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Review Article

Biofertilizers – An effective compost for soil quality improvement and plant growth

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Abstract: Plant growth and development depend on the combination and concentration of essential nutrients in the soil. A deficiency of any of the nutrients results in decreased productivity and fertility. Therefore, people utilized chemical fertilizers to maintain productivity without taking care of its negative effects on ecology and the environment. Biofertilizers have been discovered as a viable option for improving soil fertility and crop yield in a long-term manner. The fertilizers contain beneficial microbes which help in promoting the growth of plants by increasing the supply of essential nutrients. This review aims to understand the different types of microbes utilize as biofertilizers and their potentialities in another sector. The review showed microorganism-based fertilizers can enhance nutrient uptake, promote growth and protect plants from pests and diseases. Many studies showed microbial intervention can also be used to clean contaminated sites with heavy metals, industrial effluents, and to kill pathogens infecting plants. Lastly, it discussed the limitation and prospects of biofertilizer research for sustainable development and environmental management.

Keywords: *biofertilizers, micro-organism, soil fertility, sustainability*

सारांश: बोट बिरुवा को वृद्धि र विकास माटोमा आवश्यक पोषक तत्वहरूको संयोजन र एकाग्रतामा निर्भर गर्दछ । कुनै पनि पौष्टिक तत्वको अभावले माटोको उत्पादकता र उर्वरतामा कमी ल्याउँछ । तसर्थ, मानिसहरू उत्पादकता कायम गर्नका लागि रसायनिक मलको प्रयोग गर्छन जसले पर्यावरणमा नकारात्मक प्रभाव पार्छ । एक व्यावहारिक विकल्पका रूपमा जैविक मलले दीर्घकालीन रूपमा माटोको उर्वरा शक्ति र बाली उत्पादन सुधार गर्छ । मलमा लाभदायक सूक्ष्मजीवहरू हुन्छन् जसले पौष्टिक आपूर्ति बढाउँदै बोटको विकासलाई बढावा दिन्छ । यस समीक्षाले विभिन्न सूक्ष्मजीवहरू जैविक मलको रूपमा प्रयोग गर्ने र उनीहरूको क्षमतालाई अर्को क्षेत्रमा बुभ्ने लक्ष्य राखेको छ । धेरै अध्ययनहरूले देखाए कि सूक्ष्मजीवको प्रयोगले बोट बिरुवा को वृद्धि विकास र रोगजनक संक्रमित बिरुवाहरूलाई मार्न प्रयोग गर्न सकिन्छ । अन्तमा, यसले दिगो विकास र वातावरणीय व्यवस्थापनको लागि जैविक मल अनुसन्धानको सीमितता र संभावनाहरू बारे छलफल गऱ्यो।

1. Introduction

The human population is increasing raising a big threat to food security as the land of agriculture is limited and even getting reduced with time. Therefore, it is necessary to increase agriculture productivity to meet the demand of a growing population (Le Mouël and Forslund, 2017; United Nations: Department of Economic and Social Affairs, 2019). This increases the use of chemical fertilizers despite their harmful effects on the environment, humans and animals (Ajmal et al., 2018). Also, the continuous application of chemical fertilizers leads to the decay of soil quality and fertility and might lead to the collection of heavy metals in plant tissues, affecting the fruit nutritional value and edibility (Chaney, 1989; Savci, 2012; Sharma et al., 2014). Therefore, in recent years, many biofertilizers have been introduced that act as natural stimulators for plant growth with market value and health benefits (Mie et al., 2017).

Biofertilizers are substances that contain microorganisms, which when added to the soil increase fertility and promotes plant growth (Bargaz et al., 2018; Vessey, 2003; Itelima, 2018). It not only

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enhances soil quality but also provide a conducive environment for a microorganism that is beneficial for plants (Ahmad et al., 2018). Biofertilizers are applied as soil inoculants that multiply and participate in nutrients cycling and benefit crop productivity (Singh et al., 2016). Recently, many studies and research have been focused on developing and commercializing agro-waste based biofertilizers. It was reported that the use of biofertilizers elevates crop yield around 10-40% by increasing the content of proteins, essential amino acids, vitamins and nitrogen fixation (Bhardwaj et al., 2014). A study showed biofertilizers with pesticide degrading strains of bacteria (*Azospirillum, Azotobacter, Bacillus, Enterobacter, Gordonia, Klebsiella, Paenibacillus, Pseudomonas, Serratia,* etc.) help to combat the deleterious effects of pesticides (Shaheen and Sundari, 2013). El-Hadad et al., (2011) reported that some bacterial biofertilizers including the nitrogen-fixing bacteria showed the highest reduction in nematode population in tomato plants infected with the root-knot nematode. Also, they found that these biofertilizers increased shoot length, many leaves, shoot/root dry weight compared to plant which is not inoculated with biofertilizers. Likewise, when nematode-infested chilli (*Capsicum annum* L.) was inoculated with biological nitrogen fixer (*Azospirillum* and *Azotobacter*), Khan et al. (2012) discovered that the yield and quality of the chilli increased.

Nowadays, biofertilizers are considered as key agricultural components to improve crop productivity and sustainable agro-ecosystem. Biofertilizers can produce plant hormones like gibberellins and cytokinin reducing stress in plants and stabilizing their yields (Bhardwaj et al., 2014). Proline, an organic acid is accumulated in the plant during physiological response is degraded by bacteria and improves drought resistance (Verbruggen and Hermans, 2008). Similarly, Chickpea cultivars treated with plant growth-promoting rhizobacteria (PGPR) showed negative effects of drought stress with increasing biomass (Kumar et al., 2016). A meta-analysis with 112 experiments showed an increase in both yield and plant nutrient by inoculation of arbuscular mycorrhizal fungi (AMF) under open field conditions (Berruti et al., 2016). Augusto et al. (2013) showed that a high level of phosphorous availability in soil drives plant growth and also biological nitrogen fixation. These studies showed various types of biofertilizers provide optimum nutrients to crop plants causing nominal damage to the environment and enhance the biodiversity of the soil. Studies showed global biofertilizers market size was valued at USD 1.0 billion in 2019 and it is anticipated to reach USD 1.66 billion by 2020 (Grand View Research, 2020; Timmusk et al., 2017).

This review discusses how microbes can be used as biofertilizers to reduce our dependence on agrochemicals. Furthermore, it emphasizes the potential of biofertilizers in various sectors, such as agriculture, ecology, and remediation, which can help to create biofertilizers as a promising instrument for long-term agriculture development. Lastly, it tries to find the gap and prospects of biofertilizers research.

2. Use of microbes in biofertilizers

A microorganism that adds or make available different nutrients to the plants are called a biofertilizer. They form important components of integrated nutrient management and applied to soil through seeds, roots, or directly to soil where microbes multiply and mobilize the inert nutrient. Generally, biofertilizers may be classified into four types 1. Nitrogen supplementing microorganisms 2) Phosphorous solubilizing microorganisms 3. Composting microorganisms and 4. Plant Growth Promoting Rhizobacteria (PGPR) (Pathak and Kumar, 2016).

2.1.1. Nitrogen supplementing microorganisms

These are the group of microorganisms (*Rhizobium, Azotobacter, Acetobacter*) that have the capability of fixing atmospheric nitrogen from the atmosphere. A plant can utilize nitrogen only in the form of nitrate, therefore, there should be some medium of nitrogen conversion for its utilization. Some microorganism utilizes nitrogen as food and converts it to ammonia through the activity of an enzyme called nitrogenase (Kim and Rees, 1994). This ammonia is then converted into nitrate by nitrification and assimilated into the plant system. Both symbiotic and nonsymbiotic microorganism has been reported to fix nitrogen. Symbiotic nitrogen fixation is a result of a mutualistic relationship between bacteria and leguminous plants. In this case, microbes first colonize the root and form nodules in which nitrogen is converted to ammonia or its product that is supplied to plants as nitrogen sources (Ahemad and Kibret, 2014). Microbes in return obtain carbon sources from the plants specifically in the form of dicarboxylates. Non-symbiotic nitrogen fixation is mostly performed by the free-living diazotrophic microbes (*Pseudomonas, Acetobacter, Azotobacter*). The study showed inoculation of nitrogen-fixing microorganisms to crop plants serves as an integrated strategy for growth stimulation, disease suppression and maintenance of nitrogen levels in the soil of agricultural fields (Tsukanova et al., 2017).

2.1.2. Phosphate solubilizing microorganisms (PSM)

Phosphorus (P) is the second most important plant nutrients other than nitrogen for plant growth. It plays an important role in various metabolic activities (energy transfer, respiration, photosynthesis, signal transduction, and macromolecular synthesis) (Kalayu, 2019; Sharma et al., 2013). Phosphorus is available in soil in inorganic and organic form but its utilizable form is very low. This is because more than 95% of P exists in insoluble and immobilized forms which plant cannot absorb. The plant absorbs P in monobasic (H2PO4-) and dibasic (H2PO4-2) forms (Bhattacharyya and Jha, 2012). To overcome this problem, there is a certain microorganism (*Aspergillus* spp, *Arthobacter, Bacillus, Erwinia, Pseudomonas, Microbacterium Rhizobium* etc.) which have the capability of resolubilizing that insoluble phosphate, making them available to the plants. These biofertilizers are considered important as they promote plant growth and productivity by supplying phosphorus in usable forms in environment-friendly and inexpensive modes.

2.1.3. Composting microorganism

Waste from forest and agriculture fields has a sufficient amount of plant nutrients but they are not easily available to plants. There should be some decomposition process with the involvement of microorganisms. Composting microorganism is usually available in the atmosphere and help in the decomposition of dead organic matter. *Trichoderma, Penicillium*, and *Aspergillus* are some of the microorganisms which are efficient in composting a heap of agricultural waste faster and of good quality.

2.1.4. Plant growth-promoting rhizobacteria (PGPRs)

Plant growth-promoting rhizobacteria (*Pseudomonas, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Burkholderia, Bacillus*, and *Serratia*) are a heterogeneous group of microorganisms known to improve plant growth by their ability to colonize the rhizosphere besides their effects as biocontrol agents and producers of plant hormones (Joseph et al., 2007; Kloepper et al., 1980). These microbes provide a wide range of services and benefits to the plant and in return, the plants provide the microbial community with reduced carbon and other metabolites. The study showed inoculating plants with PGPR can be an effective strategy to stimulate crop growth (Backer et al., 2018). There are two main classes of PGPRs, i.e., extracellular plant growth-promoting rhizobacteria (ePGPR) and intracellular plant growth-promoting rhizobacteria (iPGPR) (Martínez-Viveros et al., 2010). ePGPR (*Serratia, Azospirillum, Azotobacter, Bacillus, Chromobacterium* etc.) typically colonize the rhizosphere or space on the surface of the root cortex and iPGPR (*Rhizobium, Bradyrhizobium, Allorhizobium, Mesorhizobium*) mostly reside in the specific nodulated parts of roots cells (Backer et al., 2018; Martínez-Viveros et al., 2010). PGPRs are known to synthesize different types of antibiotics and possess novel attributes in heavy metal detoxification (bioremediation) (Egamberdieva and Lugtenberg, 2014; Xie et al., 2016).

3. Potentialities of biofertilizers

Biofertilizers not only help to boost crop productivity but also have potentialities in other sectors. They are divided into two broad headings described below;

3.1. Bioremediation

It is defined as a process of removing hazardous wastes biologically under controlled conditions to an innocuous state (Prince, 2003). In this process, microorganisms are utilized to reduce, eliminate, transform and detoxify the unwanted products present in soils, sediments, water and air (Saranya et al., 2017; Ward and Singh, 2004). In developing countries, there is a tradition of using wastewater and sewage sludge directly into the soil due to its high nutrient concentration (nitrogen, phosphorus and organic matter). However, the long-term application can alter the physical, chemical and biological properties of soil and lead to high concentrations of heavy metals (Gottschall et al., 2009; Kharche et al., 2011). There are several methods used to detoxify this effluent but most of them are expensive and not environment friendly (Zhang et al., 2004). For this, we can utilize microorganism, which makes a significant impact by removing contaminants from soils and reducing their toxic effects on the environment (Das and Adholeya, 2012). Pandey et al. (2018) found ligninolytic mushroom *Lenzites elegans* can absorb synthetic dye by forming laccase enzyme. Similarly, *Bacillus cereus* and two strains of *Pseudomonas aeruginosa* have been found to decolourize bleached kraft paper-mill effluents (Tiku et al., 2010). *Rhodococcus biosurfactants* have been used for the bioremediation of oil-contaminated agricultural soils after an accidental oil spill (Christofi et al., 1998). Studies showed certain biofertilizers (*Phosphoren, Microbien*, *Cerealin* and *Azospirillum*) may act as a potential agent for soil inoculation to bioremediate pesticides contaminated soil (van Veen et al., 1997). Likewise, Azolla, a free-floating, fast-growing, and nitrogen-fixing pteridophyte seems to be an excellent candidate for removal, disposal, and recovery of heavy metals from the polluted aquatic ecosystems (Umali et al., 2006).

3.2. Biopesticides

Biopesticides are compounds that are used to manage agricultural pests through specific biological effects rather than broader chemical pesticides. Biopesticides contain natural organisms or substances derived from natural materials such as animals, plants, bacteria, or certain minerals including their genes of metabolites. Microorganism (e.g., bacteria, fungi, viruses, algae) have been successfully used in controlling insect pests, plant pathogens and weeds (Harding and Raizada, 2015; van den Bosch et al., 1982). For instance, microbial pesticides suppress pests through the production of a toxin specific to the pest that causes the diseases (Sharma and Malik, 2012). Application of biofertilizers such as *Trichoderma harzianum, P. fluoresecens*, and *Bacillus subtilis* helps to cure the plant diseases caused by the pathogens like *Pythium* spp., *Rhizoctonia* spp., and *Sclerotium* spp and enhance plant growth (Mahanty et al., 2017). Bhattacharya and Jha (2012) reported that the interaction between some *Rhizobacteria* and plant roots can prevent pathogenic fungi, bacteria, and viruses from affecting the host plant. Studies showed many individual bacterial components such as lipopolysaccharides (LPS); flagella; siderophores; cyclic lipopeptides; 2,4 diacetyl phloroglucinol; and homoserine lactones and volatile compounds such as 2,3-butanediol and acetonin can cause induced systematic resistance (ISR) in the host plant, allowing it to defend itself against a range of plant diseases (Lugtenberg and Kamilova, 2009; Pieterse et al., 2014). Some biocontrol bacteria produce different enzymes such as cellulases, proteases and lipases that can lyse come a portion of the cell wall of pathogenic fungi thus prevents disease spreading by killing the fungus (Beneduzi et al., 2012).

4. Limitation of biofertilizers

Though biofertilizer is eco-friendly and possesses a lot of advantages, there is some limitation associated with this technology in its application. For example, biofertilizers are plant-specific with lower nutrient density, therefore, need skilled manpower and may not benefit farmers because of inadequate awareness. Also, there may be constraints on the application and implementation of biofertilizers which may affect technology at stages of production, marketing or uses. Other constraints limiting the use of biofertilizer technology may be unavailability of suitable strains, and unavailability of the suitable carrier, short shelf life, susceptibility to high temperature.

5. Conclusion

Biofertilizers are an important component of sustainable organic farming and alternative chemical fertilizers that are associated with various environmental hazards. The fertilizers activate the microorganism found in soil in a cheaper, effective and environmentally friendly manner restoring the soil natural fertility. This help farmer to increase yield enhanced soil quality and induced drought tolerance in plants. However, for the success of biofertilizers technology, more research and development are needed to make agriculture practices more sustainable and economical. The technology should be economically viable and should be easily accepted by society.

5.1. Future perspectives of biofertilizers

Biofertilizers is the newly emerging field and use as an integral component of agriculture practice. They have been successfully used in a few developing countries and expected to grow with time. Hence, there are wide research opportunities for its overall development with integration in the agriculture sector.

- Multifunctional biofertilizers those are both competitive and cost-effective for a wide range of crops
- Make people aware that bacteria are not always harmful but are beneficial to the environment and our soil
- Should focus research on a new approach of growth, storage, shipping, formulation and its application
- Research on genetically engineered strains for more efficacy in stimulating plant growth
- Research on quality control for their proper application in the field and to ensure their benefit
- Agronomic, soil and economic evaluation of biofertilizers for diverse agricultural productions should be done.

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P.P: draft the manuscript

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