ROLE OF MICROORGANISMS IN SOIL FERTILITY

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Soil fertility refers to a soil's innate ability to supply plants with the necessary nutrients in optimal quantities and ratios for healthy plant growth. Microbes play an important role in enhancing the fertility of the soil, acting as natural regulators and catalysts. They facilitate the conversion of organic matter into essential inorganic nutrients, making them readily available to plants. Moreover, microbes serve as early indicators of soil degradation, offering valuable insights into soil health. Leveraging microbial activity presents a promising avenue for bolstering soil fertility and sustaining agricultural productivity. Healthy soils are bustling ecosystems, harboring an impressive abundance of soil microbes. A mere quantity of soil can host hundreds of millions to billions of these microscopic organisms. Among them, bacteria dominate in numbers, trailed by actinomycetes, fungi, soil algae, and soil protozoa. Recognizing the pivotal role of soil microbiology is crucial for meeting the increasing demands of a growing global population in agricultural production. However, conventional agricultural practices in many regions continue to jeopardize the microbial populations essential for soil health and productivity.

SOIL MICROORGANISMS AND THEIR CONTRIBUTION

Soil microorganisms encompass various groups such as bacteria, fungi, actinomycetes, algae, protozoa, and viruses. Each group have distinct characteristics and functions in the soil ecosystem. It's crucial to note that these organisms don't operate in isolation; rather, they interact with one another, exerting collective impact on soil fertility that often surpass effects of their isolated activities.

Bacteria: These single-celled microscopic organisms abound in the moist, fertile soil, numbering between 100 million to one billion in just a teaspoon soil. In soil, they consume organic waste, thereby liberating nutrients previously inaccessible to other organisms, contributing significantly to improve soil fertility, ecosystem functioning, and plant health. The key roles bacteria have in soil ecosystems includes:

- **Decomposition:** In soil, bacteria serve as primary decomposers, breaking down various organic substances like dead plant matter and animal carcasses. In the decomposition process, their metabolic activities convert unusable forms of plant nutrients into usable forms and releases these essential nutrients into the soil, making them available to the plants.

- **Nutrient Cycling:** Bacteria play critical role in nutrient cycling, particularly in the nitrogen cycle. They convert atmospheric nitrogen into an available form that plants can use for their growth and, such as ammonium and nitrate, through nitrogen fixation and nitrification processes.

- **Soil Structure:** Certain bacteria, such as those belonging to "aggregating bacteria," group produce substances like polysaccharides that help binding soil particles together, improving soil structure.

- **Disease Suppression:** Some groups of bacteria are beneficial for controlling soil-borne pathogens by outcompeting or antagonizing them, thus reducing the incidence of plant diseases.

- **Symbiotic Relationships:** Some bacteria can establish symbiotic relationships with plants, such as nitrogen-fixing bacteria that create nodules on the roots of leguminous plants. They transform atmospheric nitrogen into a form that plants can utilize, supplying them with an essential nutrient.

Fungi: Fungi, distinct from plants or animals, organize themselves into intricate networks of fibrous strings known as hyphae. These hyphae then form mycelium, which can stretch several meters in length despite being less than 0.8mm wide. Fungi can exert both beneficial and harmful influences on soil organisms. Beneficially, fungi possess the capacity to break down nutrients that are otherwise inaccessible to other organisms, releasing them into the soil for utilization by various organisms. Fungi can also establish symbiotic relationships with plant roots, known as mycorrhizal associations. In this mutually beneficial arrangement, the fungi supply essential nutrients to the plant and, in exchange, receive carbohydrates. Conversely, fungi can also act as parasites, attaching themselves to plants or other organisms solely for their own nutritional gain. This parasitic behavior can have detrimental effects on the host organism. Fungi in soil serve various functions:

- **Decomposers:** Saprophytic fungi break down dead organic matter into fungal biomass, CO_2, and organic acids. E.g. Pleurotus ostreatus

- **Mutualists:** Mycorrhizal fungi help plants to absorb soil nutrients, particularly phosphorus, creating symbiotic partnerships with plant roots, in return for getting carbon from plants. Ectomycorrhizae attach to root surfaces, often found with trees, while endomycorrhizae grow within root cells, common in grasses, crops, and shrubs. Eg. Zygomycota, Basidiomycota

- **Parasites:** The third group of fungi, pathogens or parasites, causes reduced production or death when they colonise in roots and other organisms. E.g. Pythium, Rhizoctonia.

Actinomycetes: Actinomycetes are soil microbes share characteristics with both bacteria and fungi, and are often considered as the potential evolutionary bridge between the two groups. However, they exhibit more similarities with bacteria than fungi. Actinomycetes are renowned for imparting a distinct aroma to the soil. Moreover, they have served as a valuable source for numerous important therapeutic drugs. Actinomycetes play several important roles in soil ecosystems

- **Decomposition**: Similar to bacteria and fungi, actinomycetes are also key decomposers in soil and contribute to nutrient recycling and soil fertility.

- **Soil Structure:** substances like hyphae and polysaccharides produce by actinomycetes help improving soil structure through binding the soil particles together, thereby, enhances the soil water retention and aeration in soil, which are essential for healthy plant growth.

- **Antibiotic Production:** Actinomycetes are prolific producers of antibiotics and bioactive compounds, helping them compete with other microorganisms. in the soil. These compounds have applications also in medicine, agriculture, and biotechnology.

- **Nitrogen Cycling:** Some species of actinomycetes are involved in processes like nitrogen fixation and denitrification, which are essential for maintaining soil fertility and ecosystem balance.

- **Disease Suppression:** Actinomycetes can inhibit the growth of pathogenic microorganisms in the soil, thus contributing to disease suppression in plants. They produce secondary metabolites that have antimicrobial properties, helping protect plant roots from soil-borne pathogens.

Algae: Algae thrive in moist and sunlit soils, with a population range of 100-10000 per gram of soil. They produce food through photosynthesis, utilizing CO_2 and sunlight. Their key roles and functions in soil include:

- Maintaining the fertility of soil, particularly in tropical regions.
- Contributing organic matter to soil upon their death, thus enhancing soil carbon content.
- Acting as a binding agent, effectively cementing soil particles and mitigating erosion.
- Increasing soil's water retention capacity, aiding in prolonged moisture retention.
- Generating oxygen through photosynthesis, promoting aeration in submerged soils.
- Mitigating nitrate loss via leaching and drainage, particularly in uncultivated soils.
- Participating in rock weathering processes and enhancing soil structure formation.

Protozoa: These colorless, single-celled organisms exhibit animal-like characteristics. Larger than bacteria, their size range from a few microns to a few millimeters. In arable soil, their population ranges from 10,000 to 100,000 per gram, and they are particularly prevalent in surface soil layers. These organisms possess the ability to endure harsh soil conditions due to their protected, dormant stage in their life cycle. Major functions, role and features of protozoa are:

- Majority of protozoans obtain their nutrition by consuming soil bacteria, contributing significantly to the balance of microbial communities in soil.
- Certain protozoa have been used as natural agents for controlling plant pathogens.
- Soil-dwelling protozoa are also implicated in human diseases transmitted through water and other vectors, such as amoebic dysentery.

STRATEGIS TO AUGMENT MICROORGANISMS IN THE RHIZOSPHERE

Soil management practices to create ideal environment for microbial growth in the soil ecosystem includes: -

Biofertilizers: Biofertilizers are materials containing living microorganisms that can improve soil fertility and stimulate plant growth. These microorganisms include nitrogen-fixing bacteria, phosphate-solubilizing bacteria, potassium-solubilizing bacteria, mycorrhizal fungi etc. microbes. When applied to soil or plant surfaces, biofertilizers colonize in the rhizosphere and form symbiotic relationships with plants, thereby improving nutrient uptake, enhancing soil structure, suppressing pathogenic organisms, and mitigating environmental stress. Unlike chemical fertilizers, biofertilizers offer sustainable and eco-friendly solutions to agricultural productivity, reducing reliance on synthetic inputs and minimizing environmental impacts. Table 1 explains some biofertilizers, organisms used in their preparation.

Organic Amendments: Addition of organic matter into the soil through organic inputs like compost, animal as well as green manure (legumes and green manure crops) not only provide nutrients to plants but also act as a food source for microorganisms to multiply in the soil ecosystem.

Table 1. Biofertilizers and their uses in agriculture

PRODUCTS	ACTIVE INGREDIENT	USE
ENRHIZO	*Rhizobium sp.*	Atmospheric nitrogen fixation for legumes
ENFOSFO-P	*Bacillus polumyxa*	Converts non-available form of phosphorus to available form
ENPOTASH	*Frateuria aurantia*	Mobilize potash and make available to roots
ENSULF	*Thiobacillus ferroxidans*	Enhances sulphur availability to plants
ENZINC	*Thiobacillus thiooxidans*	Mobilize zinc and make available to roots
ENFER	*Acidithiobacillus*	Mobilizes iron in soil

Conservation Tillage: Conservation tillage practices like zero tillage, reduced tillage and minimize soil disturbance helps to improve the soil structure, boost the soil microbial activity.

Crop Diversity: Increased plant diversity through intercropping and crop rotation provides varied food source for different microorganisms thus, helps to improve the diversity of soil microorganisms. Besides, growth in the beneficial microbes in the soils coupled with rotation of different types of crops helps to break the disease and pest cycles.

Soil Aeration and Water Management: Cover cropping and use of organic mulch are also alternative strategies to enhance soil aeration and water retention, reduce erosion, and augment the soil microbial population. improve soil structure.

Integrated Nutrient Management: Balanced use of fertilizers integrating organic nutrient preparations like *panchagavya*, fish emulsion, bone meal etc. enable slow-release of nutrients to crop plants and also provide essential nutrients to soil microorganisms.

Minimal Use of Chemicals: Elimination of plant protection chemicals or their minimal use help to check their harmful effects on the beneficial soil microbes. For this, adoption of Integrated Pest Management (IPM) strategies that ensure controlling pests and diseases while preserving microbial balance is inevitable.

CONCLUSION

The role of microorganisms in soil health cannot be overstated. These tiny but powerful organisms play a crucial role in sustaining healthy soil ecosystems and ensuring agricultural productivity. From nutrient cycling to soil structure maintenance, microbes are the unsung heroes beneath our feet. As we work to address the challenge of feeding an expanding global population while safeguarding our environment, it's crucial to acknowledge and leverage the power of soil microbes. Implementing practices that foster microbial diversity and activity can boost soil fertility, increase crop yields, and pave the way for a more sustainable future for generations ahead. Therefore, it is inevitable to promote activities contribute to enhance the microbial activity in or agricultural soils so as to unlock the full potential of the agricultural landscapes.

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Article received on: 25 June, 2024