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A Comprehensive Review on Impact of Microorganisms on Soil and Plant

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A COMPREHENSIVE REVIEW ON IMPACT OF MICROORGANISMS ON SOIL AND PLANT

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ABSTRACT

Soils have the most diversified microbial communities of any environment on the planet. Bacteria, fungi, algae, and protozoa are all found in abundance in soil. Maintaining a healthy environment for crops requires a strong link between plants and soil microorganisms that are essential for good crop development. Soil bacteria are key regulators of the nutrient cycle. Mineralization, legume nitrogen fixation, and ammonia conversion to plant-available nitrate would all be impossible without bacteria. Effective microorganisms have the ability to boost crop growth and yield. When used in conjunction with organic amendments, these bacteria performs better than to the sole application. It also contributes to soil health and provides a variety of ecological services. They also help in the cleaning of the environment, landfill disinfection, and the development and implementation of sustainable, closed-cycle organic waste treatment processes across the globe. The whole study remarks a conclusion that the application or presence of effective microbes to soil not only enhance the nutritional capacity, fertility and productivity of soils but also helps to remediate soil problems cost effectively.

Keywords: Soil effective microorganism, nitrogen fixing bacteria; photosynthetic bacteria, actinomycetes; lactobacilli.

INTRODUCTION

Daily population growth necessitates the enhancement of current agricultural production methods. Although the increased use of synthetic agrochemicals has increased agricultural yield, the management practices that have enabled this growth to have led to environmental deterioration and the inability of agricultural systems to be sustainable (Armstrong and Taylor, 2014). Environmentally friendly effective microorganisms (EM) give a variety of benefits on agricultural fields where they are utilized as fertilizer or sprayed (Alluri et al., 2007). According to Cho and Koyama (1997), microorganisms are extremely minute units of life that are ubiquitous in nature and play a crucial role in maintaining ecological balance. Effective Microorganisms are cultures of naturally occurring organisms that can be employed as inoculants to increase the microbial diversity of the soil environment. These organisms occur naturally in the environment. There is evidence that EM soil injection increases plant growth and productivity while improving soil quality (Han et al., 2006). By maintaining healthy soil ecology, plant diseases conveyed through the soil and caused by harmful microorganisms and parasites can be averted. This defense is provided by the balanced interaction in the soil system between harmful microbes and billions of beneficial microbes working together to provide protection. According to Chan et al., (2003), the difference between "alive soil" and "dead soil" is whether a particular soil system contains the beneficial bacteria in question, which decompose and ferment organic matter in the soil, converting it into nutrient-rich humus and releasing hormones that promote plant growth. They must carry hormones, nutrients, and minerals to the plant's root system to fulfil their purpose. In addition, they hold soil particles together inside the soil structure, so preserving both nutrients and moisture (Yamada and Xu, 2001).

Important Effective Microorganisms (EM)

The scientists Higa and Parr, (1994) established the first notion of Effective Microorganisms (EM). The yeast species (*Saccharomyces* spp.), photosynthetic bacteria (*Rhodobacter sphaeroides, Rhodopseudomonas palustris*), *lactobacilli* (*Streptococcus lactis, Lactobacillus casei* and *Lactobacillus plantarum*), and actinomycetes (*Saccharomy* spp.) (Javid, 2011; Higa, 1991).

Advantage of Effective Microorganisms

The EM has many positive impacts on soil, plant and the environment. Followings are the core advantages of effective microorganisms. Plants benefit from EM for germination, blooming, fruiting, and ripening. EM helps to enhance the soil's physical, chemical, and biological conditions while also suppressing infections and pests. Crop photosynthetic capability is improved by EM. Better germination and plant establishment are ensured with EM. Organic matter is more effective as a fertilizer when it is treated with EM, beneficial microbes are introduced to soils and plants by the use of EM, pests are suppressed or controlled (Joshi et al., 2019).

By boosting the competing and antagonism abilities of organisms in EM inoculants, pests and diseases may be managed or prevented. Studies have demonstrated that efficient microorganisms in agricultural soil may reduce soil-borne diseases (Singh et al., 2003). Nitrogen fixation in the atmosphere, suppression of pathogens that live in the soil, toxic substances, such as insecticides, are degraded. Plant uptake requires the production of simple organic compounds, solubilization of insoluble mineral nutrient sources, production of antibiotics and other bioactive compounds (Gondal et al., 2021a; 2021b).

Harmful Effect of Effective Microorganisms

In some cases, the bioaugmentation of these effective microbes have negative outcomes instead of positivity. Sometimes they also indirectly become the source of negativity i.e., induction of plant diseases, creation of phytotoxic constituents, stimulation of soil-borne organisms and inhibition of seed germination (Gunduz, 2018).

Lactic Acid Bacteria (LAB)

Different types or strains of bacteria are applied on soil to obtain maximum productions. The most common and widely used bacteria are *Staphylococcus epidermidis, Pseudomonas aeruginosa*, *Klebsiella pneumoniae, S. epidermis*, *Escherichia coli* (E. coli). Lactic Acid Bacteria improves food absorption and disease resistance for plants, animals, and even yourself. LAB is a fantastic odour remover, soil conditioner, and general health enhancer. It's the microbial world's rubbish disposal system. Lactic acid is produced by bacteria and is made from carbohydrates. *Lactobacillus* is a helpful bacterium that sterilizes soil and removes wastes that may otherwise accumulate and cause harm to the environment. Lactobacillus aids in breakdown as well as illness prevention. The bacterial cycle maintains the soil's composition and encourages the development of humus by promoting the growth of bacteria. Lactobacillus also has the capability to control improvement of fungi, yeast, and aerobic bacterial species (Hussain et al., 1999; Iriti et al., 2019).

It promotes breakdown of organic materials while sterilizing soils and suppressing potentially harmful bacteria (Condor et al., 2007). Lignin and cellulose may be broken down and fermented more quickly with the help of lactic acid bacteria, which aid in the breakdown of these chemical compounds. To maximize soil airflow and increase pore space, LAB is an excellent choice. LAB enhances fertilizer's solubility. Plant development and seed germination can be aided by LAB, as well as the alleviation of numerous abiotic stressors. The ammonia gas created where the immature compost is applied will be neutralized by LAB. Because LAB is conditionally anaerobic, they can also live in the presence of oxygen. LAB solubilizes phosphate - Using LAB in phosphate-abundant soil would boost the soil's ability to absorb the insoluble form of phosphates and aid in the prevention of salty disorder caused by phosphates breakdown. LAB has long been used as a biocontrol agent, and it has recently been demonstrated to be nominal against with extensive range of bacterial and fungal phytopathogens.

These probiotic microorganisms coexist in soils alongside other helpful fungi like mycorrhizae, which are known to kill harmful fungus like fusarium, and also serve as food for other species like worms. The organic acids, as well as the bacteriocins generated, are powerful pathogen controllers (Hu and Qi, 2013). Bacteriocins are enzymes that are specifically developed to combat harmful organisms, allowing LABs to shift their environment and establish themselves. These are just a few of the reasons why probiotic farmers regard LABs to be their first line of defense. LABs can be combined with water and fertilizer and applied to soils or sprayed on plants at any time all over the growth cycle (Hussain et al., 1999; Iriti et al., 2019).

Photosynthetic Bacteria (PB)

In the ecosystem, photosynthetic microorganisms perform a critical function. Microorganisms in the waters are responsible for up to a third of the earth's photosynthesis. Light-absorbing pigments and the capacity to convert light energy into chemical energy are two characteristics of photosynthetic bacteria. Phototrophic bacteria that use carbon dioxide as a source of energy produce lower-harvesting pigments. Photosynthetic microorganisms that create no oxygen are known as anoxygenic microorganisms. Being microbes, they are effectively used in water purification, biofertilizers, animal feed and chemical bioremediation to prove themselves effective microbes (Condor et al., 2007).

Actinomycetes

Gram-positive bacteria, known as actinomycetes, produce spores and grow on or in the environment. They are a member of the Actinomycetales phylum. The "earthy" smell of newly churned, healthy soil is attributed to these soil organisms, which are the most prevalent producers of thread-like filaments. Decomposing complex polymer mixtures in deceased shrub and animal and fungous material, they generate countless extracellular enzymes that are advantageous to agricultural yield. They play essential roles in organic matter cycling. Rhizosphere organic matter rotation is dependent on the presence of these microbes, which act as a deterrent to numerous plant diseases (de la Porte et al., 2020). These advantageous organisms release extracellular enzymes and EPS (Exopolysaccharides) to enhance crop's outcome (Shahzad et al., 2018). They additionally release enzymes, fix nitrogen, solubilize phosphorus, formulate metabolites and stimulate plants to release growth regulators to enhance crop production (Bhatti, 2017).

Antipathogenic Microbes

Beneficial bacteria in agricultural soil not only reduce the risk of diseases that can be spread through the soil, but they also hasten the decomposition of organic matter, which makes more of the mineral nutrients and other vital organic compounds available to plants (Singh et al., 2003). The elimination or reduction of diseases that are transmitted by soil-borne microorganisms is made easier by the introduction of good bacteria into the soil. The "Rotation effect," which occurs because of the regeneration of beneficial organisms and the eradication of pathogenic bacteria, is bolstered by the introduction of microorganisms that are efficient. This effect is the consequence of getting rid of germs that are toxic and rebuilding microorganisms that are good. Because disease-causing microbes in the soil fight for available resources with beneficial microbes introduced in effective microorganisms, the available resources in the soil will decrease, which will result in a drop in the number of pathogenic microbes due to famine. This will increase the population of microorganisms that can do their jobs through inoculation (Schnürer and Magnusson, 2005). Lactic acid can sterilize, and the presence of this acid in the soil reduces the growth of nematode populations, which in turn protects plants against diseases that are transmitted by nematodes. In addition, lactic acid bacteria contribute to the breakdown of cellulolytic and lignified organic matter in the soil, which is otherwise accomplished by other microbes that are more effective (Salminen and Wright, 2003).

Bio-Composters

Most farms today burn waste products from agricultural processing. Burning wood in the open produces harmful air pollutants, including particulate matter, inorganic gases, and organic gases, which are harmful to both the environment and human health (Korenaga et al., 2001). In addition, repeated burning leads to the damage and erosion of soil (Korenaga et al., 2001). The disposal of waste in bodies of water (such as rivers or lakes) can have a negative impact on water quality while also contributing to the growth of algae blooms and eutrophication. Because of these considerations, appropriate agro-industrial waste management is required. Composting is highly desirable for several reasons, including its potential to increase soil fertility, its low cost, and its minimal influence on the surrounding environment (Bustamante et al., 2008; Lu et al., 2009) When organic matter such as plants, animal dung, and organic fertilizers are introduced to soil, IMO break down the complex organic compounds that are there (Anastasia et al., 2004). Composting can provide more benefits to crops than fertilizing them. Composting paddy husk and corn stalk scraps, Hanim et al. (2012) investigated the physicochemical properties of the resulting compost as well as the humic acid content. According to the findings of this study, the chemical qualities of compost made from maize stalks are superior to those of compost made from rice husks. Even while residue management that is both safe and effective takes a lot of time, biodegradation is a tried-and-true method that allows most farmers to recycle waste in a hurry.

Bio-Augmenters

Effective microorganisms increase the activity of beneficial indigenous microorganisms such as mycorrhizae (both ectomycorrhiza and endomycorrhiza), which fix atmospheric nitrogen and accelerate phosphate and zinc absorption from the soil, thereby reducing the need for artificial fertilizers and pesticides. An increase in the soil's fertility significantly improves crop growth, as well as blooming, fruit development, and ripening (Levai et al., 2006).

Effect of EM on Crop Quality and Quantity

Sweet potato yields were boosted by EM, particularly during the dry season when the quantity of tubers was low, and bulking rates were reduced. Only at a later development stage in NPK modified soil did EM treatment significantly improve NPK nutrition (Javaid and Bajwa, 2011). Using efficient microorganisms in agriculture has various advantages (Vaid et al., 2017). Plants can thrive in soils that are inhabited and dominated by these beneficial microorganisms (Sun et al., 2014). Using effective microbes boosted crop output and quality (Cortez et al., 2000). Through competitive exclusion, the population of helpful soil microbes is also increased, assisting in the treatment of soil illnesses (Postma-blaauw et al., 2006).

EM was mostly used in agriculture (Sangakkara, 2012a). Carbon mineralization rates rose, as well as soil and plant resistance to water stress. Root penetration was also improved by Sangakkara (2012). Plant growth and insect and pest populations are also aided by EM (Sangakkara, 2012). When EM and compost were applied together, wheat yields increased (Hu and Qi, 2013).

Effect of EM on Crop Protection

When beneficial bacteria are introduced to soils and plants by EM, pests are controlled or managed. Inoculants containing microorganisms that compete and compete with pests and diseases may be used to naturally decrease or manage pests and illnesses. Since beneficial microorganisms are present in agricultural soil, fewer people are becoming sick from soil-borne diseases as a consequence (Singh et al., 2003).

The introduction of a population of beneficial bacteria (EM) into the soil aids in the reduction of soil-borne microbiological illnesses. The injection of EM causes the "Rotation effect," which is caused by the regeneration of beneficial organisms and the elimination of harmful microorganisms (Johan and Jesper, 2005). The earliest use of EM was to boost the productivity of organic or natural farming methods. The usage of EM in the manufacturing of this bio-fertilizer was shortened since it was mixed openly into the carbon-based materials being supplementary to grounds or composts.

Effect of EM on Soil

i. EM Soil Inoculation

EM may be administered to crops as a soil drench or directly to the growing plants. With deionized water dilute the soil to 1:500 or 1:500, depending on the kind of soil (fermented kitchen waste). Fermentation of fish waste or fish cartilage requires a dilution of 1:300 for use with Em (fermented chicken manure). Soil remediation using 'Bokashi' may require up to 2.5 metric tonnes (MT). Organic acid levels in the soil may damage plant roots if the dose is more than 2.50 MT ha–1. 'Bokashi' is sprinkled on the roots and dispersed 10–15 cm apart in the 10–14 days before planting. Chemical fertilizers and insecticides are often used on agricultural areas these days (Roberti et al., 2015). The soil, on the other hand, has degraded in quality. Chemical fertilizers may be replaced with EM fertilizers. Nitrogen from the atmosphere is absorbed by EM, which enhances soil quality. To improve crop growth, blossoming and fruit development, Levai et al., (2006) claims that increasing soil fertility has a positive influence on these processes. An important factor in crop development and growth is the microflora in the soil, which is also known as the "rhizosphere." Soil microorganism management is essential if we minimize the agricultural technologies limitation (Javid et al., 2011).

According to Jusoh et al., (2013) compost containing effective microbes has a greater N, P, and K content than compost that does not. With its minimal environmental effect and cheap cost, composting is a particularly attractive option. It may also provide an important soil fertility-enhancing product and has the added benefit of being quite simple to implement (Bustamante et al., 2008) (Perez-Murcia et al., 2005). Compost in soil has already been studied by Bustamante et al. (2008) and their results were comparable.

According to Daniel et al., (1992), the use of efficient microbes might reduce the requirement for constant fertilization and cultivation costs. They found that when bacterial isolates are used together, they perform better than when used separately, and that these isolates increase the mean Fe concentration in grain and straw by 34 % and 52.4 percent, respectively, over the non-inoculated control, and also increase total Fe uptake by 34% and 52.4 percent, respectively, over the non-inoculated control (Hu et al., 2013; Talaat et al., 2015). Effective microorganisms applied to FYM amended soil significantly improve plant nutrition during the latter growth stages of the mung bean crop. EM can improve the soil quality, plant growth and production. Not only quality and quantity of soil or crop enhances but also soil fertility enhances which resulted in increases crop production. The plant diseases can be controlled by applications of EM into soil (Rezende et al., 2008; Shin et al., 2017). When efficient microorganisms were used in conjunction with farmyard manure and mineral NPK, Hussain et al., (1999) discovered an improvement in wheat and rice crop output (Ndona et al, 2011).

Inoculation of bean plants with Rhizobia and arbuscular mycorrhizae (AM) significantly boosted pod output in plots with organic matter supplied compared to chemically, according to Aryal et al., (2003). The relative impacts of EM were also detected in plant leaf N concentration, where its co-application with organic materials boosted leaf N concentration by 38% compared to the control, compared to a 16% rise owing to organic materials application alone (Khaliq et al., 2006). EM accelerates the breakdown and mineralization of organic compounds, allowing plant nutrients to be released into the soil (Hussain et al., 1999).

Table 1: At a depth of 0–6 inches (0–15 cm), the relative number and biomass of microbial species in soil.
Hoorman, (2010); Bhowmik et al., (2017)

Sr. No.	Microorganisms	Biomass (g/m^2)	Number/g of soil
1	Nematodes	Varies	10^2 to 10^3
2	Bacteria	40 to 500	10^8 to 10^9
3	Algae	1 to 50	10^4 to 10^5
4	Protozoa	Varies	10^3 to 10^4
5	Fungi	100 to 1500	10^5 to 10^6
6	Actinomycetes	40 to 500	10^7 to 10^8

Nitrogen is required for the creation of cellular enzymes, RNA, DNA, protein and chlorophyll as well as for the generation of food and plant growth. Nitrogen is supplied to nodulating legumes by nitrogenase in rhizobial bacteroids through a symbiotic relationship with atmospheric N_2 (Toor et al., 2020). Microorganisms are critical for nutrient cycling in the soil, and all beneficial bacteria may be found in the soil around plant roots. Microorganisms have a critical role in the health of the soil and crop yield. Unless and until helpful microbes operate on soil organic matter and convert it to a usable form (humus) via the release of various enzymes, the existence of organic matter in the soil is meaningless. Fungi and bacteria in the soil serve various functions in the decomposer community and interact to release nutrients to plants; a lower soil pH will alter those connections, as well as soil carbon and nitrogen levels. Plant nutrients may get immobilized, resulting in a reduction in turnover and release nutrients (Rousk et al., 2009). Soil functions are classified as listed

i) Furnish nutrients for plant growth
ii) Provide air for plant roots
iii) Water with low nutrition content should be released
iv) Plant roots that are anchored
v) Provide water to the plant's roots

Soil microbes break down the soil organic matter, and any organic matter that is left behind or unbroken down results in the formation of humus (fertilized organic matter) (6). Humus is a dark brown amorphous residual substance that has a jelly-like consistency (Schulz et al., 2013). A gradual and constant release of nutrients into the soil is achieved by crop rotation. Water holding capacity is improved as a result of this. The soil structure has been enhanced that alter the cation exchange capacity as well.

CONCLUSION

Finally, effective microorganisms are made up of naturally occurring germs that are both safe and environmentally friendly. It is not necessary to use protective clothing, goggles, or masks when spraying effective microbes. It's also not necessary to wear a mask. In a similar line, efficient microorganisms never cause damage to water systems. The helpful microorganism is made up of components that come from the natural world. It's easy to decompose after use, and the microorganisms that do the work will never pollute groundwater. Rather, it enhances the soil, groundwater, lakes, and rivers, resulting in less negative effects on the ecosystem. Regardless of the scale of the enterprise, the beneficial microbe can be utilized in conjunction with a wide range of agricultural approaches. It is useful because it enhances the diversity of the population of helpful bacteria in the water. Beneficial microbes in products promote healthy plant growth, which leads to increased crop yields, longer growing seasons, and better crop quality. These improvements, when combined, result in more bountiful harvests.

AUTHOR CONTRIBUTIONS

Tasaddaq Younas and Muhammad Jamil conceived the presented idea. All authors participated equally in the theory's development and authored the article. The final manuscript was discussed and reviewed by all the authors equally.

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