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Know Your Agriculturally Important Soil Microorganisms: An Overview

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SUMMARY

Soil microorganisms are represented by bacteria, fungi, actinomycetes, blue-green algae, protozoa, and nematodes. These soil microorganisms are involved in the nutrient transformations of macro and micronutrients, organic matter decomposition, carbon sequestration, humification, and boost plant health in many ways. Apart from these benefits, microbes can also cause diseases in plants. This article briefly explains the type of soil microorganisms and their role in soil and plant health.

INTRODUCTION

Soil is a dynamic habitat that allows plant establishment and provides shelter to many microorganisms and invertebrates. Soil life can be categorized as macrofauna (earthworms, beetles, termites, snakes, lizards, mites and moles, etc.), mesofauna (nematodes and arthropods), and microfauna (protozoa). All these forms of living creatures interact with biotic and abiotic components of the soil ecosystems. Soil contains many beneficial and pathogenic microorganisms, which determine the success of plants' growth. These soil microorganisms perform various ecological functions like soil nutrients transformation, plant and animal polymer degradation, plant pathogens, and biocontrol agents through various microbial interactions, thereby influencing the plant's health. Soil microorganisms can be classified based on size, functions, and type of species. Although soil microorganisms constitute < 0.5 (w/w) of the soil mass, they do 60-80% of the total metabolic activities. Out of the total soil microflora, nearly 95 % are beneficial to plant, and only 5 % are pathogenic. This present article highlights the soil microorganisms and their role in the soil ecosystem and plant growth.

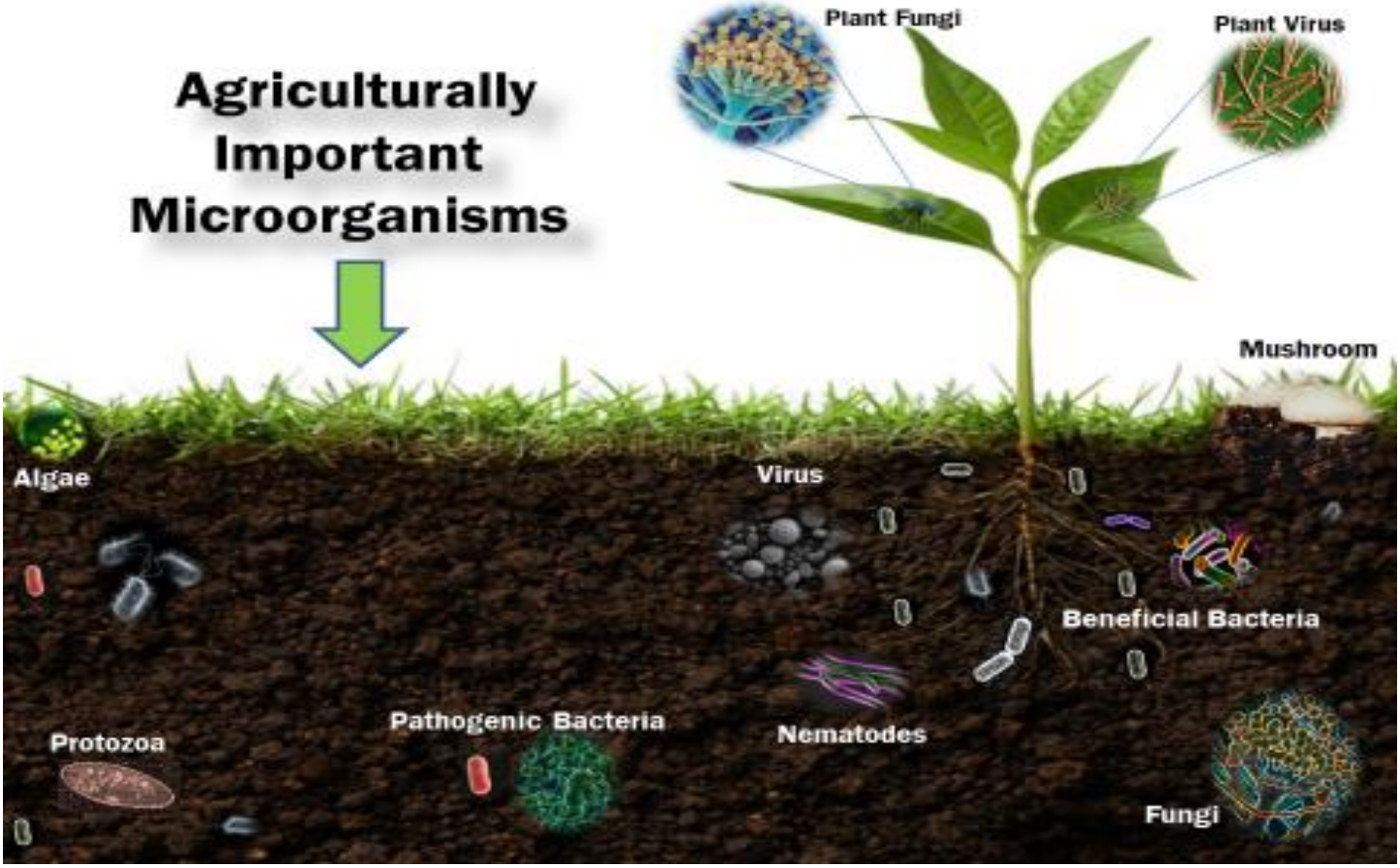

Fig.: Diverse agriculturally important soil microorganisms and their interactions with plants

A. Bacteria

Bacteria are prokaryotes and predominant soil microorganisms. One teaspoon of fertile soil may contain 100 million to one billion soil bacterial population. Bacteria can be classified based on nutrition, O2 requirement, ecological functions, and economic importance. Key bacteria and their role in transforming macro-and microelements, organic matter degradation, plant pathogens, biocontrol agents, and plant growth promoters have been mentioned below.

1. Chemoautotrophic bacteria:

This group of bacteria takes energy from inorganic compounds.

- **Nitrifying bacteria:** In nitrogen transformation, they convert biologically fixed nitrogen, ammonia into nitrite by *Nitrosomonas* sp., *Nitrosospira* sp., *Nitrosococcus* sp. and *Nitrosococcus* sp. Further, the conversion of nitrite to nitrate is done by *Nitrobacter* sp. *Nitrospina* and *Nitrococcus*
- **Sulfur oxidizing bacteria:** This group converts reduced sulfur compounds into sulfate. E.g., *Thiobacillus* sp., *Acidithiobacillus* sp., *Beggiatoa, Thioploca, Thiothrix,* and *Thiomicrospira*
- **Iron oxidizer:** They convert Fe2+ to Fe3+ in the soil. Key iron transformers are *Leptospirillum ferrooxidans, Thiobacillus, Acidithiobacillus ferrooxidans,* and *Gallionella,*
- **Manganese oxidizer:** It involves oxidation of Mn+2 to MnO2. E.g., *Leptothrix discophora*.
- **Hydrogen bacteria:** This group of bacteria grows in hydrogen and converts to water. E.g., *Hydrogenomonas, Alcaligenes, Bacillus,* and *Rhizobium.*

2. Heterotrophic bacteria:

These groups of bacteria depend upon organic compounds for their energy requirements.

- ***Rhizobiales* sp.** – This group fixes the atmospheric nitrogen in the legume plants. Key genera are *Bradyrhizobium, Sinorhizobium, Azorhizobium, Devosia, Methylobacterium, Mesorhizobium, Ochromobacter,* and *Phyllobacterium.*
- ***Azotobacter* group -** It includes *Azotobacter, Azomonas, Beijerinckia,* and *Derxia*. These are free-living, aerobic nitrogen-fixers in rice, wheat, bajra, sorghum and millets, vegetables.
- ***Azospirillum* sp.-** Free-living, microaerophilic, nitrogen fixer in bajra, sorghum, and millets
- ***Bacillus* sp.** - As PGPR, biocontrol agents against many fungal and bacterial diseases.
- ***Pseudomonas* sp**.- As PGPR, as a biocontrol agent against many phytopathogens and some Pseudomonas species act as a pathogenic to plant.
- **Other plant growth promoters** are *Burkholderia, Serratia, Kurthia* spp.,
- **Phosphorus solubilizing bacteria -** They solubilize the unavailable fixed form of phosphorus compounds into the available forms like H2PO4- and HPO4-2. Key bacterial genera are *Bacillus* sp., *Pseudomonas, Serratia, Pantoea,* and *Azotobacter,* etc.
- **Potassium solubilizing bacteria-** They solubilize the potassium-bearing minerals such as muscovite, biotite, mica, orthoclase, and feldspar. Key solubilizing genera are *Bacillus* sp., *Acidithiobacillus ferrooxidans,* and *Paenibacillus* spp.
- **Zinc solubilizing bacteria-** They solubilize the compounds like ZnO, ZnCO3, and Zn3(PO4)2. Key solubilizers are *Bacillus megaterium, Klebsiella* spp. and *Pseudomonas* spp.
- **Sulfur reducing bacteria (SRB)-** This group includes anaerobic bacteria such as *Desulfovibrio* and methanogens like *Methanosarcina* and *Methanobacterium.*
- **Methanotrophs** - The important genera are *Methylococcus, Methylomonas, Methylosinus, Methylobacter, Methylobacterium,* etc.
- **Methylotrophs-** *This group includes Klebsiella, Bacillus, Arthrobacter* and *Rhodopseudomonas,* etc.

3. Plant disease-causing bacterial genera

Xanthomonas, Pseudomonas, Erwinia, Corynebacterium, and Clavibacter

4. Organic matter decomposer

The decomposition of plant and animal complex polymers is mediated by various bacterial endo and exoenzymes. Key bacterial genera are *Cellulomonas, Bacillus, Cytophaga, Candida,* and *Pseudomonas.*

5. Degradation of xenobiotic compounds

Many soil microorganisms alleviate the toxic pesticide residue and heavy metals' lethal effects. e.g., *Pseudomonas* spp., *Bacillus* spp, and *Rhodococcus*

B. Cyanobacteria

Cyanobacteria are gram-negative, prokaryotic microorganisms and can do oxygenic photosynthesis in soil. Important genera are *Nostoc* sp., *Anabaena* sp, *Aulosira* sp, *Cylindrospermum, Scytonema, Nodularia, Lyngbya, Oscillatoria*, and *Calothrix* sp. They fix atmospheric nitrogen in their specialized cells. These cyanobacteria are often symbionts with *Azolla* and pteridophytes and fix nitrogen in rice.

C. Soil actinomycetes

Soil actinomycetes are characterized as gram-positive, unicellular bacteria but grow like hyphae and produce asexual spore-like fungi and belongs to the Actinomycetales order. The predominant genera are *Streptomyces, Nocardia*, and *Micromonospora.*

- They emit an earthy smell due to the geosmin produced by actinomycetes. They produce antibiotic compounds for controlling many plant pathogens, e.g., *Streptomycetes griseus* produces streptomycin, *S. kasugaensis* produces kasugamycin. Other antibiotics are polyoxin B and D and validamycin produced by *Streptomyces* genus. Few species of *Streptomycetes are pathogenic; among* them, *S. scabies* causes common scab of potato is most important.
- As plant growth promoter by producing IAA, make availability of plant nutrients and minerals. Other antibiotics are polyoxin B and D and validamycin produced by *Streptomyces* genus.
- Involved in bioremediation of soil by converting the toxic compounds into less toxic compounds.
- Thermophilic actinomycetes are involved in decomposing organic matter like cellulose, hemicellulose, and lignin during composting and humification. E.g., *Nocardia*, *Streptomyces*, and *Thermoactinomyces.*It helps in soil aggregation and increases the soil's water-holding capacity, weathering of rocks, and prevents loss of nitrate in the soil.

D. Fungi

Fungi are eukaryotic, aerobic, heterotrophic microorganisms consisting of mycelium. They act as plant pathogens, organic matter decomposers, mutualists with plants, nutrient transformation, and plant growth promoters.

Role as Plant pathogens

- Chytridiomycota - *Synchytrium endobioticum (Potato wart)*
- Oomycota - *Phytophthora* (blight), *Pythium* (damping off) and *Albugo* (white rust), *Peronospora* (downy mildew)
- Zygomycota- *Mucor* and *Rhizopus*
- Ascomycota- Powdery mildew fungi such as *Erysiphe* and *Uncinula,* Ergot fungus (*Claviceps* spp.)-
- Basidiomycota- *Puccinia* (rust), *Ustilago* (smut), and *Tilletia* (bunts), *Agaricus*(mushrooms).

Fungi as biocontrol agents for the plant pathogens

Fungi employ various mechanisms to control phytopathogens via various cell wall degrading enzymes and volatiles, direct antagonism, hyperparasitism, mixed-path antagonism, and physical and chemical interference. Key fungal genera are *Trichoderma harzianum, T. viride, Aspergillus niger, Penicillium* spp.

Nutrient transformation and mobilization

Fungi produce various organic acids, siderophore compounds, which help in nutrients transformation. Key elements like phosphorus, potassium, and zinc solubilization are mediated by many soil fungi- *Aspergillus* spp., *Penicillium* spp. Whereas; the nutrient mobilization is mediated by arbuscular mycorrhiza fungi (AMF) like *Glomus, Gigaspora*, and *Acaulospora*. Many ectomycorrhizal fungi are also involved in the mobilization. They were involved in the mobilization of phosphorus and many microelements.

Decomposition of organic matter

They mainly belong to Ascomycetes, Deuteromycetes, Basidiomycetes, and many ectomycorrhizal fungi. Key fungal decomposers are *Trichoderma viride, T. harzianum*, *Pleurotus florida*, *Aspergillus niger, A. awamori,* and *Phanerochaete chrysosporium*. These fungi release various exo- and endo enzymes like endoglucanases, exoglucanases, and β-glucosidases for cellulose degradation. Hemicellulose degraders have enzymes like xylanases, pectin lyases, mannanases, and arabinofuranosides. Lignin is the most resistant organic matter, which is decomposed by two categories of enzymes, namely lignin modifying enzymes-lignin peroxidases, Mn-dependent peroxides, and laccase, and the second category includes the lignin-degrading auxiliary (LDA) enzymes such as glycol oxidase, glucose dehydrogenase, aryl alcohol oxidase, cellobiose dehydrogenase, and pyranose-2-oxidase. Lignin decomposing fungi are white-rot fungus (*Phanerochaete chrysosporium*), brown rot fungi, soft- rot (ascomycetes fungi Xylariales), and many basidiomycetes like Polyporales and Agaricales (Janusz et al., 2017).

E. Soil yeasts

Soil yeasts play a role in transforming nitrogen, phosphorus, and sulfur cycle, mineralization of organic matter, soil aggregation, and acts as a plant growth promoter. Other ecological roles are controlling the many soil phytopathogens by releasing several cell wall degrading enzymes, predation of arthropods, nematodes, bacteria, and protists. Key genera are *Rhodotorula, Candida, Hansenula, Cryptococcus, Torula*, and *Kluyveromyces.*

F. Soil algae

These are photosynthetic and have chlorophyll and other pigments. They are present in 100- 10000 numbers/gram of soil. The main groups are Chlorophycophyta (green), Cyanophyta (blue-green), Xanthophycophyta (yellow-green), Rhodophycophyta (red), Bacillariophyta (diatoms). Soil algae liberate oxygen by the photosynthesis process and provide aeration in the submerged soils. They check the loss of nitrate by leaching and prevent soil erosion by binding the soil particles. Apart from this, *Cephaleuros virescens*, a red algae, causes disease in various horticultural crops.

G. Soil protozoa

Soil protists are eukaryotes and unicellular; nutrition is photoautotrophs to heterotrophs. They do several ecological functions like phagotrophy on several bacteria, fungi, and animals, symbiosis with many soil microorganisms in a multitrophic way, saprotrophy by organic matter degradation, and phototrophy by carbon fixation. Protists mainly control the bacterial population in the soils, including plant pathogens, and thus keep plants healthy. Furthermore, the nutrients stored by protists are available for plant uptake. Key protists are amoebae (Sarcodina), flagellates (Mastigophora). Some protists are phytopathogens such as *Phytomonas* spp. causes disease in oil palm, coconut, and coffee, whereas *Plasmodiophora brassicae cause clubroot disease in crucifer*.

H. Soil viruses

The population of viruses in the soil is 10^8 particles/gram of soil and has the highest genetic diversity. Viruses play a role in soil microorganisms mortality, nutrient cycling, horizontal transmission of genes, and food webs. Further, this food webs is interlinked with carbon and nutrients transformation, organic matter decomposition, emission of greenhouse gases, and agricultural production. The virus also acts as plant pathogens and causes severe yield losses. However, the role of soil viruses is not explored thoroughly.

CONCLUSION

Soil is a reservoir of diverse microorganisms, which do several ecological functions upon interaction with biotic and abiotic factors. They determine soil quality, soil fertility, plant productivity, and health. Farmers should encourage agricultural practices that increase the population of beneficial microorganisms and decrease the population of pathogenic microorganisms.

Disclaimer: The content of this article is a personal opinion and experience of the authors, not necessarily an endorsement or suggestion of the institute where they are associated with.

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