RHIZOSPHERE

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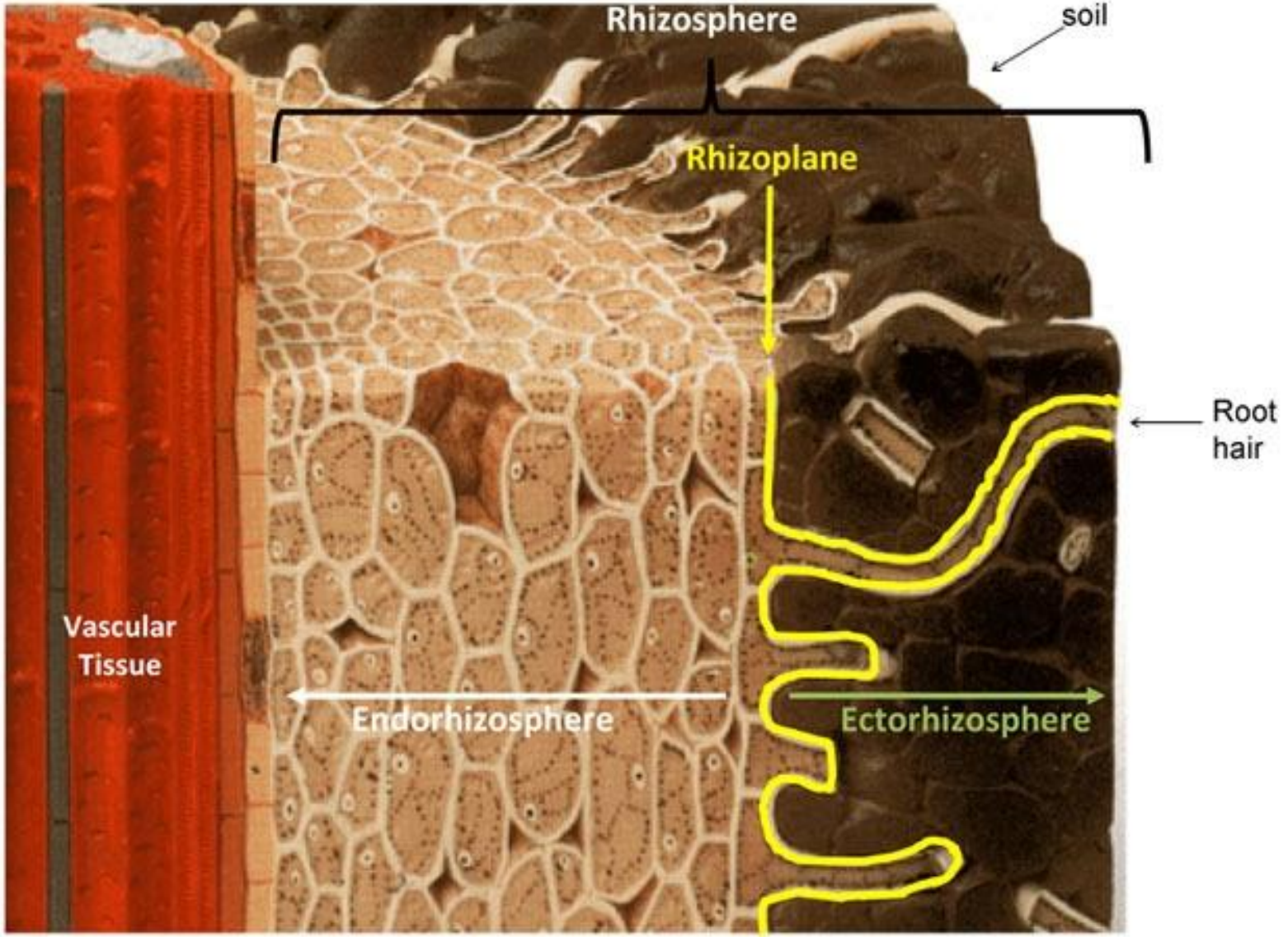
Rhizosphere

- In 1904, L. Hiltner for the first time coined the term ‘rhizosphere’ to denote the area of intense microbiological activity that extends several millimeters from the root system of the growing plants.
- Hiltner described the rhizosphere as the area around a plant root that is inhabited by a unique population of microorganisms influenced, he postulated, by the chemicals released from plant roots.
- The rhizosphere definition has been refined to include three zones which are defined based on their relative proximity to, and thus influence from, the root:
  - The **endorhizosphere** includes portions of the **cortex** and **endodermis** in which microbes and cations can occupy the "free space" between cells (apoplastic space).
  - The **rhizoplane** is the medial zone directly adjacent to the root including the root epidermis and mucilage.
  - The outermost zone is the **ectorhizosphere** which extends from the rhizoplane out into the bulk soil.
- Because of the inherent complexity and diversity of plant root systems, the rhizosphere is not a region of definable size or shape, but instead, consists of a gradient in chemical, biological and physical properties which change both radially and longitudinally along the root.


Rhizosphere
soil
Rhizoplane
Root
hair
Vascular
Tissue
Endorhizosphere
Ectorhizosphere

Root exudates

- Roots can release about 10-40% of their total photosynthetically fixed carbon.
- The C released is in both organic (e.g., low molecular weight organic acids) and inorganic (e.g., HCO_3) forms, however, the organic forms are the most varied and can have the most influence on the chemical, physical and biological processes in the rhizosphere.
- The composition and amount of the released compounds is influenced by many factors including plant type, climactic conditions, insect herbivory, nutrient deficiency or toxicity, and the chemical, physical and biological properties of the surrounding soil.
- Root **exudates** include both **secretions** (including mucilage) which are actively released from the root and **diffusates** which are passively released due to osmotic differences between soil solution and the **cell, or lysates** from autolysis of epidermal and cortical cells
- The root products imparted to the surrounding soil are generally called **rhizodeposits.**

Rhizodeposits

- The many functions of root exudates:
  - as a means of acquiring nutrients (e.g. acquisition of Fe and P),
  - agents of invasiveness (i.e. allelopathy)
  - as chemical signals to attract symbiotic partners (chemotaxis) (e.g. rhizobia and legumes)
  - the promotion of beneficial microbial colonization on root surfaces (e.g. *Bacillus subtilis*, *Pseudomonas florescence*)

Sr. No	Root Executes	Chemical Substances
1	Amino Acids	All naturally occurring amino acids.
2	Organic acids	Acetic, butyric, citric, fumaric, lactic, malic, propionic, succinic etc.
3	Carbohydrates / sugars	Arabinose, fructose, galactose, glucose, maltose, mannose, oligosaccharides, raffinose, ribose, sucrose, xylose etc.
4	Nucleic acid derivatives	Adenine, cystidine, guanine, undine
5	Growth factors (phytohormones)	Biotin, choline, inositol, pyridoxine etc
6	Vitamins	Thiamine, nicotinic acid, biotin etc
7	Enzymes	Amylase, invertase, protease, phosphatase etc.
8	Other compounds	Auxins, glutamine, glycosides, hydrocyanic acid peptides, Uv-absorbing compounds, nematode attracting factors, spore germination stimulators, spore inhibitors etc.

Rhizospheric effect

- Compared to non-rooted bulk soil, the soil compartment directly around the plant root contains much larger populations of microorganisms, known as rhizospheric effect.
- The increased microbial numbers and activities in the rhizosphere are due to the release of large amounts of organic carbon by the plant roots.
- Soil microorganisms are chemotactically attracted to the plant root exudates, after which they proliferate in this carbon rich environment.
- Carbon limitation could be demonstrated in bulk soil but not in the rhizosphere.
- Given the fact that plant root exudates differ between plant species, differences in rhizosphere microbiomes of different plant species are to be expected.
- This influence can be measured simply by plating technique and expressed as a rhizosphere effect (i.e. a stimulation that can be measured on quantitative basis by the use of rhizosphere: soil (R:S) ratio, obtained by dividing the number of microorganism in the rhizosphere soil by the number of microorganisms in the non-rhizosphere soil).

Rhizosphere Microorganisms

- The cocktail of chemicals released is influenced by plant species, **edaphic** and climactic conditions which together shape and are shaped by the microbial community within the rhizosphere.
- Microbial colonization of the plant root surface occurs in patches along the root, ultimately covering ~15- 40% of the total plant root surface.
- The density and structure of the microbes on the root surface are dictated by nutrient availability and physicochemical variations throughout the root surface. Root exudates can serve as a food source and **chemoattractant** for microbes which then attach to the root surface and form microcolonies.
- Common sites for bacterial colonization are at epidermal cell junctions, root hairs, axial groves, cap cells, and sites of emerging lateral roots.
- Microcolonies can eventually grow into larger **biofilms** consisting of multiple layers of bacteria which are encased in an exopolymeric matrix.
- In many cases the effectiveness of rhizobacteria at promoting growth occurs in a density dependant manner.

...Rhizosphere Microorganisms

- Bacteria reported from the rhizosphere and rhizoplane regions irrespective of their dominance are: *Arthrobacter, Pseudomonas, Bacillus brevis, B. circulans, B. polymyxa, B. megaterium, Agrobacterium radiobacter, A. tumifaciens, Azotobacter, Flavobacterium, Rhizobium* spp., *Cellulomonas, Micrococcus, Mycobacterium*, etc.
- Common actinomycetes are *Actinomyces chromogenes, Frankia* (inside root tissues), *Nocardia* spp., *Micromonospora* spp., *Streptomyces antibioticus, S. scabies, S. griseus* etc.
- The dominant fungi of rhizosphere were *Aspergillus flavus, A. fumigatus, A. luchuensis, A. niger, A. terreus, Cladosporium cladosporioides, Curvularia lunata* and *Fusarium oxysporum*, whereas the dominant fungi of rhizoplane were *A. niger, Cladosporium herbarum, F. oxysporum, F. solani, Macrophomina phaseolina, Neocosmospora vasinfecta* and *Rhizoctonia solani*. In addition, mycorrhizal fungi are also known to be present in rhizosphere soil and rhizoplane of roots.

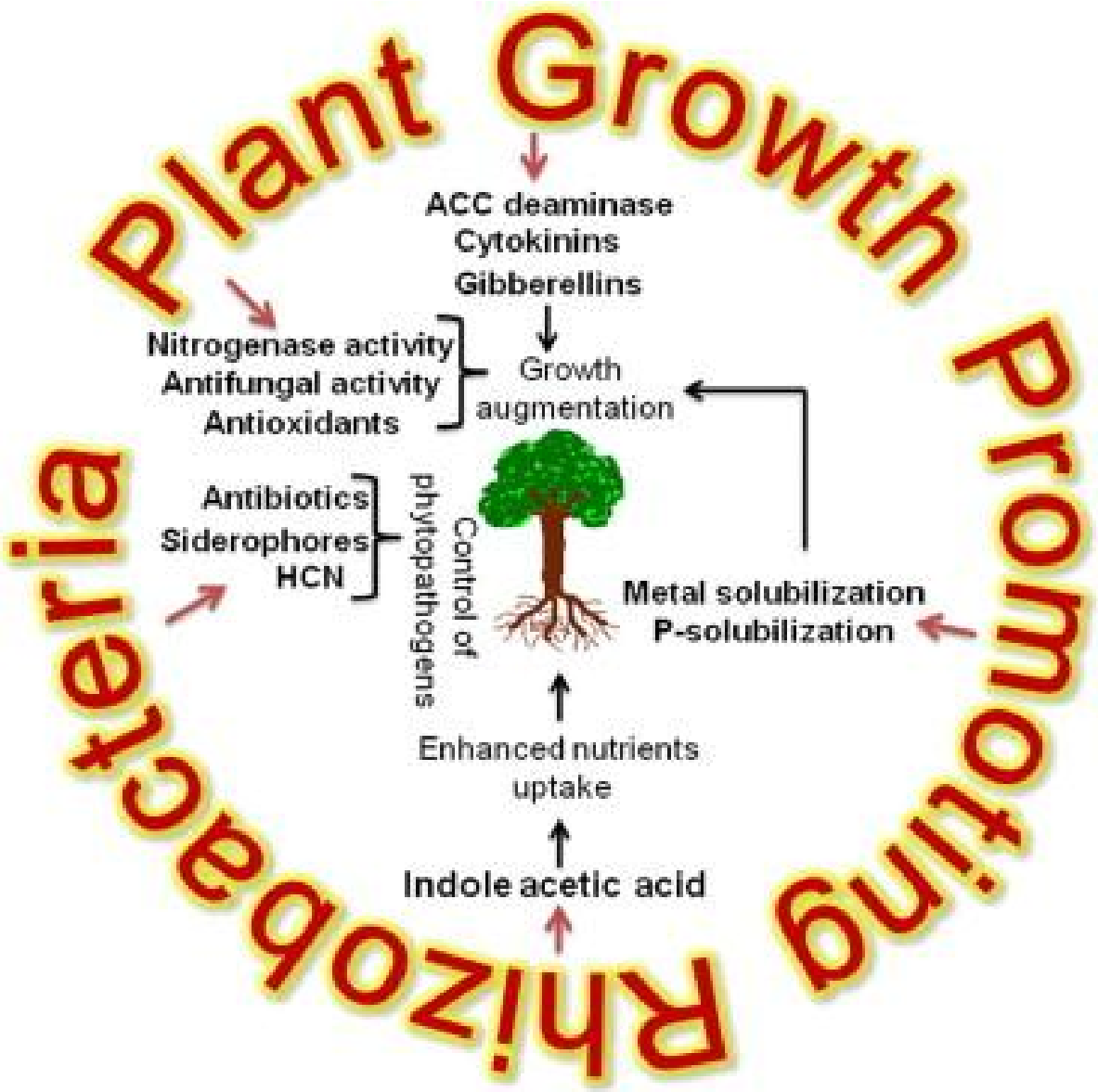
Effect of Rhizosphere on Host Plants

The rhizosphere microorganisms have either beneficial or harmful effects on the development of plant:

- The microbes catalyse reactions in the rhizosphere and produce CO_2 and form org. acids that in turn solubilize the inorg. nutrients of plants.
- Some of the rhizosphere microorganisms produce growth-stimulating substances and release elements in organic forms through the process of mineralization.
- Plant growth regulators such as indole acetic acid, gibberellins, cytokinins, etc. are known to be produced by the rhizosphere microflora.
- They influence phosphorus availability to plant through the process of mineralization and immobilization.
- Plant pathogenic microorganisms can cause severe harm to plants. Though plant growth promoting bacteria can inhibit phytopathogens through several mechanisms (competition for nutrients, production of antibiotics, lytic enzymes etc.)
- Microorganisms in the rhizosphere zone change the availability or toxicity of sulphur to plants.
- The products of microbial metabolisms sometimes have toxic effect on plants; therefore, these are termed as phytotoxins.

Plant growth promoting rhizobacteria

- The soil bacterial species burgeoning in plant rhizosphere which grow in, on, or around plant tissues stimulate plant growth by a plethora of mechanisms are collectively known as PGPR.
- PGPR based on their functional activities can be classified as:
  - biofertilizers (increasing the availability of nutrients to plant)
  - Phytostimulators (plant growth promotion, generally through phytohormones)
  - biopesticides (controlling diseases, mainly by the production of antibiotics and antifungal metabolites)
  - rhizoremediators (degrading organic pollutants)
- Example: *Rhizobium, Bradyrhizobium, Mesorhizobium, Pseudomonas Bacillus Klebsiella Azotobacter Azospirillum Azomonas*


Plant Growth Promoting Rhizobacteria
ACC deaminase
Cytokinins
Gibberellins
Growth augmentation
Nitrogenase activity
Antifungal activity
Antioxidants
Antibiotics
Siderophores
HCN
Control of phytopathogens
Metal solubilization
P-solubilization
Enhanced nutrients uptake
Indole acetic acid

Questions

- What is rhizosphere? How plants and microbes influence each other in rhizosphere?
- Write short note on:
  - Rhizospheric effect
  - Plant growth promoting rhizobacteria
  - Effect of rhizosphere on host plants