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BIO FERTILIZERS AND THEIR IMPACT ON SOIL FERTILITY

Devendra Choudhary

Research Scholar, Department of Botany, SPC Government College,Ajmer(Raj)

Prof.Manoj Kumar

Department of Botany, SPC Government College, Ajmer (raj)

Anupama Yadav

Assistant Professor, Department of Geography, Government College,Bijainagar(Raj)

Maharishi Dayanand Saraswati Vishvvidhalay, Ajmer

ABSTRACT

The breakdown of organic waste, the fixation of nitrogen, and the solubilisation of phosphorus are just a few of the biological processes that biofertilizers, which are safe for the environment and are made up of living microorganisms, employ to increase the fertility of the soil and the availability of nutrients. Biofertilizers contribute to the advancement of sustainable agriculture by improving the structure of the soil, increasing the variety of microorganisms, and fostering production over an extended period of time. On the other hand, chemical fertilisers may cause the soil to become less healthy owing to acidification, salinisation, and nutrient imbalance. This is in contrast to the situation described above. Mycorrhizal fungi, phosphate-solubilizing bacteria (PSB), Azotobacter, Azospirillum, and Rhizobium are some of the biofertilizers that are routinely used. Each of these biofertilizers plays a unique function in the process of nutrient cycling. Research has shown that the use of biofertilizers on a consistent basis has the potential to enhance crop production while simultaneously reducing pollution and the need for synthetic fertilisers. According to research, the incorporation of biofertilizers into soil results in improvements to the soil's organic matter content, water retention, enzymatic activity, and resistance to disease and insects. The use of biofertilizers may be beneficial to carbon sequestration since they increase the quantities of organic carbon in the soil. Biofertilizers provide a solution that is both cost-effective and environmentally friendly for farmers who are on the margins of the agricultural industry and want to increase soil fertility without disrupting the ecological balance. The incorporation of biofertilizers into the agricultural practices that are already in use is essential in order to achieve the goals of agroecological sustainability, the preservation of soil health, and the guarantee of food security over the long term.

Keywords: *Biofertilizers, Soil Fertility, Nitrogen Fixation, Phosphorus Solubilization, Sustainable Agriculture.*

INTRODUCTION

Biofertilizers are a gift from contemporary agricultural science that may help improve soil fertility and delay nitrification long enough by delaying it. When it comes to the management of integrated nutrition, biofertilizers are an important component. They are a vital component of a sustainable agricultural system since they offer an alternative to chemical fertilisers that is renewable, cost-effective, ecologically benign, and preserves the soil. In contrast to inorganic fertilisers, bio-fertilizers do not transport the nutrients directly to the plants that they are applied to. In order to hasten the microbial process that increases the availability of easily assimilable nutrients, colonises the interior of the plant (the rhizosphere), and promotes growth by biologically converting nutritionally important elements to available form, for example by fixing nitrogen and solubilising rock phosphate, microbial inoculants are applied to seeds, soil, or composting areas. The goal of this application is to hasten the process. The bacteria that are included inside biofertilizers not only protect plants against diseases and insects that are damaging to them, but they also encourage the growth of the plants. Biofertilizers are being proposed for in order to make advantage of the biological system of nutrient mobilisation that is already present in the environment. If you apply biofertilizers to seed or soil, you may increase the fertility of the soil and the development of plants. This is accomplished by increasing the quantity of helpful microorganisms and their biological activity. The inoculants or carrier-based treatments that are being discussed here comprise live or dormant cells of microorganisms that are capable of fixing nitrogen, soluble phosphate, and degrading cellulose.

By incorporating biofertilizers or microbial inoculants into seed, soil, or compost, the objective is to increase the population of beneficial microorganisms and the metabolic activity of these microbes. This will speed up particular microbial activities, hence increasing the amount of nutrients that are accessible in forms that plants are able to readily absorb. Biofertilizers are essential for two primary reasons: first, chemical fertilisers increase crop yields and production; however, the excessive use of these chemicals has led to major concerns regarding soil texture, fertility, and other environmental issues; second, biofertilizers are more cost-effective and less harmful to the environment than chemical fertilisers. Therefore, the most effective approach to integrated nutrient delivery in agricultural settings is to combine the use of chemical and biofertilizer treatments.

The degree of development of a nation is directly proportional to the amount of food and other nutrients that are readily available in that country. As a result of the growing population around the world, there will be an increased need for food grains. The usage of fertilisers helps to guarantee that food grains are delivered in a manner that is in line with the demand. A fertiliser is any substance that is applied to soil in order to increase its output. When nutrients are added to the soil, the fertility of the soil is increased, which in turn helps plants grow healthier and more robust. Chemical fertilisers are described as those that satisfy the nutrient requirements of plants by mixing various plant-based nutrients with solid or liquid chemicals that are manufactured in factories. Not only do chemical fertilisers normally include nitrogen, phosphorus, and potassium (NPK), but they also typically contain extra nutrients.

OBJECTIVE

1. To investigate the effects of biofertilizers on soil fertility.
2. To evaluate the long-term effects of using biofertilizer in comparison to chemical fertilisers on crop yield, soil fertility, and environmental sustainability.

HISTORY OF BIOFERTILIZER

The ultimate objective of agricultural practices is to increase the amount of crop that is produced. The use of chemical fertilisers is directly contributing to an improvement in productivity. Because it changes the chemical composition of the soil, as well as the microbial flora and ecosystem, it has a detrimental effect on the health of the soil and the biodiversity of the soil. Chemical fertiliser firms started creating synthetic fertilisers and pesticides consisting of phosphorus (P), potassium (K), and nitrogen (N) in the early nineteenth century. The purpose of these products was to increase crop yields and protect plants against a broad variety of diseases. The researchers discovered that the consistent and long-term use of chemicals led to the acidity of the soil as well as a decline in the quality of the soil. This has implications for human health and contributes to the instability of the ecosystem via its effects. For this reason, increasing agricultural yields requires the use of farming practices that are more environmentally friendly. According to this hypothesis, the microorganisms that live in the soil are essential to the sustainability of agriculture because they contribute to the preservation of ecosystem diversity and the enhancement of soil health. Bacteria that have traits that help plants develop and protect them from illnesses are referred to as plant growth-promoting bacteria, or PGPB for short. Around the same time that Bassi made the first discovery of the Beauveria bassiana infection in silkworm in the year 1835, bioformulations were already being used in agricultural practice. As a result of this discovery, the role that microorganisms play in the prevention of sickness was ultimately established. Since the discovery of the Bt (Bacillus thuringiensis) toxin, researchers have been contemplating the possibility of using microbes as a chemical alternative. In following publications, it was shown that the majority of the bacteria have the ability to function as biocontrol agents and to stimulate the development of plants. There have been several studies that have suggested the use of various bioformulations as a means of treating the ailment and enhancing the growth of plants. The successful use of PGPR as bioinoculants in the latter half of the 18th century and the early 19th century led to the marketing of this substance. The moment has arrived to use PGPB in agricultural practices that are responsible to the environment. It is important to note that the specific mechanism by which these microbial inoculants function varies depending on the host and the region in question. As a result of the expressive features that they possess, a multitude of biofertilizers that come in a variety of formulas have come into being.

Symbiotic N2 fixers

The ability of legume crops to fix nitrogen from the atmosphere is made possible by the symbiotic connection that exists between them and Rhizobium, which may be found in root or stem nodules. The gram-negative, rod-shaped, motile bacteria known as rhizobium are responsible for nitrogen fixation. Either a single polar or subpolar flagellum is present in these organisms. The rhizobial legume symbiosis is based on a series of processes that begin when the microsymbiont, which is Rhizobia, takes up residence in the macrosymbiotic organism, which is the legume. Different hosts are affected by sporadic infections and the formation of nodules. Rhizobia colonise as intracellular symbionts, which is a process that requires complicated interaction between the host and the symbiont, and this interaction results in the formation of nodules. For example, Bradyrhizobium, Sinorhizobium, Azorhizobium, and Mesorhizobium are all species that belong to the genus Rhizobia. When a particular carbohydrate receptor on the surface of Rhizobium cells attaches to a particular host legume lectin (glycoprotein), this may be an indication that the two bacteria are involved in a mutually beneficial interaction. The purpose of lectins is to act as identifying tools. It is only possible for couples to bond if they are compatible with one another. The tip of the root hair bends after the binding process has been completed, which makes it possible for bacteria to enter and grow in an infection tube. In tetraploid cells, the rhizobia are able to multiply, but in diploid cells, the normal cells are destroyed. The root epidermal cells start to increase once the generation of growth hormones has taken place. A nodule is formed when cells that are located around the perimeter of an area that has neighbours who are diploid experience rapid cell division. Bacteroides, which are deformed cells with a volume that is more than 10 times that of rhizobia, provide the perfect habitat for bacteria that divide at a rapid rate. Both singly and in clusters, bacteroids are encased with membranes that are called peribacteroid membranes. The reddening of the tissue that contains the bacteroids is brought about by the presence of leghaemoglobin. During the process of ageing, the nodules become green because the breakdown of haemoglobin into green bile pigments causes this transformation. The release of stationary phase rhizobia takes place during the process of nodule death, and the subsequent proliferation of these organisms is made easier by the breakdown products of the nodules. Nitrogenase is a unique enzyme that is present in all bacteria that fix nitrogen, and it is able to transform nitrogen into ammonia by utilising the energy that is delivered by ATP. The nitrogenase enzyme is composed of two proteins, one of which contains Mo-Fe and the other of which contains Fe. The symbiotic bacteria Azorhizobium is a kind of Rhizobium that is responsible for the formation of stem nodules and the retention of nitrogen from the surrounding air. Additionally, they produce a significant amount of indole acetic acid (IAA), which is a substance that encourages the development of plants. When Bradyrhizobium is inoculated into mucuna seeds, it not only boosts the levels of total organic carbon, nitrogen, phosphate, and potassium in the soil, but it also acts as an efficient nitrogen fixer. Consequently, it leads to a reduction in the quantity of weeds while simultaneously bringing about an increase in the quantity of soil microorganisms and plant biomass.

Free living N_2 fixers

Free-living nitrogen fixers that work together to fix nitrogen Azotobacter are bacteria that are found in the wild and are capable of fixing nitrogen. The pH range that is optimal for the growth of this heterotrophic, aerobic bacterium ranges from neutral to slightly acidic. The family Azotobacteriaceae is comprised of the genera Azomonas and Azotobacter, which are linked to one another. Azotobacter macrocytogenes, Azotobacter insignis, Azotobacter beijerinckii, and Azotobacter vinelandii are some of the other species that have been shown to exist. This region is home to the most prevalent species of A. chroococcum, which may be found in the soil. It has been shown that Azotobacter may be found in the rhizospheres of a wide variety of agricultural plants, such as rice, maize, sugarcane, bajra, vegetables, and plantation crops. The capacity of Azotobacter to generate cysts that are filled with unique fluids, the presence of a multi-type nitrogenase enzyme, and a very high oxygen tolerance are all characteristics that set it apart from other such bacteria. In order for Azotobacter to flourish, the environment must have a pH that falls anywhere between neutral and slightly acidic. Azotobacter has been the free living nitrogen fixer that has had the most amount of research and isolation due to the significance it plays in naturally existing plant life and soil fertility. Azotobacter is thought to play a large role in the nitrogen content of soil, and it is responsible for a wide variety of beneficial characteristics. These characteristics include enhanced nitrogen fixation, ammonia excretion, vitamin and growth promoter synthesis, siderophores production, and antifungal antibiotic development. It has been shown that Azotobacter secretes chemicals that inhibit the development of certain root infections while simultaneously boosting the growth of roots and the plant's ability to absorb nutrients.

Phosphate solubilizing microorganisms

It is essential for the growth and development of plants to have phosphorus in their soil. This nutrient, which is known as accessible phosphorus, is believed to be present in the soil of the majority of India, but in insufficient proportions. The quantities of phosphorus in the soil range from 0.05 to 10 parts per million, while the typical solubility of the soil is between 0 and 1 part per million. Plants can only consume a very small portion of this at any one time. Phytate (soil), inositol phosphate, phosphomonoesters, and phosphotriesters are some of the varieties of organic and inorganic forms that phosphorus may take. Phosphorus is often insoluble and can be found in a wide range of forms. Immobilisation of soluble inorganic phosphorus, which is a chemical fertiliser, occurs almost immediately after it is applied to the field. The consequence of this is that plants are unable to take it in and hence are unable to make efficient use of it.

In light of the aforementioned, it was vital to create a system that would run for an extended period of time, be kind to the environment, and be able to provide plants with a consistent supply of phosphorus nutrients at a cost that was affordable. In accordance with the findings of several research, bacteria that are capable of dissolving inorganic phosphorus have a significant impact on the amount of phosphorus that is available to plants. Citric and gluconic acids are examples of the low molecular weight organic acids that are produced by soil bacteria. These acids are responsible for the solubilisation of inorganic phosphorus. A carrier-based preparation that includes the living cells of microorganisms such as bacteria, fungus, and actinomycetes is referred to as a biofertilizer that allows insoluble phosphorus to be dissolved. This kind of biofertilizer has the potential to boost crop yield. When compared to soil that does not include rhizospheres, the rhizosphere contains a greater quantity of phosphate-solubilizing bacteria (PSB). Some of the species of bacteria that are capable of dissolving insoluble inorganic phosphorus include Pseudomonas, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Micrococcus, Acetobacter, Flavobacterium, and Erwinia. PSB not only provides plants with soluble phosphorus, but it also promotes the growth of plants by empowering nitrogen-fixing organisms to carry out biological nitrogen fixation (BNF) in a more effective manner.

Blue green algae (Cyanobacteria)

Among the photosynthetic prokaryotes that are collectively referred to as cyanobacteria, one of the most prevalent characteristics is their ability to thrive in any habitat that has liquid and light. The ability to fix nitrogen from the air is possessed by a significant number of these creatures. During the process of fixing around 20-30 kg of nitrogen per hectare in rice fields that are submerged in water, they stimulate the growth of plants by producing auxin, indole acetic acid, and gibberlic acid. They thrive in tropical conditions, especially in paddy soils, and they are ideal for the addition of biological nitrogen to the environment in which rice is grown. They are able to carry out nitrogen fixation after the energy needs of photosynthesis have been satisfied. Cyanobacteria have a number of advantages for the environment, including the ability to fix carbon and trace elements, that they have an exceptional capacity for storing water, and that they provide nitrogen with nitrogen to the soil. There are three possible structures that cyanobacteria may take: a single cell, a filamentous structure with branches, or no branches at all. They possess a peculiar structure known as a heterocyst, which is the component responsible for the fixation of nitrogen. Additionally, it has been revealed that some cyanobacteria are capable of nitrogen fixation even in the absence of heterocyst. Aulosira, Nostoc, Tolypothrix, and Anabaena are three examples of cyanobacteria that are often used in field applications. Azolla, a biofertilizer that By working in conjunction with blue-green algae that are capable of fixing nitrogen, Azolla is able to float freely in water and fix nitrogen from the atmosphere. Azolla, which has a dry nitrogen content of 45% and a wet nitrogen content of 0.2–0.4%, is an excellent organic manure and nitrogen source for rice production. It is used as a biofertilizer in the fields prior to the growing of rice. One of the most extensively used species of Azolla in India is Azolla pinnata. This is due to the fact that it is able to be propagated by vegetative means that are economically viable. Some of the other Azolla species that may be found in India, such as Azolla mexicana, Azolla filiculoides, Azolla microphylla, and Azolla caroliniana, have been brought in from other countries because of the high biomass production that they produce. Because of the rapid decomposition of nitrogen in the soil, azolla is an excellent candidate for use as a fertiliser for rice crops. In addition to this, it is an excellent source of a wide variety of micronutrients, such as phosphorus, potassium, zinc, iron, and molybdenum.

Effect of biofertilizer in photosynthesis

As a result of the fact that plants absorb carbon dioxide (CO_2) via the process of photosynthesis, which accounts for around 90 percent of their biomass, increasing the rates of photosynthesis leads to improvements in plant growth (Long et al., 2006). Rice that has been inoculated with rhizobia has been shown to have the ability to boost its photosynthetic capacity, according to studies. Certain Rhizobia strains were shown to greatly boost the plant's net photosynthetic rate, stomatal conductance, and water usage efficiency. Additionally, the plant's leaf surface area was significantly increased. According to Heidari and Golpayegani (2012), the combination of three bacterial biofertilizers—Pseudomonades, Bacillus lentus, and A. brasilense—increased the expression of antioxidant enzymes and the chlorophyll content in leaves that were having a stressful situation. Consequently, this indicates that biofertilizer has the potential to enhance the capacity of plants to flourish in challenging environments by enhancing the photosynthetic activity of the plants.

Effect of biofertilizer in amino acid synthesis

For the purpose of describing a colony of bacteria that may colonise the soil surrounding roots, the term "rhizosphere" is most often used. What are known as "root exudates" are compounds that are released by roots and may be found in soil. The presence of these compounds attracts a wide variety of microorganisms. When different chemical compounds are released into the environment, they have a considerable influence on the physicochemical properties of the soil as well as the composition of the soil microbiome that is immediately around the root surface. In other words, the sorts of amino acids that plants exude and the amount of root exudates that they produce are determined by the species of plant and the bacteria that they are associated with.

Effect of biofertilizer on bioremediation of metals

Heavy metals, hazardous waste, organic contaminants, and other pollutants have been released into the environment as a consequence of widespread agricultural activities, rapid industrialisation, and urbanisation (Shinwari et al., 2015). These factors have all contributed to the discharge of these pollutants. Heavy metals that are hazardous to human health include mercury (Hg), zinc (Zn), arsenic (As), chromium (Cr), cadmium (Cd), copper (Cu), nickel (Ni), and lead (Pb). These heavy metals exist in a variety of valence states. Despite the fact that plants need certain metals as micronutrients, the majority of plants will be harmed if there is a big accumulation of metals. In spite of this, soils that contain very high levels of heavy metals have a negative impact on the microbial community and impair the fertility of the soil. Multiple studies that have been conducted on the role of PGPR in the bioremediation of metal toxicity have shown the significance of a broad range of microorganisms in the process of lowering the toxicity of heavy metals. Among the wide range of PGPR that play an important role in the bioremediation of heavy metal toxicity, some of the most notable examples include Achromobacter xylosoxidans, A. chroococcum, Bradyrhizobium, Pseudomonas sp., Brevibacillus sp., Kluyvera ascorbata, Mesorhizobium, Pseudomonas putida, Pseudomonas aeruginosa, Ralstonia metallidurans, Rhizobium, Sinorhizobium sp., Variovoxparadoxus, Ochrobactrum sp., Psycrobacter sp., and Xanthomonas sp. are some of the PGPR that play an important role in bioremediation. The enzyme known as 1-aminocyclopropane-1carboxylate (ACC) deaminase is one of the primary defensive mechanisms that are brought about by PGPR. This enzyme reduces the quantity of ethylene, which is a hormone that plants collect when they are under stress. The microbial siderophores that are generated by PGPR are yet another effective method for lowering the concentration of metals in the environment.

Effect of biofertilizer in remediation of pesticides

The abuse and continuing use of pesticides has a detrimental effect on the environment and constitutes a threat to both people and other species. This is due to the fact that pesticides are bioaccumulative and may enter living organisms via their tissues. It has been shown that some bacteria, such as Azospirillum, Azotobacter, Bacillus, Enterobacter, Gordonia, Klebsiella, Paenibacillus, Pseudomonas, Serratia, and a great number of others, has the ability to lessen the toxicity of pesticides. Although these particular strains of Actinomycetes possess the capacity to biotransform and biodegrade substances, a great number of other strains also possess this ability. Enzymatic degradation is the principal method whereby microorganisms contribute to the breakdown of pesticides. Additionally, it has been reported that certain enzymes have the ability to reduce the toxicity of pesticides by catalysing a wide variety of reactions. These reactions include hydrolysis, oxidation, the addition of an amino group to a nitro group, dehalogenation, the reduction of a nitro group to an amino group, the substitution of oxygen for sulphur, ring cleavage, and the metabolism of side chains.

Effect of biofertilizers on plant parasitic nematodes

It was found that all of the microbial biofertilizers that were administered had considerable nematicidal activity when they were inoculated individually on tomato plants that were infected with the root-knot nematode M. incognita in sandy soil that was contained in containers. Four strains of nitrogen-fixing Paenibacillus polymyxa, three strains of phosphate-solubilizing B. megaterium, and three strains of potassium-solubilizing Bacillus circulans were among the bacteria that were used for the process of fertilisation. Notwithstanding the presence of nematode infestations (Capsicum annum), it was shown that inoculating chilli plants with biological nitrogen fixers (Azospirillum and Azotobacter) resulted in improvements in the plants' growth, production, and quality.

Effect of biofertilizer on ecosystem

Numerous studies have been conducted to investigate the impact that biofertilizers have on the rhizosphere of the soil and the food web. The majority of these studies have shown that the introduction of bio inoculants into the rhizosphere results in discernible alterations. On the other hand, the magnitude of these alterations and the influence they have on the functioning of the ecosystem are neither yet fully understood. Variables such as soil qualities, the method of biofertilizer distribution, environmental conditions, and other factors all have a role in determining the extent to which biofertilizers have an effect on the organisms that reside in the soil. In order to carry out complete multi-dimensional evaluations of biofertilizer efficacy, diversity, and risk assessment studies before to their release into the ecosystem, higher-resolution approaches should be used in combination with the procedures that are already in place.

Effect of biofertilizer in reclamation of degraded land

Reclamation of mining waste dumps requires the cultivation of an indigenous microbial population that is capable of constructing soil, encouraging plant development, and supplying plants with nutrients via a number of different biogeochemical cycles. This is important for the reclamation process to be effective. Therefore, the acidity of the soil is a significant issue for plant life since it is a result of mining. By raising the pH of these soils via the use of organic additions, it is possible to achieve a number of advantages, including the enhancement of soil quality, the enhancement of water retention capacity, and the gradual release of fertiliser. Therefore, biofertilizers have the potential to heal the soil of damaged land to a certain degree.

Effect of biofertilizers in crop production

The introduction of biofetilizers into soil results in a considerable increase in the fertility of the soil, yield-attributing properties, and the final yield. Biofertilizers are able to increase agricultural yields in a way that is environmentally friendly since they improve the health of the soil and plants and increase the availability of nutrients. As a result of its quick soil degradation and high nitrogen availability to rice plants, azolla biofertilizer is used in the process of rice cultivation. Rhizobium biofertilizers significantly increased the agronomic yield features of pulse crops grown in temperate regions. Azospirillum biofertilizers, on the other hand, improved the yield attributes, harvest index, and leaf area index of agricultural crops when they were applied to agricultural crops.

CONCLUSION

The application of biofertilizers to soil stimulates organic biological processes that enhance the availability of nutrients and the health of the soil, which ultimately results in an increase in the fertility of the soil. By incorporating them into the soil, the structure of the soil, its capacity to retain water, the diversity of microorganisms, the amount of organic matter, and the availability of essential nutrients such as phosphorus and nitrogen are all improved. Biofertilizers are an alternative to chemical fertilisers that is both sustainable and friendly to the environment. They are in accordance with the principles of sustainable agriculture and have the potential to avoid soil deterioration and adverse effects on the environment. In the long run, the use of biofertilizers helps to maintain high soil productivity, reduces the amount of money that farmers have to spend on inputs, and reduces the negative effect that farming has on the environment. Only by adding biofertilizers into traditional agricultural systems will it be possible to ensure the preservation of the quality of the environment and the health of the soil for future generations. This is the only method to ensure that there is no shortage of food.

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