Lec:4 Soil microbiology Dr.Asseel Habh

***Soil as a living system :***

Soil inhabit diverse group of living organisms, both micro flora(fungi, bacteria, algae and actinomycetes) and micro-fauna (protozoa, nematodes, earth worms ,moles, ants). The density of living organisms in soil is very high i.e. as much as billions / gm of soil, usually density of organisms is less in cultivated soil than uncultivated / virgin land and population decreases with soil acidity. Top soil, the surface layer contains greater number of microorganisms because it is well supplied with Oxygen and nutrients. Lower layer / subsoil is depleted with Oxygen and nutrients hence it contains fewer organisms. Soil ecosystem comprises of organisms which are both, autotrophs (Algae, BOA) and heterotrophs (fungi, bacteria).Autotrophs use inorganic carbon from CO2 and are "primary producers" of organic matter, whereas heterotrophs use organic carbon and are decomposers/consumers.

***Soil microbes and plant growth:***

Microorganisms being minute and microscopic, they are universally present in soil, water and air. Besides supporting the growth of various biological systems, soil and soil microbes serve as a best medium for plant growth. Soil fauna & flora convert complex organic nutrients into simpler inorganic forms which are readily absorbed bythe plant for growth. Further, they produce variety of substances like IAA, gibberellins, antibiotics etc. which directly or indirectly promote the plant growth

***Soil microbes and soil structure:***

Soil structure is dependent on stable aggregates of soil particles-Soil organisms play important role in soil aggregation. Constituents of soil are viz .organic matter, polysaccharides, lignins and gums, synthesized by soil microbes plays import ant role in cementing / binding of soil particles. Further, cells and mycelial strands of fungi and actinomycetes, Vormicasts from earthworm is also found to play important role in Soil aggregation. Different soil microorganisms, having soil aggregation / soil binding properties aregraded in the order as fungi > actinomycetes > gum producing bacteria > yeasts .Examples are: **Fungi like**

 Rhizopus, Mucor, Chaetomium, Fusarium, Cladasporium, Rhizoctonia, Aspergillus, Trichoderma

and **Bacteria like**  Azofobacler, Rhizobium Bacillus and Xanlhomonas.

***Soil microbes and organic matter decomposition:***

The organic matter serves not only as asource of food for microorganisms but also supplies energy for the vital processes of metabolism that are characteristics of living beings. Microorganisms such as fungi, actinomycetes, bacteria, protozoa etc. and macro organisms such as earthworms, termites, insects etc. plays important role in the process of decomposition of organic matter and release of plant nutrients in soil. Thus ,organic matter added to the soil is converted by oxidative decomposition to simpler nutrients /substances for plant growth and the residue is transformed into humus. Organic matter /substances include cellulose, lignins and proteins (in cell wall of plants), glycogen (animal tissues), proteins and fats (plants, animals). Cellulose is degraded by bacteria, especially those of genus

Cytophaga and other genera (Bacillus, Pseudomonas, Cellulomonas, and Vibrio Achromobacter)

and fungal genera (Aspergillus, Penicilliun, Trichoderma, Chactomium,Curvularia).

Lignins and proteins are partially digested by fungi, protozoa and nematodes.Proteins are degraded to individual amino acids mainly by fungi, actinomycetesAnd Clostridium.

Under unaerobic conditions of waterlogged soils, methane are main carbon containing product which is produced by the bacterial genera (strict anaerobes)

 Methanococcus, Methanobacterium and Methanosardna.

***Soil microbes and humus formation:***

Humus is the organic residue in the soil resulting from decomposition of plant and animal residues in soil, or it is the highly complex organic residual matter in soil which is not readily degraded by microorganism, or it is the soft brown/dark coloured amorphous substance composed of residual organic matter along with dead microorganisms.

***Soil microbes and cycling of elements:***

Life on earth is dependent on cycling of elements

from their organic / elemental state to inorganic compounds, then to organic compounds and back to their elemental states.

The biogeochemical process through which organic compound sare broken down to inorganic compounds or their constituent elements is known “Mineralization”, or microbial conversion of complex organic compounds into simple inorganic compounds & their constituent elements is known as mineralization.

Soil microbes plays important role in the biochemical cycling of elements in the biosphere where the essential elements (C, P, S, N & Iron etc.) undergo chemical transformations.

Through the process of mineralization organic carbon, nitrogen, phosphorus, Sulphur, Iron etc. are made available for reuse by plants.

***Soil microbes and biological N2 fixation:***

Conversion of atmospheric nitrogen in to ammonia and nitrate by microorganisms is known as biological nitrogen fixation.

Fixation of atmospheric nitrogen is essential because of the reasons:

1.Fixed nitrogen is lost through the process of nitrogen cycle through denitrification.

2.Demand for fixed nitrogen by the biosphere always exceeds its availability.

3.The amount of nitrogen fixed chemically and lightning process is very less (i.e. 0.5%) ascompared to biologically fixed nitrogen

4.Nitrogenous fertilizers contribute only 25% of the total world requirement while biological nitrogen fixation contributes about 60% of the earth's fixed nitrogen

5.Manufacture of nitrogenous fertilizers by "Haber" process is costly and time consuming.The numbers of soil microorganisms carry out the process of biological nitrogen fixation atnormal atmospheric pressure (1 atmosphere) and temp (around 20 °C).Two groups of microorganisms are involved in the process of BNF.

A. Non-symbiotic (free living) and B. Symbiotic (Associative) Non-symbiotic (free living): Depending upon the presence or absence of oxygen, non symbiotic N2 fixation prokaryotic organisms may be aerobic heterotrophs ( Azotobacter, Pseudomonas, Achromobacter) or aerobic autotrophs (Nostoc, Anabena) and anaerobicheterotrophs

(Clostridium, Kelbsiella)or anaerobic Autotrophs

(Chlorobium,Chromnatium, Rhodospirillum,

Symbiotic (Associative):The organisms involved are Rhizobium, Bratfyrhizobiumin legumes(aerobic):  Azospirillum (grasses), Actinonycetes frantic(withCasuarinas,Alder).

*Soil microbes as biocontrol agents:*

Several ecofriendly bioformulations of microbial originare used in agriculture for the effective management of plant diseases, insect pests, weeds etc. eg:

Trichoderma sp and Gleocladium sp are used for biological control of seed and soil bornediseases. Fungal genera  Entomophthora, Beauveria, Metarrhizium and protozoa  Maltesia grandis. Malameba locustiae etc are used in the management of insect pests. Nuclear  polyhydrosis virus (NPV) is used for the control of  Heliothis / American boll worm. Bacteria like Bacillus thuringiensis, Pseudomonas are used in cotton against Angular leaf spot and bollworms.

*Degradation of pesticides in soil by microorganisms*:

Soil receives different toxic chemicalsin various forms and causes adverse effects on beneficial soil micro flora / micro fauna, plants,animals and human beings. Various microbes present in soil act as the scavengers of these harmful chemicals in soil. The pesticides/chemicals reaching the soil are acted upon by several physical, chemical and biological forces exerted by microbes in the soil and they are degraded into non-toxic substances and thereby minimize the damage caused by the pesticides to theecosystem. For example, bacterial genera like

 Pseudomonas, Clostridium, Bacillus, Thiobacillus, Achromobacter etc. and fungal genera like Penicillium, Aspergillus, Rhizopus, and  Fusarium are playing important role in the degradation of the toxic chemicals / pesticides in soil.

*Biodegradation of hydrocarbons:*

 Natural hydrocarbons in soil like waxes, paraffin‟s, oils

etc are degraded by fungi, bacteria and actinomycetes. E.g. ethane

(C2H6) a paraffinhydrocarbon is metabolized and degraded by Mycobacteria, Nocardia, Streptomyces Pseudomonas, Flavobacterium and several fungi.

*Soil Humus:*

Humus is the organic residue in the soil resulting from decomposition of plant and animal residues in soil, or it is the highly complex organic residual matter in soil which is not readily degraded by microorganism, or it is the soft brown/dark coloured amorphous substance composed of residual organic matter along with dead microorganisms .Composition of Humus: In most soil, percentage of humus ranges from 2-10 percent, whereas it is up to 90 percent in peat bog. On average humus is composed of Carbon (58 %), Nitrogen (3-6 %, Av.5%), acids -humic acid, fulvic acid, humin, apocrenic acid, and C: N ratio 10:1 to 12:1. During the course of their activities, the microorganisms synthesize number of compounds which plays important rolein humus formation.

Functions/Role of Humus:

1.It improves physical condition of soil

2.Improve water holding capacity of soil

3.Serve as store house for essential plant nutrients

4.Plays important role in determining fertility level of soil

5.It tend to make soils more granular with better aggregation of soil particles

6.Prevent leaching losses of water soluble plant nutrients

7.Improve microbial/biological activity in soil and encourage better development of plant-root system in soil

8.Act as buffering agent i.e. prevent sudden change in soil PH/soil reaction

9.Serve as source of energy and food for the development of soil organisms

10.It supplies both basic and acidic nutrients for the growth and development of higher  plants

11.Improves aeration and drainage by making the soil more porous

Soil Microorganism: Bacteria

Amongst the different microorganisms inhabiting in the soil, bacteria are the most abundant and predominant organisms. These are primitive, prokaryotic, microscopic and unicellular microorganisms without chlorophyll. Morphologically, soil bacteria are divided into three groupsviz Cocci (round/spherical), (rod-shaped) and Spirilla I Spirllum (cells with long wavy chains).

 Bacilli are most numerous followed by Cocci and Spirilla in soil.

The most common method used for isolation of soil bacteria is the "dilution plate count" method which allows the enumeration of only viable/living cells in the soil. The size of soil bacteriavaries from 0.5 to 1.0 micron in diameter and 1.0 to 10.0 microns in length. They are motile withlocomotory organs flagella .Bacterial population is one-half of the total microbial biomass in the soil ranging from 1,00000

to several hundred millions per gram of soil, depending upon the physical, chemical and biological conditions of the soil.Winogradsky (1925), on the basis of ecological characteristics classified soil microorganisms ingeneral and bacteria in particular into two broad categories i.e. Autochnotus (Indigenous species)and the Zymogenous (fermentative). Autochnotus bacterial population is uniform and constant insoil, since their nutrition is derived from native soil organic matter (eg. Arthrobacter and Nocardia

whereas Zymogenous bacterial population in soil is low, as they require an externalsource of energy, eg.

 Pseudomonas & Bacillus.

The population of Zymogenous bacteriaincreases gradually when a specific substrate is added to the soil. To this category belong thecellulose decomposers, nitrogen utilizing bacteria and ammonifiers.As per the system proposed in the Bergey's Manual of Systematic Bacteriology, most of the bacteria which are predominantly encountered in soil are taxonomically included in the threeorders, Pseudomonadales, Eubacteriales and Actinomycetales of the class Schizomycetes. Themost common soil bacteria belong to the genera

 Pseudomonas, Arthrobacter, Clostridium Achromobacter, Sarcina, Enterobacter  etc. The another group of bacteria common in soils is theMyxobacteria belonging to the genera

 Micrococcus, Chondrococcus, Archangium, Polyangium,Cyptophaga.

 Bacteria are also classified on the basis of physiological activity or mode of nutrition, especiallythe manner in which they obtain their carbon, nitrogen, energy and other nutrient requirements.

They are broadly divided into two groups i.e. a) Autotrophs and b) Heterotrophs

1.Autotrophic bacteria are capable synthesizing their food from simple inorganic nutrients,while heterotrophic bacteria depend on pre-formed food for nutrition. All autotrophic bacteria utilize Co2 (from atmosphere) as carbon source and derive energy either fromsunlight (photoautotrophs, eg. Chromatrum. Chlorobium. Rhadopseudomonas

or fromthe oxidation of simple inorganic substances present in soil (chemoautotrophs eg.  Nitrobacter, Nitrosomonas, Thiaobacillus).

 2.Majority of soil bacteria are heterotrophic in nature and derive their carbon and energyfrom complex organic substances/organic matter, decaying roots and plant residues. Theyobtain their nitrogen from nitrates and ammonia compounds (proteins) present in soil andother nutrients from soil or from the decomposing organic matter. Certain bacteria alsorequire amino acids, B- Vitamins, and other growth promoting substances also.

*Functions / Role of Bacteria*

Bacteria bring about a number of changes and biochemical transformations in the soil andthereby directly or indirectly help in the nutrition of higher plants growing in the soil. Theimportant transformations and processes in which soil bacteria play vital role are: decompositionof cellulose and other carbohydrates, ammonification (proteins ammonia), nitrification(ammonia-nitrites-nitrates), denitrification (release of free elemental nitrogen), biologicalfixation of atmospheric nitrogen (symbiotic and non-symbiotic) oxidation and reduction of sulphur and iron compounds. All these processes play a significant role in plant nutrition, Process/reaction

Bacterial genera  Cellulose decomposition (celluloytic bacteria ) most cellulose decomposers aremesophilica. Aerobic :

 Angiococcus, Cytophaga, Polyangium, Sporocytophyga, Bacillus,chromobacter, Cellulomonas

 b. anaerobic: Clostridium Methanosarcina,ethanococcus

 Ammonification (Ammonifiers) Bacillus, Pseudomonas

  Nitrification (Nitrifying bacteria) itrosomonas, Nilrobacter Nitrosococcus Denitrification (Denitrifies)

chromobacter, Pseudomonas, Bacillus,icrococcus  Nitrogen fixing bacteria a Symbiotic- Rhizobium, Bradyrrhizobium b Non-symbiotic: aerobic – Azotobacter Beijerinckia(acidic soils), anaerobic-Clostridium

 Bacteria capable of degrading various plant residues in soil are :

Cellulose

Hemicelluloses

 Lignin

 Pectin

 Proteins

 Pseudomonas Bacillus Pseudomonas Erwinia Clostridium Cytophaya Vibrio Micrococcus ProteusSpirillum Pseudomonas Flavobacteriumm PseudomonasActinomycetes Erwinia Xanthomonas BacillusCellulomonas Streptomyces