atmospheric nitrogen
- Solubilization of phosphorus
- Seuestering Iron

✔ **Indirect mechanism**

- Role in photosynthesis
- Role in amino acid synthesis
- Effect on bioremediation of metals
- Role in remediation of pesticides
- Effect on plant parasitic nematodes

Direct Mechanism:

Fixation of atmospheric nitrogen :

Azospirillum, *Rhizobium*, and *Azotobacter* are a few of the significant bacteria that play an important role in the fixation of nitrogen. An intricate enzyme structure known as nitrogenase is responsible for fixing nitrogen. Iron (Fe) acts as an enzyme cofactor for dinitrogenase reductase, while iron (Fe) and molybdenum (Mo) are cofactors for the enzyme dinitrogenase. The NIF genes, which are found in nitrogen-fixing, free living and symbiotic bacteria are involved in N2 fixation (Black et al., 2012). Among this genus, *Azospirillum lipoferum* and *A. brasilense* are very beneficial to the plants. Several other species in this genus include *Azospirillum brasilense*, *Azospirillum amazonense* and *Azospirillum halopraeferens*(Mishra et al., 2013).

Solubilization of phosphorus:

Rhizobium, *Bacillus*, *Achromobacter*, *Agrobacterium*, *Flavobacterium*, *Micrococcus*, *Burkholderia*, *Acetobacter*, and *Erwinia* are some of the bacteria that are capable of dissolving phosphate.They include both anaerobic and aerobic strain, among which the aerobic strain is mostly harboured by the submerged soil. However, the rhizosphere typically has more phosphate-solubilizing bacteria (PSB) than the soil which lacks in the rhizosphere layer (Youssef and Eissa, 2014). In addition to supplying the plants with solubilized phosphorus, PSB promotes growth of the plant by increasing the effectiveness of biological nitrogen fixation (BNF), which is accomplished with the aid of microbes that fix the N2 (Mohammadi and Sohrabi, 2012).

Sequestering Iron:

Iron mostly resides as Fe^{3+}. It generally remains in an aerobic environment and produces large quantities of hydroxides and oxyhydroxides which are insoluble in nature.Due to this nature of iron , most of it cannot be accessed by the plants and their bacteria. (Rajkumar et al., 2010). However, the siderophores produced by bacteria have a strong attraction to complex iron. As a result, siderophores serve as solubilizers for iron in organic or mineral compounds. To be effective, they need iron-limiting environments, though.

Indirect Mechanism:

Role in photosynthesis:

*Bradyrhizobium sp. (*IRBG 271*)*, *Rhizobium* sp. (IRBG 74), and *R. leguminosarum* were infected with biofertilizers. This boosted the plant's rate of photosynthesis done by a single leaf when compared to the control that was not inoculated. When both the experiments were compared, the bacteria that contained the IRBG strain demonstrated the greatest increase in photosynthetic activity (14%) in the plant (Peng et al., 2002).

Role in the synthesis of amino acid:

The amino acid type is determined by the plant and its related microbes. This also includes the composition of root exudates that the plant releases. (Kang et al., 2010; Bardgett and van der Putten, 2014).

Effect on metal bioremediation:

Numerous studies conducted on the role played by PGPR in the bioremediation of metal toxicity have revealed that a wide range of bacteria are essential for the remediation of the toxicity brought on by the accumulation of heavy metals. *A chroococcum*, *B. megaterium*, *Pseudomonas* sp., *Pseudomonas putida* play an important role in the bioremediation of heavy metals (Dixit et al., 2015).

It is well recognised that heavy metals release harmful chemicals that stress plants. As a result, the hormone ethylene is created, which, in large concentrations, can prevent plant growth. 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which is produced by PGPR, lowers the level of ethylene build up. Therefore, the production of ACC deaminase by PGPR offers host plants an efficient defence against the stress response brought on by toxicity produced by the heavy metals. The generation of siderophores is another efficient method used by PGPR to minimise these toxicities (Singh et al., 2015; Radzki et al., 2013).

Effect on pesticide remediation:

Since pesticides can easily enter live things' tissues and cause disease, their excessive and prolonged usage cause environmental hazard and pose risk to both the plants and people (Aktar et al., 2009; Kumar and Puri, 2012). Research on bacteria strains that can degrade pesticides is now being seen as a possible way to counteract the harmful effects of pesticides. Numerous studies on PGPR have focused on its important function in horticulture, forestry, and environmental protection. Microorganisms can decrease pesticide toxicity, including *Serratia*, *Gordonia*, *Paenibacillus*, *Enterobacter*, *Bacillus*, *Azotobacter*, *Azospirillum*, *Pseudomonas*, and *Klebsiella* among others.

Effect on plant parasitic nematode

Plants of tomato were infected by *M. incognita*, then some biofertilizers containing microbial organisms were applied, including the N2 fixer, Paenibacillus *polymyxa* (four strains), the phosphate solubilizing bacteria, B. *megaterium*, and three strains of *Bacillus circulans*. It was discovered that all the applied microbial biofertilizers showed significant decline in the growth of the nematode population (El-Haddad et al., 2011).

Polyculture over monoculture:

Polyculture is the practice of raising many species (such as plants, fish species, integrated aquatic animals and plants, or aquatic animals) in the same area simultaneously. Since polyculture produces superior yields and minimises fertiliser wastage, it is preferable than monoculture. Monoculture provides a constant supply of plant hosts, which causes repeated outbreaks of pest assault (Altieri et al., 1983). Pesticides become hazardous in the environment when they are used continuously. Monocultures also take the place of the natural ecosystem's intrinsic controls and functions. Due to their genetic uniformity, the majority of these crops are susceptible to attacks from pests and diseases (Wade, 1972).

On the other hand, polyculture offers a wide spectrum of genetic variants within the species. With minimal levels of external inputs, the polyculture method offers advantages, including greater output per unit area, because a variety of species uses the nutrient available in the soil and water in a more appropriate manner (Wang and Lu, 2015). Polyculture practices also improve microclimate, water balance, equally distributed food production (self-sufficiency), lower production risk, and internal nutrient cycling.

Types of Polyculture:

The common types of polyculture include intercropping, cover cropping, strip cropping, permaculture, and integrated aquaculture.

1. **Intercropping:**

The process of Intercropping is defined as "The growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage" (Gomez & Gomez, 1983). It consists of the largest category of multiple cropping and shows the crops' interactions very efficiently. Intercropping is further divided into:

- **Mixed Intercropping:**

When more than two plants can be grown concurrently without any clear layout of a row, this is known as mixed intercropping (Andrews & Kassam, 1976). It brings up the possibility of mixing inside rows. However, mixed intercrops may have distinct crop maturation periods and are often planted together (Willey, 1979a).

- **Row Intercropping:**

Cultivation of two or more crop plants in a single row together is known as row intercropping (Andrews & Kassam, 1976). Peas with canola, maize, soybeans, and numerous tree-based systems exhibit this intercropping pattern (Vandermeer, 1990).

- **Strip Intercropping:**

Plants are stripped in this type of cropping technique. The crops are situated far enough apart to allow for separate cultivation but close enough for them to interact with one another (Andrews & Kassam, 1976).

- **Relay Intercropping:**

It involves the plantation of the second crop after the first one before it reaches the reproductive stage (Andrews & Kassam, 1976).

2. Cover Cropping:

A crop plant is grown next to a plant that is not a crop in cover cropping. In addition to halting soil erosion, cover crops can promote surface water retention, physically squelch weed growth, and, in the case of legumes, supply nitrogen molecules.

3. Permaculture:

The polyculture of perennial plants, like legume grass and wildflower combinations, is known as permaculture. It can prevent soil erosion, control water use, and lessen the need for ploughing. It can also boost soil fertility by fixing nitrogen. As a result, it aids in maintaining soil nutrients.

4. Integrated agriculture aquaculture (IAA):

Aquaculture practices that combine crops and integrated agriculture are done thus to promote sustainable development.

Polyculture practices in the fishery sector

It involves the culture of several freshwaters, estuarine or marine fishes in a single aquatic environment. Fish polyculture is based on the total utilisation of spatial and trophic niche in a pond at different levels. It is done to obtain a maximum number of fish per unit area. Generally, fast growing compatible fish species with different feeding habits or fish of the same species but different size and weights are stocked together to obtain high production per hectare. In India, initial fish polyculture started with three species of carps namely- catla (*Catla catla*), mrigal (*Cirrhinus mrigala)* and *rohu (Labeo rohita.* Later on more fishes are added.

The fish polyculture provides many advantage over the fish monoculture since there is complete utilisation of spatio-trophic habitats of the pond, the fishes can be stocked according to the preference of the market demand, it prevents competition since each species has different feeding habits and therefore occupies different pond niche and this technique can contribute to the improved health of the pond.

Method:

Pond preparation:

It needs a certain depth of the water with a supply of biofertilizer combined and wastes from livestock for a few days that increase the productivity of culture. Different parameters of water, like pH, salinity, and dissolved oxygen, need to be checked regularly to control the system for a better culture.

Stock preparation:

Preparation of different species for stocking is a very important technique. The number of species according to the volume of the culture pond is necessary to assess. Also, the diseased specimen should be isolated and monitored properly.

Feed management:

In the culture pond, different species require special attention to manage their feeding material. Generally, in a sustainable manner, optimum doses of bio fertiliser, cattle manure and specific fish meal combinations can increase productivity. And the leftover feed contributes to primary productivity, which the herbivorous fish utilise.

Water quality analysis:

Analysis of water samples from the culture pond is necessary to improve production. Water parameters like- temperature, pH, salinity, dissolved oxygen, and alkalinity are important to check. In addition, water nutrient parameters like- Ammonia-N, nitrite-N, and phosphate-P are essential to perform in certain intervals. For chlorophyll-a parameters, certain centrifuge and spectrophotometric techniques are used monthly to assess the rate of primary productivity in the culture system. Using an optimum amount of biofertilizer in polyculture systems can increase cultured species' growth as the feed materials' nutrient load improves. It ultimately increases the growth of phytoplankton & zooplankton, thus helping to increase productivity sustainably.

Biofertilizers are widely used in many agricultural fields for various crops to sustainably promote plant growth without causing any harmful environmental effects. Biofertilizers are mostly used for soil or field treatment, seed treatment, and seedling root dipping.

Seed Treatment:

The most common way to apply biofertilizers is seed treatment, which was mentioned. 100 grams of fertiliser are applied for each 5 kg of seeds. The quantity of fertiliser needed to be applied in the agricultural fields per hectare is determined by the number of seeds that will be sown in a field. A water and biofertilizer mix in the ratio of 1:2 is then added to the seed container with the seeds before the applying. The mixture can be gently mixed with an adhesive, such as jaggery, acacia, gum etc., to ensure that the seeds are evenly coated with the biofertilizer. In order to avoid direct sunlight, the seeds are then spread out on a clean sheet or piece of fabric, subjected to 30 minutes of drying and then sown. According to Kumar et al. (2017) and Garca-Fraile et al. (2015), this approach is typically recommended for crops including oilseeds, fodder and pulses.

Seedling Root Dip:

For this kind of treatment, a dilution consisting approximately 1-part biofertilizer and water in the ratio 1:10 parts water is advice. In general, the approach is advised only for transplanted crops. In the field, a bed is constructed, and water mixed with certain biofertilizers for rice is poured into it. After being submerged in this solution for 8 to 10 hours, seedlings are replanted. This method is advised for replanting crops at the seedling stage, such as cabbage, chilly, paddy, brinjal, potato, tomato etc. Garcia-Fraile et al. (2015) demonstrated the treatment of plants of ornamental value like dahlia, Jasmine, chrysanthemum, rose and marigold.

Soil or main field treatment:

A certain amount of compost or dried powdered farmyard manure (20 kg) is combined with the suggested biofertilizers (4 packets), and the mixture is allowed to sit overnight. The soil is then treated with this mixture either just before transplanting or when seeds are sown (Rana et al., 2013).

Cause of sustainability:

1) Chemical fertilisers, which are used in huge amounts to produce large crop yields, have devastating effects on the environment. Consuming the food grown with the help of chemical fertilisers can cause health issues. On the other side, biofertilizers promote the plant growth without causing any degradation to the environment.
2) Since the biofertilizer is generally made from organic waste, it is comparatively cost-effective.
3) Generally, in monoculture practices, the excess nutrients are left untreated. It causes an increase in phytoplankton, Ammonia concentration and changes the dynamics of dissolved oxygen in the aquatic body. But Polyculture adds secondary species that utilise these excess nutrients, which increase the main culture's yield by improving water quality and thus completely fits in a sustainable method of agriculture.
4) It is a mixed type of culture where a product utilised by different species in the culture system can mimic the natural conditions.
5) Polyculture improves production and economics for many small-scale farmers.
6) The effluent water can be used in various agricultural crops as fertiliser.
7) It increases the profit level by optimizing the use of available resources.
8) It is reported in polyculture that algal bloom and pH condition are more stable than monoculture systems.

Objective:

1) To promote sustainability by increasing the yield in polyculture by biofertilizers.
2) To increase the net productivity of aquaculture farms by utilizing by-products.
3) To improve the economic balance by managing wastes produced at poultry and cattle farms in a sustainable way.
4) To manage the aquatic bodies & their natural production in organic ways & minimize the utilization of chemical products that ultimately damage mother nature.

Challenges:

- Polyculture is an alternative culture technique that promotes sustainability along with greater yield and production varieties. Detailed knowledge of Polyculture techniques like the selection of species according to the environment, their stocking rates and other management strategies in different climatic locations, is required to establish it.
- Proper combinations of different types of species in an adequate density maximising the production. It needs greater precision.
- Proper assessment is required to optimise the balance of bio fertiliser in culture ponds, without that, the total system can collapse, causing greater loss.
- The farmers need high management skills and proper education to establish the method.
- It shows positive results in small-scale culture farms worldwide, but in the case of large-scale industries, it needs much more studies to implement.

Global market report of Biofertilizer:

International Report:

According to the International Plant Nutrition Institute, Brazil uses between 60 and 70 K tonnes of biofertilizers annually. Nearly 70% area of soyabean crop field of 30 million hectares in Uruguay, Bolivia, Argentina and Paraguay and in South America receive *Bradyrhizobium* sp. inoculation each year, and these countries are regarded as having a sizable soybean market. While *Pseudomonas* sp. and *Azospirillum brasilense* are suggested for wheat and maize with an expected production improvement of maize and wheat, 4%–9%, a yield difference of 7.5% was detected between inoculated and non-inoculated crops. Biofertilizer production is increasing in nations with advanced research and development and high-end technologies, such as Japan, Korea, and Taiwan (FFTC Report).

National Report:

Over 100,000 hectares of land in India are used for organic farming, supported by almost 100 different types of biofertilizers producers located all over the nation. Special attention is being paid to developing horticulture, oilseeds, and medicinal plants. The use of biofertilizers has enabled the cultivation of almost 167 million hectares of land. However, it was discovered that rhizobium was the most effective (GBMAIF Report).

Conclusion:

As polyculture techniques maximise the consumption of all nutrients and boost annual yield for small-scale farmers, several publications and evaluations from around the world demonstrate higher production and favourable results when compared to monoculture practises. Positive outcomes are also produced by economic metrics like net profit, rate of return, and cost-effectiveness. It can stabilise farmers' income, and since a diversity of produce enhances that, it ensures their ability to feed themselves as the pace of production rises. It demonstrates how these environmentally friendly methods advance aquaculture and agricultural technologies as a whole. Using the leftovers and waste from one component as fertiliser for another is a long-term lucrative and sustainable cultural system. The farmers' managerial abilities, insurance coverage, level of education, and support from the community and government all favourably correlate with this strategy. For large-scale polyculture systems using biofertilizers to be successful, farmers, industrialists, and researchers will need to be more knowledgeable and precise. In the end, it is a fantastic advancement in aquaculture technology that will enhance ecosystem sustainability for the benefit of both people and the environment.

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HOW TO CITE

Biplab Bhowmik, Bipasa Dey and Riya Mondal (2022). Application of Biofertilizers in Polyculture: A way towards sustainability. © International Academic Publishing House (IAPH), Dr. N. R. Madhu & Dr. B. K. Behera (eds.), *A Basic Overview of Environment and Sustainable Development*, pp. 1-17. ISBN: 978-81-957954-2-0 doi: https://doi.org/10.52756/boesd.2022.e01.001