Microbiology of Rhizosphere:

- The rhizosphere is the narrow region of soil around the plant root that is influenced by several factors like the root exudates and the associated soil microorganisms.
- The soil surrounding the plant root where root exudate migrates and microbiological activity is exceptionally high is called rhizosphere.
- The surface of root is called rhizoplane.
- Plant root produce and release various exudates containing sugar, aminoacids, organic acids, fatty acids, vitamins, nucleotides and other organic matters that promotes growth of microorganisms.
- Therefore rhizospheric soil is characterized by greater number of microorganisms than soil away from plant roots.
- The intensity of rhizospheric effects depends on the distance to which root exudates can diffuse. The number of microorganisms decreases continuously as the distance from the plant root increases.
- The term rhizosphere to soil ratio (R:S) indicates number of microbes in rhizospheric soil divided by number of microbes in soil free of plant root.
- R:S ratio is greater for bacteria (20:1) and less for fungi and actinomycetes.
- Effects of rhizosphere is almost negligible for algae and protozoa. It is because algae are photosynthetic and do not depends upon organic matter present in root exudates.
- On the other hand most bacteria cannot utilize relatively resistant to organic matter of soil and depends on easily available decomposable matter of root exudates. Therefore number of bacteria is exceptionally high in rhizosphere.

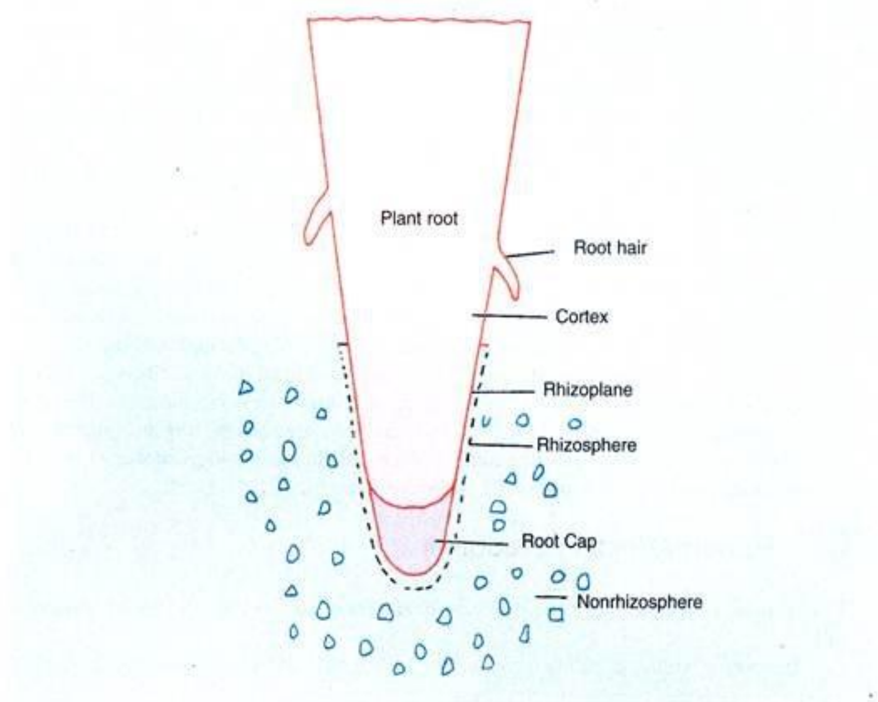

Fig. 30.4 : A typical plant root showing rhizosphere, rhizoplane and non-rhizosphere region

Examples of rhizospheric microorganisms:

- The microbial population in the rhizosphere is known as the rhizosphere microbiome and the microbial population in such an area much higher than the bulk soil.

Large number of bacteria, fungi and actinomycetes are found in rhizosphere.

- **i. Bacteria:**
  - Many nitrogen fixing bacteria and phosphate solubilizing and other bacteria are found in rhizosphere.
  - For examples: *Pseudomonas, Arthrobacter, Azotobacter, Agrobacterium, Flavobacterium, Cellulomonas, Rhizobium, Clostridium etc.*
- **ii. Fungi:**
  - Some fungi are found associated with root forming mycorrhiza and other occurs freely in soil.
  - For examples: *Marticella, Cephalosporium, Tricoderma, penicillium, Gliodadium, Gliomastix, Fusorium etc.*
- **iii. Actinomycetes:**
  - *Frankia, Derxia etc*

Factor affecting rhizospheric microorganisms:

Various factors affect rhizospheric microbes and some of them are;

i. Proximity of soil to root:

- The number of rhizospheric organisms is greater near the root and their number continuously decreases with increase in distance from the root.
- It is because concentration of organic matter released by root in exudates decreases with increases in distance from the root.
- More nutrient availability near to the root surface

ii. Temperature and light intensity:

- Low temperature and low light intensity decreases the rate of exudate secretion from the root so that number of rhizospheric organisms decreases.
- On the other hand number of microbes in rhizosphere increases when temperature and light intensity increases as multiplication rate is high.

iii. Type of soil:

- Types of soil also influences rhizospheric effects.
- For example; R: S ratio is very high in sandy soil and low in clay soil. It is because sandy soil contains very little or no organic matter and the root region is the only place where organics matter is available and microorganisms can grow. Therefore, number of microbes is high around root in sandy soil.
- On the other hand in fertile soil such as clay soil, organic matter is sufficiently available for growth, so microorganisms need not to depend on the root exudates for growth.

iv. Age of plant:

- With age of plant, rate of exudates secretion is altered so that number of rhizospheric microbes changes.

v. Types of plant and location of root:

- Location of root affects number of rhizospheric microbes.
- Root cap and regions of root from where **lateral root** arises are primary sites of exudate secretion. Therefore, number of microbes is comparatively high around these locations.
- Amount and type of exudates secretion differs with species of plant that influences growth of rhizospheric microbes. For example; some plant root release antimicrobial chemicals such as glycosides, hydrocyanic acids and several antifungal agents that inhibits rhizospheric microbes.

vi. Depth of root:

- In general number of rhizospheric microorganisms decrease with increase in depth of root, which is mainly due to anaerobic condition.

vii. Root respiration:

- Plant root release carbon-dioxide during respiration that make the soil acidic.
- Acidity of soil decrease number of rhizospheric bacteria.

viii. pH of soil:

- pH of rhizosphere become acidic due to root respiration and by oxidation of sulphur caused by ***Thiobacillsu spp.*** Acidification of rhizospheric soil decrease number of microorganisms.

ix. Pesticides and antibiotics:

- Spray of pesticides and antibiotics on agriculture crops decreases the number of rhizospheric organisms.

<u>Positive Role of rhizospheric microbes:</u>

Rhizospheric microorganisms are important for plant growth. They promote plant growth by various ways as given below;

- Some rhizospheric bacteria such as *Rhizobium, Azotobacter, Clostridium* etc. fix atmospheric **nitrogen** and make it available for plant gowth.
- Many **phosphate solubilizing** microbes such as Bacillus polymyxa found in rhizosphere release free phosphate from inorganic salt of phosphate. Free phosphate is important nutrient for plant growth.
- Several rhizospheric microbes (*Azotobacter, Arthrobacter, Pseudomonas, Agrobacterium)* produce growth hormone such as Gibberllin, Indole acetic acid (IAA) etc. that promote plant growth.
- Many rhizospheric fungi are associated with plant root in the form of mycorrhiza. Mycorrhizal fungi promote plant growth by various ways.
- Rhizospheric microbes induce development of lateral root, root hairs development and mucilage secretion from plant root.

- Some rhizospheric microbes produces antibiotics and other antimicrobial chemicals that inhibit plant pathogens. Some time it may inhibit beneficial N2 fixing and phosphate solubilizing bacteria.
- Microorganisms also increase rate of exudate secretion. Exudate secretion from plant root helps in formation of soil aggregate that improve soil fertility.
- Some rhizospheric microbes eg *Pseudomonas* produces Siderophore. Siderophore is a chelating agent that tightly bind iron and make it unavailable for growth of pathogenic microorganisms.

Negative Effect of plant root on rhizospheric microbes;

Plant root usually promote growth of rhizospheric microbes. Sometimes plant root give minor unwanted effect to microorganism. Some of them are;

- Some plant root produces antimicrobial chemicals such as glycosides, Zhydrocyanic acids and antifungal agents that inhibits growth of rhizospheric microorganisms.
- Plant root release CO_2 during respiration that make habitat acidic and anaerobic.
- Some plant root produce chemicals that bring fungistasis. Fungistasis is referred to the inability of spore to germinate. For eg. Root of *Allium* produces alkylcystein sulfoxide that inhibit germination of sclerotia (spore) of *Sclerotium capivarum*.

The rhizosphere, the zone of soil under the influence of root is characterized by high microbial diversity, activity, number of organisms and complex interactions. There is a mark difference in the availability of microorganism and their effect in rhizospheric and non rhizospheric region.

A comparison of respiratory and microbial activities under integrated plant nutrient system between rhizosphere and non rhizosphere was attempted by Arpana and coworkers in 2020 (Int. J. Curr. Microbiol. App. Sci. (2020) 9(6): 2527-2535). From the study it is concluded that certain bacteria, fungi and actinomycetes are able to colonize the root soil environment where they carry out a variety of interactive activities known to benefit plant growth and health and soil quality. An increased respiratory activity was also noticed in the rhizoshere zone than the non rhizosphere zone. Under integrated plant nutrient system, it is clearly evident that the microflora was more in rhizosphere than in the non rhizosphere.

Phosphate Solubilization

Phosphorus (P) is one of the major growth-limiting macronutrients required for proper plant growth, particularly in tropical areas, due to its low availability in the soil . It accounts for between 0.2 and 0.8% of the dry weight of plants [2], and it is contained within nucleic acids, enzymes, coenzymes, nucleotides, and phospholipids. P is essential in every aspect of plant growth and development, from the molecular level to many physiological and biochemical plant activities including photosynthesis development of roots, strengthening the stalks and stems, formation of flowers and seeds, crop maturity and quality of crop, energy production, storage and transfer reactions, root growth, cell division and enlargement, N fixation in legumes, resistance to plant diseases , transformation of sugar to starch, and transporting of the genetic traits.

Availability of Phosphorus in the Soil

Phosphorus is a reactive element and does not exist as elemental form in the soil. Phosphorus in the soil solution exists as insoluble inorganic phosphorus and insoluble organic phosphorus. Its cycle in the biosphere can be described as “sedimentary,” because there is no interchange with the atmosphere, and unlike the case for nitrogen, no large atmospheric source can be made biologically available. Consequently, deficiency of phosphorus severely restricts the growth and yield of crops . The concentration of soluble P in soil solution is usually very low, normally at levels varying from ppb in very poor soils to 1 mg/L in heavily fertilized soils. Plant cell might take up several P forms, but the greatest part is absorbed in the forms of phosphate anions mainly HPO_4^{2-} or H_2PO_4- depending upon soil p. The main input of inorganic P in agricultural soil is applying phosphorus fertilizers. Nearly, 70 to 90% of phosphorus fertilizers applied to soils is fixed by cations and converted inorganic P. P gets immobilized by cations such as Ca2+ in calcareous or normal soils to form a complex calcium phosphate ($Ca_3(PO_4)^2$) and with Al^{3+} and Fe^{3+} in acidic soils to form aluminum phosphate (AlPO) and ferrous phosphate (FePO). These are insoluble forms and consequently unavailable.

Phosphate solubilizing microorganisms (PSMs)

PSMs are group of beneficial microorganisms capable of hydrolyzing organic and inorganic phosphorus compounds from insoluble compounds. Among these PSMs, strains from bacterial genera (Bacillus, Pseudomonas, and Rhizobium), fungal genera (Penicillium and Aspergillus), actinomycetes, and arbuscular mycorrhizal (AM) are notable. Soil is a natural basal media for microbial growth. Mostly, one gram of fertile soil contains 101 to 1010 bacteria, and their live weight may exceed 2,000 kg ha^{-1}. Among the whole microbial population in soil P, solubilizing bacteria comprise 1–50% and P solubilizing fungi 0.1 to 0.5% of the total respective population. PSMs are ubiquitous, and their figures differ from soil to soil. Most PSMs were isolated from the rhizosphere of various plants, where they are known to be metabolically more active. Apart from those species, symbiotic nitrogenous rhizobia and nematofungus Arthrobotrys oligospora have also shown phosphate solubilizing activity.

Mechanism of phosphorus Solubilization

Lowering Soil pH. The principal mechanism for solubilization of soil P is lowering of soil pH by microbial production of organic acids or the release of protons. In alkaline soils, phosphate can precipitate to form calcium phosphates, including rock phosphate (fluorapatite and francolite), which are insoluble in soil. 'eir solubility increases with decreases in soil pH. PSMs increase P availability by producing organic acids that lowers the soil pH. PSMs are also known to create acidity by evolution of CO2 , as observed in solubilization of calcium phosphates. Production of organic acid coupled with the decrease of the pH by the action of microorganisms resulted in P solubilisation.

Chelation- Organic and inorganic acids produced by PSM dissolve the insoluble soil phosphates by chelation of. The hydroxyl and carboxyl groups of the acids chelate the cations bound to phosphate, thereby converting it into soluble forms. Production of inorganic acids, such as sulphidric, nitric , and carbonic acid, react with calcium phosphate and convert them into soluble forms.

Mineralization The other mechanism of solubilizing soil P is mineralization. Organic phosphate is transformed into utilizable form by PSM through process of mineralization, and it occurs in soil at the expense of plant and animal remains, which contain a large amount of organic phosphorus compounds such as nucleic acids, phospholipids, sugar phosphates, phytic acid, polyphosphates, and phosphonates. Mineralization and immobilization of soil organic P plays a vital role in phosphorus cycling of the agricultural land.