Frankia - Symbiotic Association

COURSE: B.Sc. MICROBIOLOGY

SEMESTER: II

PAPER: MBIO CC204- AGRICULTURAL MICROBIOLOGY

PREPARED BY:

Jaya Philip

Head, Department of Microbiology,

Patna Women's College

- jayaphilipmicrobio@gmail.com

Introduction:

- The aerobic Gram-positive actinomycetes belonging to the genus *Frankia* are diazotrophic bacteria
- They are capable of inducing formation of N_2-fixing nodule lobes in roots of many dicotyledonous angiosperms.
- The plants nodulated by *Frankia* strains are known as actinorhizal plants and include 8 families, 25 genera, and over 200 species
- most of which are perennial woody shrubs or trees distributed in all landmasses except Antarctica.

Host of Frankia:

- The actinorhizal plants share a predilection for marginally fertile soils and the majority are pioneers on nitrogen-poor sites.
- In addition, many actinorhizal species are able to tolerate environmental stresses such as heavy metals, high salinity, drought, cold, and extreme pH.
- They inhabit a variety of ecosystems, including coastal dunes, riparian zones, alpine communities, arctic tundra, glacial tills, and forests.
- Actinorhizal plants are especially important in high latitude regions, such as Scandinavia, Canada, Alaska, and New Zealand where Leguminosae are absent or rare while actinorhizal plants are abundant and capable of vigorous growth.
- Much of the new nitrogen entering these ecosystems comes from the actinorhizal symbioses that, on the whole, account for over 15% of the biologically fixed nitrogen worldwide.

Biology of Frankia:

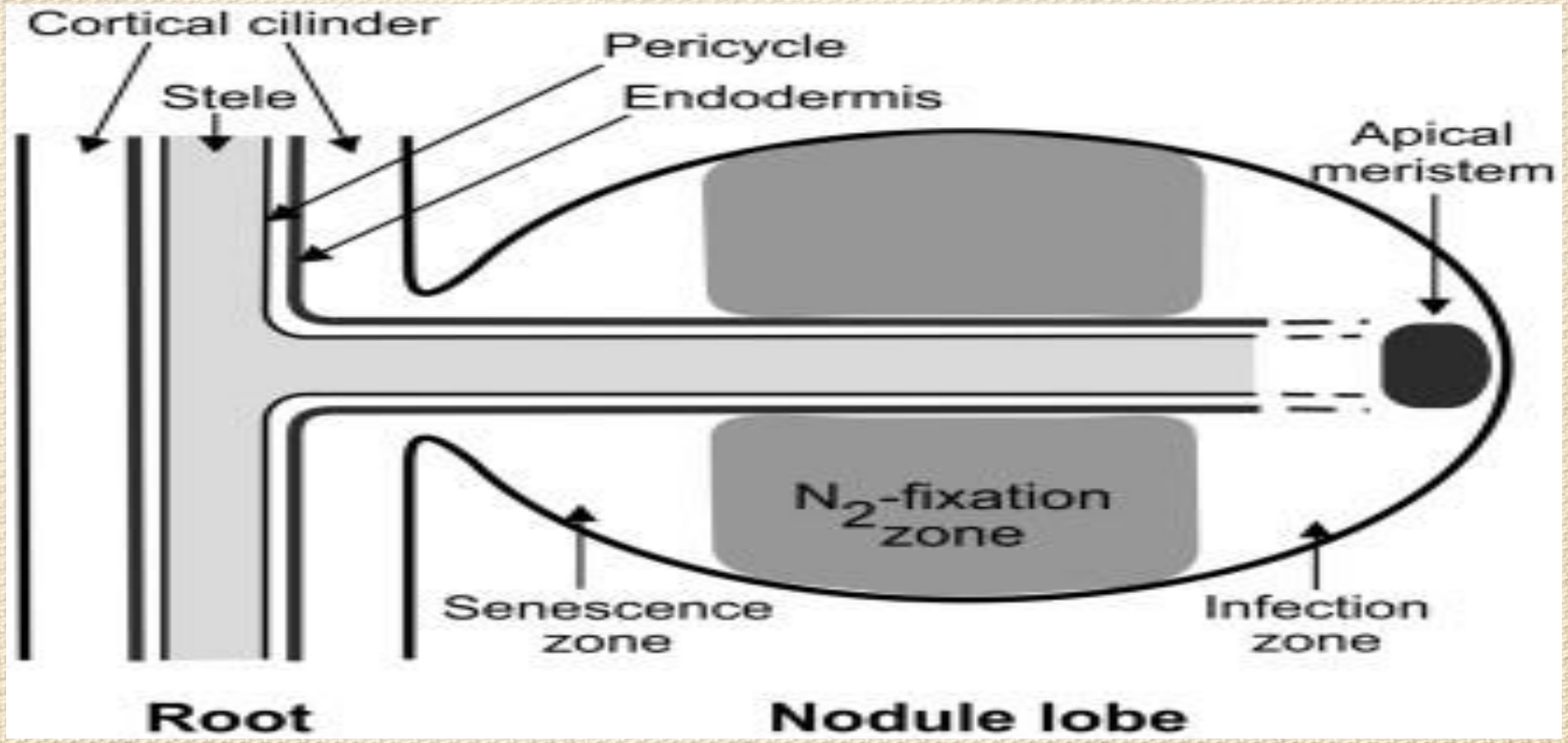
- The filamentous frankiae, besides in symbiotic association with actinorhizal plants, can also occur as free-living diazotrophic organisms (Benson and Silvester, 1993).
- In pure culture, *Frankia* strains produce extensive hyphae and sporangia. In response to nitrogen deprivation, they also differentiate vesicles, named diazovesicles, which contain nitrogenase and are the site of N_2 fixation.
- The diazovesicles are encapsulated by a series of laminated lipid layers that are rich in neutral lipids, glycolipids, and hopanoids.
- This envelope, whose thickness depends on the environmental O_2 concentration, works as an oxygen-diffusion barrier, providing an anaerobic environment for nitrogenase to function inside vesicles.

- ***Frankia*** **strains can infect the host root by intracellular or intercellular mechanisms.**
- **Intracellular infection, such as that occurring in genera *Myrica*, *Comptonia*, *Alnus*, *Casuarina*, starts with penetration of bacterial hyphae in a curled root hair.**
- **Afterward the hyphae move in cortical cells encapsulated with a layer of plant cell wall material surrounded by host plasmalemma.**
- **In intercellular infection, common in genera *Elaeagnus*, *Ceanothus*, and *Cercocarpus*, the bacterial hyphae penetrate between two adjacent rhizoderm cells and progress apoplastically through cortical cells encapsulated in a pectic matrix.**

- **Concomitantly, cell divisions induced in the root pericycle give rise to the nodule lobe primordium to which the hyphae move.**
- **The mature actinorhizal nodule lobe resembles a modified lateral root with an apical meristem but without a root cap.**
- **It shows a central stele with vascular tissues and has *Frankia* hyphae restricted to the cortical cells.**

- **Actinorhizal nodule lobe is shown in the following picture**

A mature actinorhizal nodule lobe.



- In most actinorhizal symbioses, the N_2-fixing activity of *Frankia* in infected cells is associated with differentiation of diazovesicles whose morphology is strictly controlled by the host plant.
- As in the free-living frankiae, these vesicles are surrounded by the multilayered lipid envelope and contain nitrogenase.
- However, in some symbioses (with plants of genera *Myrica*, *Coriaria*, *Comptonia*, and *Casuarina*), the *Frankia* hyphae proliferate without forming vesicles.
- The mature anatomy of a nodule lobe is reached at about 2 weeks after inoculation while the N_2-fixation can be detected after three weeks.

- In infected cells of mature nodule lobes, some mechanisms take place to lower the oxygen tension near the site of the oxygen-intolerant nitrogenase.
- The first diffusion resistance to oxygen is provided in diazovesicles by the multilayered envelope and a further reduction of the $p\,O_2$ is obtained through their high respiration rate.
- In many nodule lobes devoid of diazovesicles, the infected cells contain high levels of hemoglobins that have homologous sequences to leghemoglobins and are believed to play the same role (Fleming et al., 1987).
- In these nodules, moreover, a low pO_2 may be maintained by lignification of the host cell walls.

- Finally, the activity of uptake hydrogenases can also help to protect the nitrogenase against O_2 in both hyphae and diazovesicles of the symbiotic frankiae (Leul et al., 2009).
- In free-living *Frankia* strains, as in the other free-living diazotrophs, the ammonia produced by N_2 fixation is assimilated by the organism via the GS-GOGAT pathway.
- On the contrary, these enzymes are differently regulated in the symbiotic frankiae.
- In diazovesicles of root nodule lobes GS activity is very low and ammonia remains unassimilated
- As in rhizobia–legume symbiosis, NH_3 is released into the host cell where its assimilation gives rise to amino acids and other organic nitrogen compounds.
- Some are furnished to the bacterium, but most of them are transferred to the plant shoot.

- The scarcity or lack of GS activity in the diazotrophic symbiont also characterizes the rhizobia legumes as well as some cyanobacterial symbioses such as *Anabaena* – *Azolla*, showing a remarkable convergence of physiological strategies in the N_2-fixing associations.
- The actinorhizal plant must provide photosynthates to the symbiotic bacterium.
- As in the rhizobia–legume symbiosis C_4 dicarboxylates derived from sucrose metabolism occurring in the host cell are likely to be the carbon sources for *Frankia* strains in actinorhizal symbiosis.
- Furthermore, as it occurs in rhizobia–legume symbiosis, the actinorhizal plants can control infection by *Frankia* and regulate number and development of nodule lobes on roots by systemic autoregulatory processes

Thankyou