

Biofertilizer as an Alternative for Chemical Fertilizers

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ABSTRACT

The agriculture industry plays a vital role in the survival of nations, therefore maintaining its quantity and quality is essential for feeding the population and economic exports. The industry has undergone various scientific innovations in order to make it more efficient. However, if such advancements, more commonly known as the Green Revolution, have resulted in better yields they have simultaneously also caused the degradation of the environment. Biofertilizers and biopesticides propose a sustainable solution to the reduction in the use of chemical fertilizers while meeting the demands of the growing population. The use of biofertilizers and pesticides in place of chemicals is likely to reduce the impact on soil, air and water and also has the potential to improve human health. They are not only high in nutritional value but also supply productive microbes to the soil. Biofertilizers increase the effectiveness of chemical fertilizers by using a carrier material on which microbes are mounted. These growing organisms that can be manufactured in both solid and liquid phase with a shelf life difference of 6 months to 2 years have a positive effect on the plant growth and can also be used as fish feed. Biofertilizers and pesticides have also been noted to have some disadvantages. Manufacturers might have to face some complications during various processes. Health risks might also arise with some chances of heavy metal contamination. If these limitations can be overcome, biofertilizers and pesticides can be the answer to the pollution being caused by chemical fertilizers.

INTRODUCTION

To cater to the food requirement of the people, the concept of domestication of plants and animals only became common about 10,000 years ago. It began with very controlled farming that did not pose any threat to the environment. Today the industry not only fulfils the food needs of a country but also improves the economic condition through agricultural exports. However, the world population is growing rapidly and is expected to reach 9 billion in 2040. Due to this population explosion and the changing diets of people there is an expected increase in the demand of food by 70% in 2050 ^[4,2]. Other factors may include problems like increase in the population, water scarcity, climate change and volatility are decreasing the agricultural yield. Hunger is already common in the world with 870 million people suffering from chronic hunger.

Agriculture has been promoted to a very sophisticated and mechanized farming system which has resulted in the production of hazardous waste. The Green Revolution (GR) technology up until 2000 helped increase the yield of crops per hectare from 12 to 13% of food supply. The GR technology generally included genetic improvement, irrigation practices and use of fertilizers and pesticides. In the desire to increase agricultural yield farmers have been using chemicals such as fertilizers, pesticides, insecticides, herbicides etc ^[3,4] which has increased exponentially over time. All these chemicals are affecting the environment by degrading the air, soil and water quality ^[5]. Talking about human health, studies have shown evidences where farmers exposed to these fertilizers were at risk of giving birth to children with limb defect ^[6,7]. It has been estimated that about 50% of the fertilizer leaches down into the soil and also ground water and has started showing its effects on human health in the form of diseases such as methemoglobinemia in children ^[8].

Excessive nitrogen fertilizer washes down in the lakes, rivers and estuaries and causes eutrophication, the nitrogenous fertilizers generally not absorbed and can interfere with both ground and surface water ^[9]. Artificial fertilizers can also cause the

emission of greenhouse gases such as nitrous oxide and Ammonia. Although this increase in agricultural yield reduced poverty but at the same time it threatened the environment with its detrimental impacts. These impacts include the degradation of soil fertility, water hardness, increase in the toxic residue and development of resistance in insects. Therefore, agricultural waste, which was once thought of as harmless, has now grown in quantity and intensity. To overcome these challenges organic farming is the new trend that includes the use of sustainable farming practices like the use of bio fertilizers ^[10,11].

Keeping this challenge in mind there is a need to increase the crop yield from the same land area and that too in an environmentally safe way ^[12]. Pests affecting the crops is a growing concern for farmers as a lot of expenditure is required to control their growth. While finding solutions there is a need to consider the three Ps which include the people, prosperity and the planet.

DISADVANTAGE OF INORGANIC FERTILIZERS

Soil pollution

The effect of chemical fertilizer is not evident immediately on soil as it has a great buffering capacity. However, over time the natural balance of the soil elements and pH is disturbed, and the accumulation of toxic chemicals leads to toxication of the food chain. This is caused by fertilizers containing high levels of sodium and potassium. Acidic fertilization results in liming and is the reason for imbalance in the symbiotic nitrogen fixing. Unprecedented use of fertilizers may also result in nutrient imbalance and disrupts the receiving capacity of the agricultural field. Moreover, effects are also lethal for organisms like worms and soil mites ^[13].

The non-organic fertilizers mainly contain phosphates, nitrates, ammonium and potassium salts. On the other hand, these fertilizers are also a source of heavy metals like Hg, Cd, As, Pb, Cu, Ni, and Cu; natural radionuclide like ²³⁸U, ²³²Th, and ²¹⁰Po ^[14,15], therefore causing major environmental problems. These heavy metals may accumulate in the soil and plant system and travel through the food chain as well resulting in water, soil and air pollution. The general hazards include the increase of nitrates in drinking water and rivers, the increase of phosphates in the same due to the transport with the surface flow and carcinogens like nitrosamines in leafy plants like spinach ^[16]. like nitrosamines in leafy plants like spinach ^[16]. For most of the parameters the highest values were recorded in the monsoon rainy season ^[17]. They also have the potential to eradicate the microbes and insects that may be beneficial for the soil.

Water pollution

It is very important to note that knowledge of adequate application of chemical fertilizers is necessary. If fertilizers are applied in excess, they will only end up contaminating surface and ground water. It has been estimated that in ideal conditions, about 2-10% of the fertilizers interfere with the surface and ground water ^[18]. Nitrogen pollution in water can occur by three mechanisms namely drainage, leaching and flow. Leaching occurs mainly due to the use of nitrogenous fertilizers in cultivation. The problem is accelerated in arid and semi-arid areas where evaporation rate is high. After the fertilizer reaches the depths of the soil, they are converted to nitrates through nitrification by microorganisms. This nitrate is then further taken down to the ground water. Nitrate is the most common nitrogen contaminant as it dissolved in water easily; however other contaminants like nitrites, nitrogen gas organic nitrogen and nitrogen oxide are also present. The effect of this nitrogen concentration (usually more than 50 mg/L causes inflammation of bowel, digestive and urinary system. It also has the potential to cause infant diseases like methemoglobinemia where the blood carrying capacity is reduced due to reduction in hemoglobin. These compounds are also known carcinogens that can affect human health negatively. Intensive use of fertilizer can cause eutrophication where water quality is degraded due to the increase in biological oxygen demand by algae and higher aquatic plants. This causing the killing of fishes and other species, creates bad odor in the water and leaves the water unsuitable for any recreational activity ^[19].

Morakinyo ^[20] pilot study project shows that fertilizers do create water pollution which was determined by the sampling, analysis and comparison with the quality standards. A major increase in the phosphate concentration was observed, the value for which was 14.2 mg/l and 11.19 mg/l compared to the standard of 30 µg/l. This concentration is likely to trigger eutrophication is water and diseases like methemoglobinemia and blue baby syndrome as far as human health is concerned. This phosphate concentrated water cannot be used for agricultural or domestic purpose because of its turbidity, change in color and odor.

Air pollution

Excessive use of fertilizers produced oxides of nitrogen that are emitted into the atmosphere. These compounds are then transformed into other dangerous compounds like water vapor, carbon dioxide, methane, hydrogen sulfide (H₂S) with chloro-fluoro hydrocarbons, such as halon gases. Evaporation of NH₃ occurs from alkaline soils that have been treated with ammonium fertilizers. This can cause acid rain eventually after some chemical transformation which can cause damage to animals and vegetation ^[21,22].

Human health

In contrast to the Americans, Indian intake about 40 time more pesticides through food. The major cause of the environmental pollution is due to the use of chemical fertilizers in the field at every level like manufacturing or application sites ^[23]. When the

water based fertilizers applied to the plant, due to its watery nature most of the nutrients run off and leaches down to the soil instead of absorbing as a nutrient to the plant. The leached nitrate further washes out to the rivers and the ponds and make the growth of organisms which further after decomposition cause foul smell. The food produced by the use of chemical fertilizers, have very adverse effect on the health of humans as well as animals [24,25].

- The central nervous system can be badly affected by the residues of pesticides and herbicides which cause respiratory diseases and gastro intestinal disorders [26].
- Some other diseases like wheezing, nausea, lung infections are also the result of deep inhaling and long-term exposure.
- Due to the exposure with the chemical residues people come in contact with depression, insomnia, oral acetomatism, myoclonus and hyper reflexia.
- Plant having excess quantity of nitrogen accumulation cause infant diseases and methemoglobinemia, also the produced amines from the N₂ based fertilizers can cause cancer.
- Due to the higher aluminium exposure asthma is caused together with Alzheimer's and bone diseases.
- Other diseases like neurological toxicity, growth retardation, cognitive delay, and damage to the nervous system is caused due to the exposure to calcium.
- Lung damage occurred due to the extensive exposure to cobalt and boron causing low sperm count, nose throat and eye irritation.

BENEFITS OF ORGANIC FERTILIZER

Bio fertilizers are mainly constituted of selected living cells of microbes which provide the plants with nutrients through their root system. The microbes in these fertilizers use different mechanisms to provide nutrients to the plants. They are capable of nitrogen fixing, phosphate solubilizing, phosphate mobilizing, and promotion of rhizobacteria [27]. The preparation includes selective microorganism that may be useful for the soil. The suitability of the packaging is ensured for a longer shelf life and the safety of the environment and the user [28]. The use of bio fertilizers is becoming popular because of their nutritious value and relatively lower environmental impacts [29]. They are also a renewable resource which can be actively used in place of chemical fertilizers. They are also easier to process which generally comprise of pulverization, neutralization, sterilization, packaging and transport.

Biofertilizers provide supplement nutrients and microbes that may not be present in soil or those that are of less quantity. These fertilizers then speed up the process of microbial activity and provide sufficient and balanced quantities to the soil and plants. Upon reaching the field, they are easier and more comprehensive to use. Bio fertilizers are beneficial in increasing the yield as they utilize the chemical fertilizers more effectively and control the soil borne diseases.

Due to these qualities the demand for bio fertilizers is increasing and was expected to reach the worth of USD 10.2 million by 2018. The Asia- Pacific region is expected to have 34% of the total demand whereas Europe and Latin America also will be shifting their consumption to these fertilizers due to regulation imposed on the chemical fertilizers. In the same way bio pesticides are also being developed from natural materials that are using biological mechanism to fight plant insects [30,31].

To save the crops from the adverse effects of pests, the use of chemicals was started in 1940s with dichloro-diphenyl-trichloroethane (DDT) being the most famous pesticide. However due to the adverse effects of these agrochemicals on the soil fertility, quality of water and toxic residues. Moreover, they have helped the insects develop resistance and caused genetic changes in plants. These chemicals have triggered the outbreak of secondary pests and accumulated toxic substances in the food chain, air, water and soil. To overcome this challenge and maintain the crop productivity, biofertilizers and bio pesticides are predicted to play an important role with their natural ingredients, non-toxic mechanisms and eco-friendly effects. *Bacillus thuringiensis* also known more commonly as BT is a widely used strain of bacteria as a microbial pesticide.

Bio pesticides are gaining popularity due to their ability to target specific pests. They are efficient at the same time and biodegradable in an environmentally safe way. The new trend of organic agriculture greatly favors the use of bio fertilizers and pesticides. Although these biological solutions cannot replace chemicals completely, but they can provide protection to the crops to the level that environmental safety is ensured. Bio pesticides are gaining popularity since 1995 and is growing by the rate of 10% every year and the current production of these pesticides is 3000 tons per year globally. The main driver of the market is the growing need for an agricultural produce that does not leave any harmful residue and gives organic products. USA, Canada, Mexico and European Union countries widely use the bio pesticides whereas Asia is behind in this development and uses only 5% of the sold bio pesticides [32].

The manure of dairy cattle is widely used as fertilizer in organic farms. This manure is produced from 42 kg to 64 kg which can be composted and used in the fields [33,34], other than that animal slurry is also used as fertilizers [35]. This organic waste needs to be decomposed so that it can be used as a fertilizer. A bioreactor is an environmental friendly technology where anaerobic digestion of organic matter takes place. The method is affected by the concentration of substrate, moisture, temperature, pH

[36,37]. It reduces environmental impact by capturing the releases of methane in its sealed container from being released into the atmosphere. The burning of this methane will produce carbon neutral carbon dioxide which collectively reduces the greenhouse effect. However, this process is slow and has low efficiency therefore to speed up the process, various chemicals and enzymes are used [38,39]. Factors such as agitation speed, fermentation temperature and ventilation rate are monitored as they were believed to affect the physical, chemical and microbial characteristics of bio fertilizer. These fertilizers not only enhance the growth of the plants but also provide protection against diseases and stress [40-42].

To make the application easier, the microorganisms are mounted on any material before being released into the fields. This material not only helps increase the shelf life of the fertilizer but also facilitates rapid growth upon release. Example of carrier material can be charcoal, peat, paddy, soil rice bran etc. To make sure that the material will work well with the organism selected, the viability of both is tested. The material is also pre-sterilized and enriched with nutrients like maltose, sucrose and molasses to ensure a longer shelf life. Such treatments provide environment for the organisms to maintain or grow [43]. Bio fertilizers can also be formulated in liquid state to increase their shelf life. In liquid state, more nutrients can be added together with cell protectants and inducers for cell, spore or cyst formation. The difference between solid and liquid carrier shelf life is 6 months and up to 2 years, respectively. Liquid bio fertilizers are more heat tolerant (as high as 55 °C) but their cost of manufacturing is much more than solid fertilizers [44].

In an experiment, it was seen that bio fertilizers had a positive impact on the growth of the plant *Gladiolus grandiflorus* L.) which was taken as the sample. Maximum sprouting time was taken in the control experiment. The presence of nitrogen in the fertilizer made the plants grow taller and more in weight. The macro and micro nutrient absorption was also enhanced. Another positive effect was seen as in early flowering in plants like rose because of the early development of auxiliary bulb to reproductive phase. In *Gladiolus*, biofertilizer improved the physiological growth and vase life which indicates preserving ability of bioferts [45]. The weight and cormel production also increased which was attributed to the availability of phosphorus [46]. Positive effect on the nutrient uptake of leaves was also observed.

The use of animal manure (bio fertilizer) in aquaculture for the production of high protein fish is one very effective use of bio fertilizers. Since livestock and poultry play a major role in improving the economy of India, the waste products of these industries can be utilized as feed for the fisheries [47]. This does not only reduce the impact of the livestock waste that it would have on the environment if not utilized properly but also cut down the cost of buying feeds and fertilizers. If managed in a sensible manner there will be no need of any supplementary feeds. The basic principle used in by Kaur et al. [48] is that plankton feeds on the animal manure and grows. This abundance of plankton can cause the fish yield to increase as it feeds on the plankton [49]. Positive improvement in fat content of the fish muscles was also seen in the fertilized experiment. Between the organically treated and inorganically treated samples, more protein and fat were found in the organically treated fish.

NEGATIVE IMPACTS OF BIO-FERTILIZERS

In contrast to the bio-fertilizers, the nutrient based fertilizers give better results and are reliable as well. The core effectiveness of the procedure is maintained by the biological and chemical interactions which are further affected by physical factors like pH, moisture, temperature and other environmental variables as well. If the conditions are not suitable for microbes to multiply and do their work properly their population diminishes gradually with time, and this results in waste of time and money.

Mutation during fermentation

During the process of fermentation bio-fertilizers mutate which results in the rise of production and quality control cost. There is a need to give more attention to this aspect in order to eliminate such unwanted conditions.

Unavailability of appropriate and efficient strains

The lack of effective strains is one of the most important flaws that make the bio-fertilizers unfit for the crops and soil. The selected strains have to be far better and competitive than others. They should be compatible to different environmental conditions and should be able to survive in broths and inoculant carriers.

Health risk

As we know that the animal manure is rich in nutrients and can be used to facilitate the plant growth. However, some of its limitations are also associated that increase the risks on the safety of the consumers, physiochemical and biological stability of the soil. The higher content of ammonia present in the manure burns plant roots and foliage, together with increasing the transportation cost and weed production. Other than that, the heavy metal present in it causes cancer and other fatal diseases and is likely to be deposited in the food chain by bio-accumulation and bio magnification. So, there is a need to make a detailed assessment while using manure fertilizer for the soil and also consider the cost-benefit ratio. Although some technical tests could have been performed to verify and assure the safety concerns.

Heavy metal content

The USEPA categorizes the bio-solid according the amount of heavy metal in it. The solids with the lower content can be

kept on the flexible security systems as well. And the solids with the higher content are assigned to the strict security control and are not likely to be used. The Bio-solid can be rejected or accepted according to the level of its hazardous characteristics like corrosively, reactivity, toxicity, flammability and other biological hazards. Bio-solids clear from these characteristics are certified as safe and applicable. The sanitary conditions are meant to lessen the health risks to the human and the environment, but it has the potential to contaminate the soil, water, crops and the ecosystem as well [50].

Unavailability of suitable carrier

Due to the unavailability of the suitable culture in which the bacteria grow and multiply itself, the bio-fertilizers shelf life is restricted. Peat of good quality containing carbon content more than 75% is very rare. Since a good quality carrier should have a combination of various characteristics like moisture holding capacity, free of toxic substances and adjustable pH, finding such carrier is not an easy task.

Native microbial population

At times the microorganisms that are already present in the soil restrict the efficiency of the inoculant and reduce the effective establishment of the bio fertilizer.

Lack of expertise

The personals responsible for the sales of the bio fertilizers are not aware of the proper inoculation techniques. Since these products contain living organisms, their handling, transport and storage is not very easy to manage. Therefore, the lack of expertise and the level of uncertainty in this field give rise to complications.

Soil and climatic factors

The factors which affect the microbial growth and crop responses are fertility of soil, climatic conditions, high nitrate level, high temperature, unfavorable pH, drought, deficiency of phosphorus, copper, cobalt, Mo and other toxic substances (Table 1).

Table 1. Factors affecting the microbial growth and crop responses.

Sr no	Type of Bio fertilizer	Bacteria	Species	Type of effect	Value of growth with Biofertilizer	Control growth	Reference
1.	Biofertilizer	Azospirillum-based	Rice	Grain	0.2 to 0.5 t ha ⁻¹		Banayo et al. [51]
2.	Effective microorganisms + biopower	photosynthetic bacteria, lactobacilli, yeast, actinomycetes	Rice	Shoots biomass	59.3 bc	52.5 bc	Javaid [52]. Thenmozhi et al. [53]
3.	Effective microorganisms + biopower	photosynthetic bacteria, lactobacilli, yeast, actinomycetes	Rice	Shoots length	94 ac	88 bd	Javaid [52]
4.	Biofertilizer+ 25% chemical fertilizers	<i>Pseudomonas</i> sp.	Cucumber	Mean of chlorophyll	3.5 g/m ²	3.15 g/m ²	Isfahani and Besharati [54]

CONCLUSION AND RECOMMENDATIONS

In the future the bio fertilizers and pesticides are likely to be the center of attention globally. They are known to be the solution to weeds, pathogens and insects. At the same time, they are less harmful to human health and the environment. USEPA has found close to no adverse effects of such technology and has legalized their sale and distribution. Countries are amending their policies to discourage the use of chemicals and promote bio pesticides. But the cost of manufacture and market barriers due to the current popularity of chemical fertilizer is becoming a problem for the industry. Another major problem that comes as a hindrance for the promotion of bio pesticide is that its mode of action, effects and regulatory issues are still unknown to the public and policymakers. Therefore, their importance is still not widely understood. There is a need to create awareness among farmers, policymakers, government and manufacturers to understand the importance of bio pesticides.

For pest control natural substances like antifeedant, deterrent, repellents and vegetable oils have been tested and found to be environmentally safer pesticides [55]. Moreover, to increase the efficiency of bio pesticides, DNA recombinant technology and protein fusion are being experimented with. To promote the use of bio pesticides and fertilizers in farmers there is need to make them more effective and efficient so that they can play their role in bringing sustainability to the agriculture sector. Farmers also need to be educated about the proper use of fertilizers to minimize runoff and possible adverse effects.

Universities and research organization need to take this aspect of agriculture with priority as it seems like an answer to the problem of food security and environmental health. However, this technology needs to be researched upon and improved so that it shows desired results and gains the trust of the farmers. The areas that need to be focused for research are the quantification for commercial production and strain authentication. Bio fertilization has become an important component of precision farming which is one way to make sure that plant nutrients for the growth and quality of the crop are optimized. Bio fertigation is a way to ensure that the organisms are properly delivered to the root zone, but it could increase the chance of chemical toxicity in the

microbes. Therefore, it requires a differentiation between the application of biological and chemical inputs. The efficiency of these fertilizers can be improved by exploring the genetic and functional diversity of plant growth rhizobacteria. It is being researched to find ways that can make bio fertilizer more compatible with the soils and genetic engineering is expected to play a vital role in the combining two kinds of microorganisms for better efficiency^[56,57].

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