LECTURE

Interactions among soil microorganisms

The microbial ecosystem is the sum of the biotic and abiotic components of soil. It includes the total microbial flora together with the physical composition and physical characteristics of the soil. The microorganisms that inhabit the soil exhibit many different types of interactions or associations. Some interactions are indifferent or neutral; while some are positive and some are negative in nature. The associations existing between different soil microorganisms, whether of a symbiotic or antagonistic nature, influence the activities of microorganisms in the soil.

Neutral associations

Neutral association or neutralism is the association between microorganisms, where two different species of microorganisms occupy the same environment without affecting each other. Such an association might be transitory; as conditions change in the environment, like nutrients availability, there might be a change in the relationship.

Positive associations

There are three types of positive associations exist between microorganisms, which are given below.

Mutualism

Mutualism is an example of a symbiotic relationship in which each organism benefits from the association. The way in which benefit is derived depends on the type of interactions. **Syntrophism** is a type of mutualistic association, which involves the exchange of nutrition between two species. The association between blue green algae and a fungus (lichen) is known as syntrophism.

The fungus surrounds the algal cells, often enclosing them within complex fungal tissues unique to lichen associations. In this type of association, algae benefits by protection afforded to it by the fungal hyphae from environmental stresses, while the fungus obtain and use O_2 released by the algae during photosynthesis. The algal or cyanobacterial cells are photosynthetic, and as in plants they reduce atmospheric carbon dioxide into organic carbon sugars to feed both symbionts. Both partners gain water and mineral nutrients mainly from the atmosphere, through rain and dust. The **lichen association** is a close symbiosis. It extends the ecological range of both partners but is not always obligatory for their growth and reproduction in natural environments, since many of the algal symbionts can live independently.

Another mutalistic association is characterized by different metabolic products from the association as compared with the sum of the products of the separate species. A mutualism between *Thiobacillus ferrooxidans* and *Beijerinckia lacticogenes* helps in ore

leaching. Both of these species when grown in a medium free of added carbon and nitrogen sources and with a sterile ore concentrate, the growth of the two species in association and the resulting effect on the rate of leaching copper from the ore concentrate is observed. Leaching is process of recovery of metal from the ore, where microorganisms play the important role of oxidizing insoluble metal sulphides to soluble sulphates.

Microorganisms may also form mutualistic relationships with plants in soil, an example of which is nitrogen fixing bacteria i.e. *Rhizobium* growing in the roots of legumes (Plants of the family leguminoceae). In this Rhizobium-legume association, *Rhizobium* bacteria are benefited by protection from the environmental stresses while in turn plant is benefited by getting readily available nitrate nitrogen released by the bacterial partner.

Commensalism

Commensalism refers to a relationship between organisms, in which one species of a pair benefits whereas the other is not affected. This happens commonly in soil with respect to degradation of complex molecules like cellulose and lignin. For example, many fungi can degrade cellulose to glucose, which is utilized by many bacteria. Many bacteria are unable to utilize cellulose, but they can utilise the fungal breakdown products of cellulose, e.g., glucose and organic acids.

Another example of commensalism is that of a change in the substrate produced by a combination of species and not by individual species. For example, lignin which is major constituent of woody plants and is usually resistant to degradation by most of the microorganisms. But in forest soils, lignin is readily degraded by a group of Basidiomycetous fungi and the degraded products are used by several other fungi and bacteria which can not utilize lignin directly.

Proto-cooperation

It is a mutually beneficial association between two species. Protocooperation is a form of mutualism, but they do not depend on each other for survival. An example of protocooperation happens between soil bacteria or fungi, and the plants that occur growing in the soil. None of the species rely on the relationship for survival, but all of the fungi, bacteria and higher plants take part in shaping soil composition and fertility. Soil bacteria and fungi interrelate with each other, forming nutrients essential to the plant's survival. Plants utilize these microorganism synthesized nutrients through root nodules thereby decomposing organic substances. Soil bacteria and fungi help in improving the fertility of the soil and shaping of soil. Plants get essential carbon dioxide and nutrients. Nutritional proto-cooperation between bacteria and fungi has been reported for various vitamins, amino and purines in terrestrial ecosystem and are very useful in agriculture.

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Negative associations

Antagonism

It is the relationship in which one species of an organism is inhibited or adversely affected by another species in the same environment. The relationship is also known as antagonism. The species which adversely affects the other is said to be antagonistic. Such organisms may be of great practical importance, since they often produce antibiotics or other inhibitory substances which affect the normal growth processes or survival of other organisms.

Antagonistic relations are most common in nature. One example of which is the antagonistic nature of both *Staphylococcus aureus* and*Pseudomonas aeruginosa* towards the fungus *Aspergillus terreus*. Certain *Pseudomonas* pigments inhibit germination of *Aspergillus* spores.*Staphylococcus aureus* produces a diffusable antifungal material that causes distortions and hyphal swellings in *Aspergillus terreus*.

An antibiotic is a microbial inhibitor of biological origin. Soil microorganisms are the most common producers of antibiotics. Production of antibiotics in soil may enable the antibiotic producing organism to thrive successfully in a competitive environment. One example of which is the presence of large populations of actinomycetes in the chitinaceous shells of dead crustaceans in the sea. Their existence, in the environment free of other microorganisms, is may be due to the production of antibodies by them. Several species of *Streptomyces* from soil produces antibacterial and antifungal antibiotics. Most of the commercial antibiotics such as streptomycin, chloramphenicol, Terramycin and cyclohexamide have been produced from the mass culture of*Streptomyces*. Thus, species of *Streptomyces* are the largest group of antibiotic producer's in soil. The bacterial genus *Bacillus* produces an antifungal agent which inhibits growth of several soil fungi.

Antibiosis may result from a variety of other conditions operative in mixed populations. Certain fungi produce cyanide in concentrations toxic to other microorganisms and the algae elaborate fatty acids which exhibit a marked antibacterial activity. Many soil microorganisms, for example the myxobacteria and streptomycetes are antagonistic because they secret potent lytic enzymes which destroy other cells by digesting their cell wall or other protective surface layers. It appears that in the natural environment producers of lytic substances are often found in close proximity with sensitive organisms and do not predominate over them.

Ammensalism is the interaction between two species, where one species suppresses the growth of other by producing toxins like antibiotics or harmful gases like methane, ethylene, nitrite, or HCN or sulphides and other volatile sulphur compounds.

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Competition

Soil is inhabited by different kinds of microorganisms, and therefore they exhibit competition among themselves for nutrients and space. In this kind of situation, the best adapted microorganism will predominate or eliminate the others which are dependent upon the same limited nutrient substance. The organisms with inherent ability to grow fast are better competitors.

Exogeneous nutrients are required for the germination of chlamydospores of *Fusarium*, Oospores of *Aphanomyces* and conidia of *Verticillium dahlae*in soil. But other fungi and soil bacteria deplete these critical nutrients required for spore germination and thereby hinder the spore germination resulting into the decrease in population. Soil bacteria compete for space and suppress the growth of the fungal population.

Parasitism

Parasitism is the relationship between two organisms, in which one organism lives in or on another organism. The parasite is dependent upon the host and feeds on the cells, tissues or fluids of the host organism. The parasite lives in intimate physical contact with the host and forms metabolic association with the host. All major groups of plants, animals, and microorganisms are susceptible to attack by microbial parasites.

The bacterial parasite of Gram-negative bacteria *Bdellovibrio bacteriovorus* which is widespread in soil and sewage attaches to a host cell at a special region and eventually causes the lysis of that cell. As a consequence, plaque like areas of lysis appear when these parasites are plated along with their host bacteria. Parasitism is widely spread in soil communities. Viruses which attack bacteria (bacteriophages), fungi, and algae are strict intracellular parasites since they cannot be cultivated as free-living forms. There are also many strains of fungi which are parasitic on algae and other fungi by penetration into the host. Fungi with antagonistic activity toward plant pathogens have an essential role in plant growth and health. Mycoparasites and presumptive mycoparasites have biocontrol potential, some are responsible for natural suppressiveness of soils to certain plant pathogens. Several species of *Trichoderma* were used successfully against certain pathogenic fungi. *Trichoderma* sp. was used as commercial bio-fungicides to control a range of economically important soil-borne fungal plant pathogens. Soils contain a large number and great diversity of oospore parasites, which may have the potential to reduce populations of plant pathogenic Phycomycetes in soil.

Predation

Predation is an association in which predator organism directly feed on and kills the pray organism. Predators may or may not kill their prey prior to feeding on them, but the act of predation often results in the death of its prey and the eventual absorption of the prey's tissue through consumption.

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Many species of the soil-dwelling myxobacteria are predators of other microbes. Many myxobacteria, e.g., *Myxococcus xanthus*, exhibit several complex social traits, including fruiting body formation and spore formation cooperative swarming with two motility systems, and group predation on both bacteria and fungi. Myxobacteria use gliding motility to search the soil matrix for prey and produce a wide range of antibiotics and lytic compounds that kill and decompose prey cells and break down complex polymers, thereby releasing substrates for growth. The nematophagous fungi are the best predatory soil fungi. Species of *Arthrobotrytis* and *Dactylella* are known as nematode trapping fungi.