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Soil Microorganisms: Characteristics, Importance and their Functional Role

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soil is the upper layer of the Earth's crust that has been altered by weathering, physical/chemical, and biological processes. It is made up of mineral particles, organic matter, water, air, and living organisms that are organised in genetic soil horizons. Different soils represent the effects of the various underlying factors in their formation, and as their physicochemical characteristics shift along different axes (surface and subsurface horizons), variability exists from site to site and within a given site in the range of micro niches. Such strange characteristics convert/transform soils into a composite of very diverse ecosystems, making its study difficult because very diverse communities can coexist in a very small scale of the same sample. Soil organisms involve macro/megafauna, mesofauna, and microfauna/flora, and despite accounting for less than 1% of the total mass of a soil, they play critical functional roles in maintaining the soil ecosystem. This study describes various approaches to structural and functional characterising key soil microorganisms such as bacteria, archaea, plant growth promoting bacteria, arbuscular mycorrhizas, and nematodes.

Keywords: Soil; microorganisms; macro/ megafauna; mesofauna; microfauna.

1. INTRODUCTION

"Soils are the naturally occurring physical covering of the earth's surface, and represent the interface of three material states: solids (geological and dead biological materials), liquids [1] water), and gases (air in soil pores). Each soil is a unique product of the combination of

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geological parent material, glacial and geomorphological history, the presence and activity of biota, and the history of land use and disturbance regimes. Soils are the foundation of all terrestrial ecosystems and are home to a vast diversity of bacteria, Achaea, fungi, insects, annelids, and other invertebrates as well as plants and algae. These soil dwellers provide food or nutrients that support organisms that live above and below ground. Soils also play critical roles in buffering and filtering freshwater ecosystems" [2]. "Consequently, soils are extremely important to human societies. We depend on soils for the basis on which we and our buildings stand, and for the production of food, building materials, and other resources; indeed, soils influence most ecosystem services on which we depend" [3].

"Soil is an excellent culture media for the growth and development of various microorganisms. Living organisms present in the soil are grouped into two categories as Soil and Soil fauna. Soil is not an inert static material but a medium pulsating with life. Soil is now believed to be dynamic or living system. Soil provides shelters for many animal types, from invertebrates such as worms and insects up to mammals like rabbits, moles, foxes and badgers. The objective of learning this module is to know about all these aspects, in addition to the understanding of the biological components present in the soil" [4].

"The soil is not a mass of dead debris, merely resulting from the physical and chemical weathering of rocks; it is a more or less homogeneous system which has resulted from the decomposition of plant and animal remains. A normal soil is made up of solid, liquid, and gaseous constituents. These can be broadly divided into five groups" [5]:

1. Mineral Particles.
2. Plant and Animal Residues.
3. Living Systems.
4. Water.
5. Gases. Living systems is also plays a major role in soils.

2. SOIL MICROORGANISMS

The groups of soil microorganisms include the following: Bacteria Bacteria are characterized by their diversity and the diversity of their requirements, so they occupy a great place among the rest of the soil microorganisms, actinomycetes, fungi, algae, protozoa and viruses [6].

3. DIVISION OF SOIL MICROORGANISMS

3.1 Winogradsky's Division of Soil Microbiology [7]

Soil microorganisms are divided according to the nature of their presence in the soil into two groups by the Russian scientist Winogradsky, which are:

A: Autochthonous microorganisms are the microorganisms whose original and permanent habitat is the soil and are found in all types of soil and have a fundamental role in the biochemical changes that occur in the soil. Or it may be present in the form of active vegetative cells in the soil [8].

B. Allochthones microorganisms This type of microorganisms find their way into the soil either by treating the soil with organic fertilizers, whether by adding green plant residues or mineral materials, or by contaminating the soil with sewage water or the organisms that are added to the soil when planting legumes as bacteria. Root ganglia to increase the efficiency of biological nitrogen fixation [9].

3.2 Classification of Soil Micro-organisms According to Thermal Requirements

Temperature is an essential factor that controls all the vital processes of soil biology. Each type of microorganism has an optimum temperature for growth and has a specific temperature range so that vital activity stops outside this range. Soil microorganisms have been placed into three main groups according to the optimum temperature and range. Thermal in which it can grow [10]:

a. Mesophiles: Most of the microscopic soil organisms are types that live in a medium temperature, and the optimum temperature for them is between 25-35°C and they can grow at temperatures between 15-45°C [10].
b. Psychrophiles, which are the organisms that grow best in temperatures below 20°C, and this type of organism is common in the soil. There are many soil organisms that have the ability to grow at low temperatures that fall between freezing and 5°C.

c. Thermophiles species These types of organisms are widespread and grow at temperatures between 45-65 °C and some types are high-temperature-loving, which sometimes reach 80°C [10].

3.3 Division of Soil Micro-organisms in Relation to Energy and Carbon Sources

A: **As for the carbon source: Soil microorganisms are classified according to the carbon source into [12]**

1- Autotrophic Organisms:. They are microorganisms that use carbon dioxide as a source of carbon [12]
2 .Heterotrophs, which are microorganisms that use organic compounds as a source of carbon [12]

B: **As for the energy source: Soil microorganisms are classified according to the energy source as [12]**

1. .**Prototroph**, which are microscopic organisms in which light is a source of energy
2. **Chemotrophic**, which are the organisms that oxidize organic or mineral compounds to obtain the energy needed for various biological processes

C: **The soil microbiology was also divided in relation to the interaction between carbon and energy sources into four sections:**

1- Photoautotrophs, which are plant-like microorganisms that use carbon dioxide as a source of carbon and light as a source of energy.
2- Chemoautotrophs are microorganisms that use carbon dioxide as a source of carbon and oxidize mineral compounds as a source of energy for converting carbon dioxide into glucose and then converting it to other organic cell compounds. This section includes a number of economic bacterial genera, which in turn are divided into other groups on the basis of the compounds of the elements that you oxidize to obtain energy, which are [12]

2-1- Bacteria that oxidize ammonium ions to nitrite ions to obtain energy, such as the genus *Nitrosomonas*.

2-2- Bacteria that oxidize nitrite ions to nitrate ions to obtain energy, such as the genus *Nitrobacter* A:

2-3- Which oxidizes sulfur compounds to sulfate ions to obtain energy, such as *Thiobascillus* genus

2-4- Which oxidizes ferrous ions added to the soil in the form of ferrous sulfate to sediments of ferric hydroxide to obtain energy, such as the genus *Ferrobacillus*

3-Chemoheterotrophs, which are microorganisms that use organic compounds as a source of carbon and energy, and include all fungi, protozoa, most bacteria, and all Actinomycetes. Which reduces nitrate to nitrogen gas and the genus Micrococcus of its types. M urea hydrolyzed urea and sex Cytophage hydrolyzed cellulose

4-Photohetrotrophs This group was developed for the purpose of completing the division and so far no organism has been discovered in the soil that falls within this division.

3.4 Division of Soil Microorganisms in Relation to their Need for Oxygen

The presence or absence of oxygen divides soil microorganisms into three main groups. The basis for this division is mainly due to the nature of energy production systems and the groups are [11]:

a. Obligate aerobic organisms are microorganisms that need oxygen as a final acceptor of electrons for the purpose of oxidation, and when this is the only way to produce energy, this organism is of the obligatory aerobic type. Most soil microorganisms are of this type. Examples include the bacterial genera Nitrobacter, Nitosomonas, and Thiobacillus [11].
b. Facultative anaerobic microorganisms are microorganisms that obtain energy in the absence of oxygen and can also grow in the presence of oxygen, that is, they can grow with or without oxygen, such as the bacterial genera Bacillus and Pseudomonas [11].
c. Obligate anaerobic microorganisms are microorganisms that have an energy production system that does not need oxygen. Despite oxygen being a common and efficient acceptor of electrons, some

organisms with primitive nuclei have the ability to benefit from some inorganic (metal) electron acceptors, as nitrate is reduced to Ammonia, nitrous dioxide and nitrogen gas by the obligatory anaerobic bacteria Pseudomonas dentrificans, where nitrate is one of the sources of electron acceptors for these bacteria, or sulfate (SO_4) can be an electron acceptor as it is reduced to sulfides by obligatory anaerobic bacteria Desulfovibrio desulfuricans or it can be a second or oxide acceptor. Electrons are reduced to methane by obligatory anaerobic bacteria of the genus Methanobacterium [11].

3.5 Soil Life are Classified into 3 Groups as

•Macrofauna: Mice, moles, etc.; Earthworms and other worms; Ants, beetles, termites, spiders [13]
•Mesofauna: Nemaodes, arthropods (mites, centipedes, and springtails) and mollusks [14]
• Microfauna: fungi, algae, protozoa and viruses [13]

3.5.1 Macrofauna

“Members of species classed as macrofauna are visible to the naked eye (which are generally> 2 mm in diameter). Macrofauna includes vertebrates that primarily dig within the soil for food or shelter, and invertebrates that live in and feed in or upon the soil, the surface litter and their components. The vertebrates includes snakes, lizards, mice, rabbits, moles, etc The invertebrates includes snails, earthworms and soil arthropods such as ants, termites, millipedes, centipedes, caterpillars, beetle larvae and adults, fly and wasp larvae, spiders, scorpions, crickets and cockroaches. In both natural and agricultural systems, soil macrofauna are important regulators of decomposition, nutrient cycling, soil organic matter dynamics, and pathways of water movement as a consequence of their feeding and burrowing activities” [15].

3.5.2 Mesofauna

“Mesofauna (0.1-2 mm in diameter) includes mainly micro-arthropods, such as pseudo-scorpions, springtails, mites, and the worm-like enchytraeids. Mesofauna have limited burrowing ability and generally live within soil pores, feeding on organic materials, microflora, microfauna and other invertebrates. Nematodes are tiny filiform roundworms that are common in soils everywhere” [16].

3.5.3 Microfauna

The microfauna (<0.1 mm in diameter) includes mainly protozoa.
“These generally live in the soil water films and feed on microflora, plant roots, other microfauna. There may be sometimes larger which feed on insects and other larger invertebrates .They are important to release nutrients immobilized by soil microorganisms” [15].

3.6 There are Other Divisions in Addition to the Divisions above, as Soil Bacteria are Divided into Two Parts in Relation to their Formation of Spores

1. Spore-forming bacteria, such as Bacillus genus and Clostridium genus, former spore
2. Non-forming bacteria, including all other species. In the soil there are also positive and negative bacteria for gram dye

4. FACTORS AFFECTING THE TYPES AND DISTRIBUTION OF MICROORGANISMS IN THE SOIL

1-Soil type: Soil organisms, shapes, and numbers vary according to the mechanical composition of the soil. Medium-textured soils are richer in microorganisms than heavy sand or clay soil [17].

2- Light: Most soil organisms prefer to stay away from light, except for some algae that prefer to live on or near the surface of the soil [17].

3- Aeration: Most of the soil organisms are aerobic species that only grow in the presence of aerobic air, some of them are anaerobic, their growth stops with the availability of air, and others are optional that grow in the presence or absence of air. The numbers, shapes, and distribution of these neighborhoods vary in the soil depending on the degree of aeration [18].

4- Moisture: The presence of moisture is necessary for soil life, but it differs in the extent of its tolerance to drought. There is a strong relationship between soil moisture and the degree of aeration and the effect of all of them. Subscriber in neighborhoods [19].

5 -Heat: Soil organisms, especially micro-organisms, are found in all soils of the world, and most of them are low or medium heat-loving, but high-temperature-loving species are available in some soils rich in organic matter, and their effective role increases after partial heat sterilization of soils.[19]

6- pH: Soils with a neutral pH are the richest in terms of number and diversity. The types of microorganisms in the soil vary according to its degree of acidity [20].

7-Nutrients type and quantity: Soil organisms are either predatory, parasitic, receptive and commensal. There are species whose self-feeding is light, chemical, or photodynamic, and their density is related to the availability of their own food.[21]

8-The effect of adding mineral or organic fertilizers.

This addition affects the number, distribution and diversity of soil organisms. Fertilization also affects new numbers of organisms to the soil. The use of organic in itself adds an effect of pesticides, herbicides, fungi, or chemical sterilizers negatively and to varying degrees on soil biota, in addition to the effect of plant root secretions. Depending on the stages of its growth as well as the nature of agricultural services to the soil [20].

5. IMPORTANCE OF SOIL ORGANISMS [22]

- Responsible for cycling of C, N and other nutrients
- Enhance soil structure • Relocate and decompose organic materials
- Maintain soil quality and health
- Increase soil aeration and penetrability
- Involved in disease transmission and control

The role of soil microorganisms are many.

1. Soil microbes break down organic matter
2. Soil microbes recycle nutrients
3. Soil microbes create humus
4. Soil microbes create soil structure
5. Soil microbes fix nitrogen
6. Soil organisms promote plant growth
7. Soil microbes control pests and disease

6. CONCLUSION

The soil is an integrated environment in which all environmental conditions are available suitable for the growth of various microorganisms such as fungi, protozoa, algae and bacteria, which differ in the requirements of their growth and reproduction in terms of temperature, oxygen and pH. And depends on these requirements in the classification and division of microorganisms in the soil. The microorganisms in the soil have benefits and importance in all scientific, industrial, agricultural and medical fields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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