Quadrant II- Transcript and Related Materials

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Paper Title : Biofertilizers

Unit : 2

Module Name : *Frankia* and Actinorhizal symbiosis

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Notes:

***Frankia* and Actinorhizal symbiosis**

Introduction:

Frankia: Characteristics

- Frankia is defined as the N2-fixing microsymbiont of actinorhizal plants
- Frankia is a genus of soil actinomycetes
- This genus was originally named by Jørgen Brunchorst, in 1886 had identified to be a filamentous fungus. In 1970 redefined as containing prokaryotic actinomycetes.
- *Frankia* strains are specific to different plant species.
- *Frankia* is gram-positive means that the bacteria is made up of thick cell walls made out of protein called peptidologlycan.
- Hyphal structure shows presence of both vesicles and spores
- Three genotypes of Frankia has been identified

- Filamentous and convert atmospheric nitrogen into ammonia via the enzyme nitrogenase, a process known as nitrogen fixation.
- They do this while living in root nodules on actinorhizal plants.
- *Frankia* may be an advantage for degraded soil.
- It grows best at around 30 degrees Celsius with an environment pH between 6.5 and 7
- Some Frankia strains are very tolerant to salinity and can be used as biofertilizers in land affected by salt.

Classification

Division: Bacteria

Class: Actinobacteria

Order: Frankiales

Family: Frankiaceae

Genus: *Frankia*

Actinorrhizal Plant:

- Group of angiosperms characterized by their ability to form a symbiosis with the nitrogen fixing actinobacteria *Frankia*.
- This association leads to the formation of nitrogen-fixing root nodules.
- Actinorhizal plants are found on all continents except for Antarctica.
- Most actinorhizal plants are therefore pioneer species that colonize young soils where available nitrogen is scarce like moraines, volcanic flows or sand dunes.
- Actinorhizal plants from 8 families including Betulaceae, Casuarinaceae, Coriariaceae, Datiscaceae, Elaeagnaceae, Myricaceae, Rhamnaceae, and Rosaceae, distributed in 25 genera and approximately 200 angiosperms species.

- Plants of Casuarinaceae and Betulaceae families are the most widely planted around the world for the rehabilitation of degraded lands. Examples *Casuarina* and *Alnus*

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Frankia and Actinorrhizal Symbiosis: Divided into three stages

a. Pre-infection stage
b. Infection stage

c. Actinorhizal Nodule Formation

a. Pre-infection stage:

- The first step towards symbiosis is the recognition of compatible symbionts.
- There is fine-tuned exchange of signals between the two partners
- Actinorrhizal tree roots gives out aqueous exudates which changes the physiology and symbiotic properties of Frankia. Root exudate increases the growth of Frankia and causes hyphal curling leading to changes surface property.

b. Infection Stage: After pre-infection events, Frankia can enter the plant root by two ways

1. Intracellular infection- by root hair.
    - Intracellular infection is found in the genera like *Myrica*, *Alnus* and *Casuarina*
    - Frankia bacteria secrete factors that induce root hair deformation
    - Sugar-binding lectins produced by Frankia might help the bacteria to bind the root hairs in some actinorhizal plants.
    - Frankia hyphae become entrapped by plant cell polysaccharides at the tip of some deformed root hairs and a local hydrolysis of primary cell occurs at the site of Frankia penetration
    - Frankia secretes effector-like molecules to communicate with its host and trigger the al loosening to the cell wall necessary for infection to occur.
    - In some deformed root hair, the plasma membrane invaginates and forms an infection thread structure.
    - Growing Frankia hyphae are encapsulated by a cell wall-like matrix made of xylan, hemicellulose, cellulose and pectin.

- Root hair deformation occurs 24–28 h after inoculation. However, only growing root hairs are infected by *Frankia*.
- In these infected root hairs, a high metabolic activity is observed
- Simultaneously with infection, cell divisions occur in cortical cells adjacent to the infected root hair inducing the formation of a protuberance called the prenodule.
- Infected threads grow towards the prenodule and invade some of its cells that become hypertrophied and both the plant cell and bacteria differentiate to fix nitrogen
- While the prenodule is an obligatory step of the infection process, it is not the precursor of a nodule lobe. As the prenodule develops, cell divisions occur in the pericycle opposite to a protoxylem pole giving rise to a nodule primordium .
- The nodule primordium develops into a nodule lobe that is infected by Frankia hyphae coming from the prenodule.

2. Intercellular infection- by the middle lamellas of cell epidermal
   - Intercellular infection occurs in some actinorhizal plant genera *Shepherdia* and *Discaria*.
   - During intercellular infection, some signal exchange occurs between the two partners but no root hair deformation is observed.
   - Instead, Frankia enters through the middle lamella between adjacent epidermal cells and then progresses intercellularly in the root cortex.
   - During intercellular infection, prenodule formation has not been reported.

- Nodule primordium formation occurs through cell divisions in the pericycle in front of a xylem pole.
- The nodule lobe primordium is then colonised by intercellular hyphae. Frankia hyphae become intracellular when they invade cortical cells of the young nodule primordium.

c. Actinorhizal Nodule Formation

- Actinorhizal nodule lobes are formed from cell divisions occurring in the pericycle in front of a xylem pole.
- New nodule lobes are formed by branching, giving rise to a coralloid actinorhizal nodule formed of multiple lobes.
- Each lobe contains a meristem at its apex, a central vascular bundle and a periderm.
- In the nodule, four zones have been defined:

(1) The meristematic zone: The meristematic zone is localised at the apex and produces new cells responsible for the indeterminate growth of actinorhizal nodules.

(2) The infection zone: The infected zone is adjacent to the apical zone. In this zone, Frankia hyphae infect some of the new cells.

(3) The fixation zone: composed of infected and uninfected cells. Infected cells are filled with *Frankia* hyphae and hypertrophied. Vesicles differentiate and nitrogen fixation occurs. Assimilation of the fixed N probably occurs in uninfected cells.

(4) The senescence zone: localized at the base of old nodules. In this zone, the host cytoplasm and the bacteria degenerate. Because of its origin, i.e. cells divisions in the pericycle in front of xylem poles and its structure, the actinorhizal nodule lobe has

been considered as a modified lateral root. Moreover, in some actinorhizal plants such as C. glauca, a structure called nodular root is formed. The nodular root is a very specialized root showing negative geotropism (growing upward) and cortical aerenchyma and lacks a root cap and root hairs. It has been suggested that it plays an important role under flooding or waterlogged conditions by increasing gas exchange between the nodule and the atmosphere.