**Lec:7 soil microbiology dr.asseel habh**

**What are Bacteria?**

* Bacteria are the smallest and most numerous cellular organisms in soils. They are prokaryotic organisms that are usually 0.5 to 1 mm wide and 1 to 2 mm long.
* The tiny bacteria, termed ultramicrobacteria, can be as small as 0.3 mm in diameter with cell volumes less than 0.1 mm3.
* Although a variety of cell shapes exists for bacteria, including rod, spherical, spiral, and filamentous, the most common cell shape found in soil is a short rod (coccoid rod).
* Bacteria are one of the most abundant groups of microorganisms found in soil with most of them present around the rhizospheric region.
* Bacteria in the rhizosphere are larger and have higher proportions of Gram-negative and denitrifying bacteria than those in the bulk soil.
* **Examples of Bacteria found in Soils**
* Bacterial biomass found in soil ranges from 300 to 3000 kg/ ha. There are approximately 108 to 109 bacteria in a gram of soil, most of them (>99%) have not been or cannot be cultured in the laboratory.
* Common bacterial genera isolated from soil include *Bacillus, Arthrobacter, Pseudomonas, Agrobacterium, Alcaligenes, Clostridium, Flavobacterium, Corynebacterium, Micrococcus, Xanthomonas*, and *Mycobacterium*.
* In contrast to simple morphology, bacteria have the greatest metabolic diversity.
* In terms of carbon utilization, there are autotrophs and heterotrophs, and in terms of energy consumption, there are chemoorganotrophs, chemolithotrophs, and phototrophs.
* Aerobic bacteria use oxygen as an electron acceptor; anaerobic bacteria use alternate electron acceptors such as nitrate, ferric iron, sulfate, carbonate, and organic matter.
* Since soil is an oligotrophic (nutrient-poor) environment, most bacterial cells are believed to be dormant.
* The one area in the soil where metabolically active microorganisms are commonly found is the rhizosphere, where nutrients are not limiting.
* In waterlogged or heavily compacted soils, the number of aerobic bacteria is reduced, whereas the microaerophilic and finally the anaerobic bacteria will increase.
* Unlike the other soil microorganisms, most bacteria prefer nutrient-rich soils of neutral or slightly alkaline pH and a close C/N-ratio.

**Positive effects of Bacteria in Soil**

* Bacteria are an important part of the biotic component of soil as they are responsible for numerous physiological activities occurring in the soil.
* Soil bacterial communities provide a multitude of ecosystem services that directly, and indirectly, affect the overall functioning of the soil environment.
* Many bacteria in the soil produce polysaccharides or glycoproteins that form a layer on the surface of the soil particle. These substances thus, act as cementing agents and improve the soil structure.
* Bacteria are a part of different biogeochemical cycles like the nitrogen cycle and carbon cycle where they are involved in the production of a large number of nutrients for the soil and the plants.
* The process of natural succession is also enhanced by bacteria that improve the quality of soil so new plant communities can survive.
* Besides, bacteria are important for the enzymatic degradation of the complex organic and Soil substances to nutrients and the release of nutrients and trace Enzymes elements from the mineral soil fraction.
* Bacterial communities in soil act as indicators for the condition of the soil condition.
* **Negative effects of Bacteria in Soil**
* Pathogenic bacteria in the soil might have harmful effects on the crops, resulting in poor crop health, poor yields leading to crop loss.
* Some bacteria are known to disturb the ecological balance of the soil, which results in soil infertility and decreased soil health.
* Besides, pathogenic bacteria found in soil can cause different forms of plant diseases.
* The release of different by-products might change the chemical properties of soil, like the pH, cation exchange capacity, and nutrient content.
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**Fungi in Soil**

**What are Fungi?**

* Soil fungi are eukaryotic organisms, which can be unicellular, but often are multicellular.
* Compared to bacteria, fungi have more complex morphologies and life cycles. Yeasts are single-celled fungi that reproduce asexually through budding.
* Most other fungi have highly branched filaments with strands 2 to 30 mm in diameter and several centimeters long.
* Most fungi are aerobic except for yeasts, which can survive in anaerobic environments by fermenting sugars into alcohol.
* **Examples of Fungi found in Soils**
* In many ecosystems, fungi constitute the largest biomass of all the soil organisms, ranging from 500 to 5000 kg/ha.
* An individual fungus can include many fruiting bodies scattered across a large area with extensive underground hyphae.
* Among the soil fungi, one can find oomycetes, hyphochytriomycetes, trichomycetes, chytridiomycetes, zygomycetes, ascomycetes, basidiomycetes, and imperfect fungi.
* Fungi found in soil fall mostly within three groups; decomposers, mutualists (mycorrhizal fungi), and pathogens.
* Some of the common fungi found in soil include *Amanita, Tricholoma, Torrendia, Descomyces, Thelephora, Verticillium, Phytophthora, Rhizoctonia,* and *Pythium*.
* Since fungi prefer a rather low soil pH and a wide C/N-ratio, they dominate in raw humus and moder and mull soils.
* Mycorrhizal fungi are mostly found around plant roots, whereas other groups of fungi are found distributed throughout the soil.
* Fungi, in general, tend to dominate over bacteria and actinomycetes in acidic soils as they can tolerate a wider range of pH levels.

**Positive effects of fungi in Soil**

* Fungi play essential roles in the soil where they help in nutrient cycling, water dynamics, and disease suppression, all of which maintain the health of the soil and increases crop yield.
* Fungal hyphae bind soil particles together and stabilize soil aggregates.
* Fungi also form beneficial mycorrhizal symbioses with almost all terrestrial plants. Mycorrhizal fungi enhance the uptake of mineral nutrients (e.g., phosphorus and zinc) to the plant in exchange for carbon compounds fixed by plant photosynthesis.
* Fungi are important decomposers of organic matter in the soil here they use nitrogen in the soil to decompose woody carbon residues.
* The large size of fungi protects plants against pests, diseases, and drought. Fungi are also producers of antibiotic compounds such as penicillin and cyclosporins.
* Lichens are symbiotic associations of a fungus and an alga or a cyanobacterium. They are important soil colonizers that play critical roles in soil formation and stabilization.

**Negative effects of fungi in Soil**

* The pathogenic group of fungi in soil results in various plant diseases by penetrating the plant tissue and creating a weakened, nutrient-deficient plant.
* In addition to the direct effects on the plants, fungi also affect the interactions between plants which change the competitive balance between two species.
* Mycorrhiza and fungal pathogens also affect seedlings, resulting in harmful consequences for plant population dynamics.

**Actinomycetes in Soil**

**What are Actinomycetes?**

* Actinomycetes are filamentous bacteria, most of which are Gram-positive bacteria and are more abundant in neutral to alkaline soils.
* Actinomycetes are mostly anaerobic that form either colonies or extensive mycelia. However, in some cases, the mycelia might break off, resulting in rod- or coccoid-shaped forms.
* Even though they are bacteria, their biomass and distinct characteristic resulted in a distinct classification.
* Depending on the species, the size of actinomycetes ranges between 0.5 to 1.5 µm.

**Examples of Actinomycetes found in Soils**

* Actinomycete population is largest in the surface layer of soils and gradually decreases with the depth; individual actinomycete strains are present in all soil layers.
* They are widely distributed in the soil with estimated values ranging from 104 to 108 per gram of soil.
* They grow as hyphae like fungi, resulting in the characteristically “earth” smell of freshly turned healthy soil.
* *Streptomyces* is the most abundant species of actinomycetes in soil, followed by other species like *Micromonospora, Thermoactinomycetes,* and *Nocardia*.
* Besides, some actinomycetes are rarely isolated from desert soil, which includes *Microbispora, Microtetraspora, Amycolaptosis, Actinomadura,* and *Saccharothrix.*
* Almost 90% of actinomycetes genera have been isolated from the soil where they often form much-branched hyphae when growing, which then break up into spores, either by the tip of the hyphae producing one or two spores.
* Actinomycetes in the soil are mesophilic organisms that are sensitive to acidity/low pH (optimum pH range 6.5-8.0) and waterlogged soil conditions.
* Like other groups of microorganisms, some actinomycetes might be pathogenic, resulting in different diseases in plants.

**Positive effects of Actinomycetes in Soil**

* Actinomycetes decompose the more resistant and indecomposable organic substances and produce several dark black to brown pigments which contribute to the dark color of the soil humus.
* These organisms are also responsible for the subsequent decomposition of humus (resistant material) in soil.
* Actinomycetes are important in agricultural soils because they contribute to the carbon cycle by fixation (photosynthesis) and decomposition.
* Actinomycetes form associations with some non-leguminous plants and fix N2, which is then available to both the host and plants in the near vicinity.
* Actinomycetes are the leading group of soil microorganisms that play a major role in the recycling of organic matters in the environment by the production of hydrolytic enzymes.
* They possess direct or indirect mechanisms that favor plant growth while improving the availability of nutrients and minerals, synthesized plant growth regulators, and suppression of phytopathogens.
* Many properties related to actinomycetes have the ability to act as biocontrol tools.
* **Negative effects of Actinomycetes in Soil**
* Some products of Actinomycetes might affect the microorganisms of the soil, resulting in decreased diversity.
* Pathogenic species of actinomycetes result in plant diseases that affect plant health and crop loss.

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**Protozoa in Soil**

**What are Protozoa?**

* Protozoa are unicellular eukaryotic microorganisms that lack cell walls.
* They are motile heterotrophs that obtain food by ingesting bacteria, yeasts, algae, small protozoa, and organic matter.
* Free-living soil protozoa fall into three categories: flagellates, amoebae, and ciliates.
* These single-celled animals differ in shape, size, and distribution with some protozoan species found in land habitats like soil.

**Examples of Protozoa found in Soils**

* Amoeba, ciliates, and flagellates are the three groups of protozoans found in soil.
* Numerous heterotrophic flagellates and naked amoebae are available in agricultural soils, grassland, forest soil, bottom sediment of freshwater, coastal and marine waters.
* The presence of protozoa in the soil is influenced by the presence of living and dead plant roots and the organic content of the soil.
* The inhabitation of soil by protozoa depends on the structure and texture of the soil. Mastigophorans (flagellates) tend to dominate in drier soils, while ciliophorans (ciliates) are abundant in moist soil.
* Similarly, cultivated soil and clay soil are predominated by flagellates and amoebae while the soil of coarse texture consists of large flagellates, testaceans, and ciliates.
* Some protozoans might remain in a symbiotic relationship with other microorganisms like bacteria and fungi.

**Positive effects of Protozoa in Soil**

* Protozoans are crucial in terrestrial ecosystems where they act as bacterial consumers, leading to mineralization of organic soil nitrogen to form ammonium.
* Protozoans community in the soil can also be used to assess and monitor the changes in the biotic and abiotic component of soil, thus acting as bioindicators of the soil.
* Protozoa have been found to increase plant biomass independently of nutrient contents in plant tissue.
* Many protozoan species feed on bacteria and other microorganisms which enhances the nutrient cycles and the energy flow between the microorganisms, animals, and plants.

**Negative effects of Protozoa in Soil**

* As most bacterial communities in the soil are the source of food for protozoan, the presence of protozoa in soil affects bacterial diversity.
* Some protozoa might be harmful to the plant, which decreases crop health and crop yield.

**Blue-green algae (cyanobacteria) in Soil**

**What are Blue-green algae?**

* Cyanobacteria are phototrophic bacteria that are important in soils where light and water are available.
* Cyanobacteria are autotrophic eukaryotes that consist of both free-living photosynthetic bacteria and endosymbiotic organisms.
* Blue-green algae exist in the form of motile filaments of cells that travel away to form new colonies.
* Blue-green algae are found in colonial or filamentous form, and the filamentous forms show heterocystous or non-heterocystous filament.
* The heterocysts are thick-walled, large cells responsible for nitrogen fixation under anaerobic conditions.

**Examples of Blue-green algae found in Soil**

* Blue-green algae in the soil are present in a wide variety of moist soils, primarily present around the plant root in the form of the symbiotic association.
* These organisms might either occur freely in the soil or in the form of symbiotic relationships with plants of lichen-forming fungi.
* Cyanobacteria species have certain structures like heterocysts that are involved in nitrogen fixation and thus, are present in the anaerobic area of soil.
* Some of the common cyanobacteria include *Nostoc, Prochlorothrix, Anabaena, Nodularia*, etc.
* Cyanobacteria have been reported from a wide range of soils, thriving both on and below the surface.
* Blue-green algae in soil survive at the mesophilic temperature that is sensitive to acidity/low pH (optimum pH range 6.5-8.0) and waterlogged soil conditions.

**Positive effects of Blue-green algae in Soil**

* Cyanobacteria are among the first microbial communities to colonize terrestrial ecosystems.
* These microorganisms play essential roles in soil by fixing nitrogen and carbon by the synthesis of exopolysaccharides that increase soil fertility and water retention capacity.
* The application of cyanobacteria as inoculants to induce biocrust formation on the soil is a novel technology that restores barren degraded areas and prevents desertification processes.
* They play important roles in increasing soil physical structure, porosity, and retaining soil moisture due to their filamentous structure.
* These organisms also produce mucilaginous substances, release phytohormones, vitamins, amino acids, and secondary metabolites in the soil.
* Many of the cyanobacterial species have the intrinsic ability to fix atmospheric nitrogen with the help of a very specialized cell called heterocyst.
* The application of N2-fixing cyanobacteria as a potential N2-biofertilizer source in the field, act as an alternative to the commonly used organic and chemical fertilizers.

**Negative effects of Blue-green algae in Soil**

* In some cases, blue-green algae might form algal blooms, releasing toxins into the soil that directly or indirectly affects the vegetation.
* The loss of a large amount of cyanobacteria community in the soil affects the bacteria communities as it causes oxygen depletion.

**Viruses in Soil**

**What are Viruses?**

* Viruses are genetic elements that can replicate independently of a cell’s chromosomes but not independently of cells themselves.
* Viruses are smaller than bacteria and range in size from 20 to 30 nm in diameter. Viruses are obligate parasites of bacteria, fungi, insects, plants, and animals that inhabit the soil.
* Viruses can act as dormant structures or particles that can survive for a long period in different habitats.
* As viruses are obligate parasites, they can be found anywhere in the world where there is life

**Examples of Viruses found in Soil**

* Viruses are the most abundant biological entities on our planet and exceed the number of cellular organisms in marine and soil habitats.
* The concentration of viruses in soil has been estimated to be 109 virus particles per gram dry weight.
* The majority of the soil viruses are tailed bacteriophages that prefer wetland forest soil over drier agricultural soils.
* Some of the common viruses inhabiting soil include small spherical virus particles similar in size to single-stranded (ss) RNA containing bacteriophages of the *Leviviridae* family or to some plant viruses, and larger spherical viruses similar to the double-stranded (ds) DNA containing viruses of the *Partitiviridae, Chrysoviridae,* and *Totiviridae* families.
* Diverse viruses of the *Myoviridae*, *Siphoviridae,* and *Podoviridae* families with genomes ranging in size from 45 to 270 kb are found in the Sahara desert surface sands.
* Soils act as reservoirs of viruses, but these are probably not entirely static reservoirs as at least some viruses seem to move readily between environments.

**Positive effects of Viruses in Soil**

* The main way in which viruses in soils act beneficially is by transferring genes between microbial hosts by horizontal gene transfer. The gene transfer enables the transfer of beneficial characteristics between different communities.
* Another way that viruses in soils have potential benefits for plants is by infecting organisms that are pathogenic for plants.
* Viruses of different microbes in the soil as pathogens have an essential role in regulating the population structure of their microbial hosts.
* Virus populations may also act as reservoirs of genes involved in all the biochemical functioning of their microbial hosts, and by recombination among themselves during co-infections, could be a source of new gene variants.

**Negative effects of Viruses in Soil**

* Among the virus community in soil, distinct proportions are plant pathogens that reach the plant via mechanical means, nematode vectors, or fungal vectors.
* Viruses also affect other microbial communities of bacteria, fungi, and protozoa that cause an imbalance in the biotic component of the soil.
* Viruses might even affect the physical and chemical properties of soil by affecting the biotic and abiotic components of the soil.

**Nematodes in Soil**

**What are Nematodes?**

* Nematodes are small invertebrates with smooth, unsegmented bodies that are typically 50 µm in diameter and 1 mm in length.
* Most nematode species are highly specialized parasites of vertebrates, including humans, insects, and other invertebrates.
* Nematodes are different from other worms in that they are mostly parasitic with non-segmented bodies. These also generally reside in soil surfaces and water bodies.

**Examples of Nematodes found in Soil**

* Nematodes found in soil reside in the top layer of the soil with organic matter even if they do not feed on the dead and decaying matter.
* These feed on living microorganisms that are present on the soil surfaces. Nematodes in the soil can be either free-living or parasitic.
* Most of the nematodes present in the soil include roundworms that move through the soil if they are free-living.
* Soil nematodes can be classified into four different groups; bacterial feeders, fungal feeders, protozoan feeders, and omnivores.
* In the case of agricultural soil, about a teaspoon of soil supports about 100 nematodes. However, the number differs depending on the microbial community and the organic content of the soil.

**Positive effects of Nematodes in Soil**

* Soil nematodes, especially those feeding on bacteria and fungi, help maintain the microbial community of the soil and also ensure that enough nitrogen is available in the soil for the plants.
* Some free-living nematodes are capable of mineralization where they convert organic compounds into their inorganic forms, aiding in the biogeochemical cycles.
* Nematodes might even enhance soil fertility by decomposing complex organic compounds into simpler forms.
* Some of these animals feed on pests by either parasitizing them or by feeding on them.
* The movement of nematodes through the soil increases the porosity of the soil, thus maintaining a balanced soil ecosystem.

**Negative effects of Nematodes in Soil**

* Predatory nematodes in soils harm the useful microbial community of the soil, decreasing the soil health.
* Plant-parasitic nematodes feed on seedlings and plant roots that cause crop loss in different agricultural soil.